THE AMERICAN COLLEGE OF RADIOLOGY
2022 ANNUAL COUNCIL MEETING
Sunday, April 24 – Tuesday, April 26, 2022
Washington Hilton, Washington DC & Virtual

I. FIRST COUNCIL SESSION—Sunday, April 24, 2022

CALL TO ORDER

The Speaker, Amy L. Kotsenas, MD, FACR called the 99th Annual Meeting of the American College of Radiology (ACR) to order, on Sunday, April 24, 2022, at 2:30 p.m.

WELCOME

Dr. Kotsenas welcomed Councilors, Alternate Councilors, Members of the Board of Chancellors and Council Steering Committee (CSC), Chapter Officers, ACR Members, Residents, Fellows, Medical Students and Guests, joining in-person or via the virtual platform, to ACR 2022, the 99th Annual Meeting of the ACR. Dr. Kotsenas acknowledged being back in-person for the first time since 2019 and commended Dr. Richard Duszak, Jr., MD, FACR, past Council Speaker for presiding over two virtual annual meetings.

Dr. Kotsenas reminded members of the Meeting Code of Conduct and the expectation that all attendees treat each other with respect. Dr. Kotsenas provided the ACR Helpline for attendees to report any incidents of bullying, harassment, discrimination, demeaning speech, or other similar unprofessional activity at the meeting.

OVERVIEW OF MEETING PROGRAM

Dr. Kotsenas acknowledged 2022 as the first hybrid ACR annal meeting and provided an overview of events held prior to the Council session and activities to follow through Tuesday afternoon.

She acknowledged the 172 New Fellows, along with the Honorary Fellows – Anca-Ligia Grosu, MD and Janet Elizabeth Siarey Husband, MD, and the Gold Medalists – Katarzyna Macura, MD, FACR, Anne Roberts, MD, FACR, and Christopher Ullrich, MD (award presented posthumously).

PARTICIPATING IN THE COUNCIL SESSIONS

Dr. Kotsenas provided guidance for in-person and virtual attendees to participate in the Council sessions.

TELLERS COMMITTEE

Dr. Kotsenas recognized Kathleen Gundry, MD, FACR as chair of the Tellers Committee and acknowledged the committee members –

- Nicholas Beckmann, MD
- Andrew Bowman, MD, PhD
- David Jordan, PhD, FACR
- Jiyon Lee, MD, FACR

CREDENTIALS COMMITTEE REPORT

Dr. Kotsenas recognized Scott Cameron, MD as chair of the Credentials Committee, to present the credentials report.

Dr. Cameron queried the Council to determine whether 1/3 of the Council was present. Over 130

Councilors were present representing a quorum.

Dr. Kotsenas thanked Dr. Cameron for his volunteerism.

APPROVAL OF STANDING RULES

Dr. Kotsenas presented the Standing Rules for consideration by the Council. The rules were developed to both expedite and ensure equitability in the proceedings. Dr. Kotsenas reported that the rules are reviewed annually and that they were presented with minor revisions to accommodate the hybrid meeting. The Standing Rules for the 2022 Annual Meeting of the Council were adopted without objection.

APPROVAL OF MINUTES

The minutes of the meeting of the 2021 ACR and ACRA Council were published and distributed to the Council. Dr. Kotsenas asked if there were any corrections to the 2021 ACR Council Minutes. Absent objection, the minutes were approved as drafted.

SUNSET POLICIES

The 2012 policies as listed in the Agenda Materials were withdrawn and transferred into the historical file without objection in accordance with ACR Bylaws, Article V, Section 10.

UPDATE TO PROCEDURES OF THE COUNCIL

Dr. Kotsenas provided background on an update that the Council Steering Committee made to the Procedures of the Council. This update is the addition of a provision for developing and approving Honorary Resolutions. Honorary Resolutions are intended to recognize an event or accomplishment, for example the anniversary of an ACR program or the centennial of a chapter.

These resolutions do not tend to require debate, nor do they reflect ACR policy that needs to be retained in the Digest of Council Action for 10-years. Given this, the updated Procedures allow these resolutions to be presented as a consent calendar and adopted by majority vote.

CONSIDERATION OF HONORARY RESOLUTION

Dr. Kotsenas presented an Honorary Resolution commemorating the 10-year anniversary of the Radiology Leadership Institute (RLI). Without objection, the Honorary Resolution was adopted, and the Council offered congratulations to the RLI for 10 years of successfully advancing radiologist leadership education and training.

EDITORIAL CHANGES TO RESOLUTIONS

Dr. Kotsenas outlined editorial changes that were made to four resolutions. The changes were made in the agenda materials available online.

- Resolution 1 – updated to reflect a change to be consistent with standard ACR terminology to refer to Registered Radiologist Assistants

- Resolution 3g, a 10-year extension of policy – updated to reflect consistent language used in other policies.

- Resolution 10 – duplicate language was struck in line 192.

- Resolution 47 – updated with standard RRA language from ACR policy.

SPEAKER'S REPORT

Dr. Kotsenas acknowledged the role of the Speaker and Vice Speaker as members of both the Council Steering Committee and the Board of Chancellors. She recognized members of the 2021-2022 Council Steering Committee and their roles as liaisons to chapters and societies and as chairs and co-chairs for reconciliation committees to prepare Practice Parameters and Technical Standards.

Dr. Kotsenas thanked the Chair and Vice Chair of the Board of Chancellors for encouraging and facilitating the work of the CSC and collaborations with the Board of Chancellors.

Dr. Kotsenas reported on work groups formed for 2021-2022.

- Annual Meeting – Chaired by Dr. Matthew Hawkins, the work group facilitated the review of ACR 2021 meeting evaluations, provided recommendations for the 2022 annual meeting, and vetted topics for open microphone sessions that they would moderate during the meeting.
- Communications – Chaired by Dr. Madelene Lewis, the work group helped to facilitate CSC liaison outreach and develop mechanisms for ensuring we have an informed Council throughout the year. This work group will become a standing work group for the CSC to assist with distributing news from the CSC, increasing utilization of the Council Community on Engage and holding Council Town Hall webinars.
- Digest of Council Actions – Dr. Taj Kattapuram led a work group to address the accessibility of the Digest of Council Actions and work will continue in this area to improve access to Council policy.
- Referred Resolution 1 – chaired by Dr. Derrick Siebert, this work group managed the referred resolution from ACR 2021 and developed Resolution 2 presented on the 2022 Council agenda.
- Referred Resolution 2f – chaired by Dr. Kurt Schoppe, this work group managed the referred resolution from ACR 2021 and developed Resolutions 26 and 27 presented on the 2022 Council agenda.

Dr. Kotsenas acknowledged work the CSC did over the past year to be responsive to member concerns, specifically with respect to MARCA, and to help facilitate the development of resolutions.

Dr. Kotsenas acknowledged that in 2020 staff and volunteer leaders came together on six-weeks' notice to put together a governance essentials meeting. She further acknowledged that in 2021 when we again went virtual, we were able to offer a more robust meeting with educational and section-specific programming. She recognized the ACR as a "can-do" organization, holding its first hybrid meeting. She expressed appreciation to the volunteers and staff that made the meeting happen and to the attendees joining in person and online.

LEADERSHIP REPORTS

The following reports were presented to the Council:

- Report of the Chair of the Board of Chancellors – Howard B Fleishon, MD, MMM, FACR
- Report of the Chief Executive Officer – William T. Thorwarth, Jr., MD, FACR
- Report of the Treasurer – Dana Smetherman, MD, FACR

PRESIDENTIAL ADDRESS

Dr. Kotsenas introduced Beverly Coleman, MD, FACR, ACR President, who delivered the 2022 Presidential Address.

RECESS

The meeting was recessed, without objection, at approximately 4:20 pm.

II. SECOND COUNCIL SESSION—Monday, April 25, 2022

CALL TO ORDER

The Speaker, Amy L. Kotsenas, MD, FACR, called the second session of the 99th ACR Annual meeting to order at 10:30 a.m. on Monday, April 25, 2022. Jim Jones, PRP was present to provide parliamentary assistance.

ANNOUNCEMENTS

Dr. Kotsenas reminded RFS and YPS members to vote in their respective elections, with polls closing at 11am.

AWARD PRESENTATIONS

The Chapter Recognition Awards were presented via video. Dr. Kotsenas acknowledged the vital role chapters play in the College and the work of the Committee on Chapters, under the leadership of Dr. Evelyn Anthony.

Overall Excellence

Hawaii Radiological Society	Division A
Arkansas Radiological Society	Division B
Radiological Society of Connecticut	Division C
Minnesota Radiological Society	Division D
New York State Radiological Society	Division E

Government Relations

New Mexico Society of Radiologists	Division B
Alabama Academy of Radiology	Division C
Radiological Society of New Jersey	Division D
Texas Radiological Society	Division E

Meetings & Education

Idaho Radiological Society	Division A
Puerto Rico Radiological Society	Division B
Canadian Association of Radiologists	Division C
District of Columbia Metropolitan Radiological Society	Division C
Virginia Radiological Society	Division D
Massachusetts Radiological Society	Division E

Membership

Council of Affiliated Regional Radiation Oncologists	Division A
Utah Radiological Society	Division B
Radiological Society of Louisiana	Division C
Washington State Radiological Society	Division D
North Carolina Radiological Society	Division E

Quality & Safety

Colorado Radiological Society	Division C
Georgia Radiological Society	Division D
Michigan Radiological Society	Division E

The ACR meeting was adjourned, and the ACRA meeting was convened to present the RADPAC Achievement Award and recognize the Advocate of the Year. These awards were presented via video.

Dr. Don Yoo was recognized with the RADPAC Achievement Award.

Dr. Tilden Childs, III was recognized as the Radiology Advocacy Network's Advocate of the Year.

The ACRA meeting was adjourned, and the ACR meeting was convened.

CREDENTIALS COMMITTEE REPORT

Dr. Kotsenas recognized Scott Cameron, MD as chair of the Credentials Committee, to present the credentials report.

Dr. Cameron queried the Council to determine whether 1/3 of the Council was present. Over 130 Councilors were present representing a quorum.

Dr. Kotsenas turned the presiding officer role over to Vice Speaker, Timothy Crummy, MD, FACR.

REPORT OF THE COLLEGE NOMINATING COMMITTEE

Dr. Crummy introduced the chair of the College Nominating Committee, Dr. Elizabeth Maltin to present the Nominating Committee Report.

The nominees for uncontested positions were:

President:
Howard B. Fleishon, MD, MMM, FACR

Vice-President:
Frank J. Lexa, MD, MBA, FACR

Board of Chancellors – Commission on Radiation Oncology/ASTRO Representative
William Small, Jr, MD, FACR

Board of Chancellors – Member-at-Large
Timothy L. Swan, MD, FACR

Intersociety Committee: (Selected Position)
Arne E. Michalson, MD, FACR

The nominees for contested positions were:

Board of Chancellors – Commission on General, Small, Emergency and Rural Practices
Mark D. Alson, MD, FACR
Eric B. Friedberg, MD, FACR
Agnieszka Solberg, MD

Board of Chancellors – Commission for Women and Diversity
Sharon D'Souza, MD, MPH
Johnson B. Lightfoote, MD, FACR
Sabala R. Mandava, BS, MB

ACR Council Steering Committee:

Rachel Gerson, MD
Atul K. Gupta, MD, FACR
Nolan J. Kagetsu, MD, FACR
Andrew K. Moriarity, MD
Derrick Siebert, MD

ACR College Nominating Committee:
Harris L. Cohen, MD, FACR
Betsy Jacobs, MD
Neil U. Lall, MD
Christopher R. McAdams, MD
Tanya W. Moseley, MD
Christopher M. Mutter, DO
Ali Noor, MD
Victor J. Scarmato, MD, MBA, FACR

CANDIDATE PRESENTATIONS

The Nominating Committee put forth several candidates for contested elections. Dr. Crummy reported that each candidate would provide a two (2) minute speech. Ms. Chris Ryan was thanked for providing public speaking consultation for those candidates wanting to take advantage of her expertise. Attendees were reminded of the ACR Electioneering Policy and asked to refrain from promoting candidates or providing voting suggestions for the election. He thanked the members of the College Nominating Committee for their work over the past year and congratulated each candidate for being nominated and thanked them for their willingness to serve.

Dr. Crummy announced that the polls would open at 12:00pm and remain open for three hours. He noted that those members appropriately credentialed could vote electronically via their smart phone, tablet, or laptop, or in the Cabinet Room.

Dr. Crummy yielded the role of presiding officer to Dr. Kotsenas, Speaker of the Council

REPORTS

Dr. Kotsenas introduced Dr. Derrick Siebert, chair of the CSC Work Group on Resolution 1 to present a report on the resolution referred from ACR 2021.

Dr. Kotsenas introduced Dr. Kurt Schoppe, chair of the CSC Work Group on Resolution 2f to present a report on the resolution referred from ACR 2021.

Dr. Kotsenas introduced Dr. Howard Fleishon, chair of the Board of Chancellors, to provide a report on Resolution 10b, referred from the 2020 ACR Council meeting.

RECESS
The meeting recessed, without objection, at approximately 12:00 pm.

CALL TO ORDER

The meeting was reconvened at approximately 1:30 pm.

REFERENCE COMMITTEE OPEN HEARINGS

Dr. Kotsenas provided an overview on the procedures of the open reference committee hearings. As stipulated by ACR Bylaws, the body will follow The Standard Code of Parliamentary Procedure by Alice

Sturgis, 4th edition.

Dr. Kotsenas introduced Jim Jones, PRP, as the parliamentarian for the meeting. She noted the previously adopted Standing Rules and reviewed the procedures for submitting proposed amendments and testimony during open hearings.

Dr. Kotsenas explained that the hearings are designed for the Reference Committees to determine what they need to make their recommendations to the Council, and that as such, they would be granted discretion to determine what questions they need to ask and the testimony they need to hear.

Dr. Kotsenas cautioned against being intimidated by the process. The process is necessary to ensure order and fairness in the debate. He acknowledged that staff and the parliamentarian were present to assist in the process.

REMINDER OF UPDATE TO PROCEDURES OF THE COUNCIL

Dr. Kotsenas provided a reminder of an update to the Procedures of the Council that was adopted in 2015. The change to the procedures reflects that a vote to refer a parameter at its 5-year limit will result in the original practice parameter being extended for one year. The intent is to ensure that we are not without a parameter in place during the referral period.

RECOGNITION OF COLLABORATING ORGANIZATIONS

Dr. Kotsenas recognized representatives from collaborating organizations that attended to assist with and answer questions that arise from collaborative practice parameters and technical standards.

Dr. Kotsenas thanked the representatives for their expertise and service.

REMINDER OF CONFLICT OF INTEREST POLICY

Dr. Kotsenas called attention to the College's focus on Conflict of Interest and reminded attendees of the process for introducing themselves and identifying any relative Conflict of Interest before providing testimony to a Reference Committee.

OVERVIEW OF INSTRUCTIONS FOR PROVIDING TESTIMONY

Dr. Kotsenas thanked the reference committees for their preparation in advance of the meeting and noted the following:

1. Any ACR member can speak at the microphones or be recognized via the virtual platform.
2. Others may speak at the discretion of the Chair. We encourage everyone to participate. As per our standing rules please try and keep your comments to 2 minutes. If you are supporting what another speaker has already said, please do so concisely.
3. When recognized by the chair, please first state your name, status, for whom you are speaking, any relevant conflicts of interest, and if you stand for or against the resolution.
4. All amendments must be voiced at the reference committee hearings and submitted in writing by using the electronic amendment tool.

CREDENTIALS COMMITTEE REPORT

Dr. Kotsenas invited Dr. Cameron to present the credentials report.

Dr. Cameron queried the Council to determine whether 1/3 of the Council was present. Over 130

Councilors were present representing a quorum.

REFERENCE COMMITTEE OPEN HEARINGS

The open hearings for Reference Committees I, II, III, and IV were held. The sessions ran sequentially. Michael H. Brown, MD, FACR; Sammy Chu, MD, FACR; Suzanne L. Palmer, MD, FACR and Amanda J. Ferrell, MD, chaired the reference committees respectively.

At the conclusion of the open hearings, members were reminded to refrain from communicating with members of the Reference Committees during closed session.

Dr. Kotsenas noted that Reference Committee reports would be posted online when finalized.

RECESS
The Council recessed, without objection, at approximately 5:30 p.m.

III. THIRD COUNCIL SESSION—TUESDAY, APRIL 26, 2022

CALL TO ORDER
The Speaker Amy L. Kotsenas, M.D., FACR, called the third session of the 99th ACR Annual meeting to order at approximately 8:00 a.m. on Tuesday, April 26, 2022. Jim Jones, PRP was present to provide parliamentary assistance.

ANNOUNCEMENTS

Dr. Kotsenas provided announcements and an overview the day's schedule. See reported that Reference Committee reports were posted online and available through the ACR 2022 meeting web site.

AWARD PRESENTATIONS

The Gold Merit Abstract Awards were presented via video. Dr. Kotsenas thanked Dr. Vivek Kalia and all those that reviewed abstracts for 2022.

Advocacy, Economics and Health Policy
Lead Author – Eshani Choksi
Title – Patients' Out-of-pocket Costs for Non-Invasive Diagnostic Imaging: Perspectives from National Patient Surveys Over Two Decades

Informatics and Data Science
Lead Author – Keval Parikh
Title – Assessing the Economic Value of a Cloud-based Image Exchange Tool on a Tertiary Care Academic Healthcare System

Leadership and Practice Management
Lead Author – Stefan Santavicca
Title – Professional Services Rendered by Nurse Practitioners and Physician Assistants in Radiology Practices

Quality and Safety
Lead Author – Nina Capiro
Title – Breast Imaging Orders and the Electronic Health Record: How To Help Your Providers Get It Right

Training and Education

Lead Author – Matin Goldooz
Title – Pitfalls in Post COVID-19 vaccination PET/CT findings – Beware of different patterns of uptake during interpretation and patient's immune status

IN MEMORIAM

Dr. Kotsenas asked the Council to pay tribute to those ACR members who passed away during the period from May 7, 2021 – April 19, 2022

CEREMONIAL LEADERSHIP CHANGES

Dr. Kotsenas presided over leadership changes for 2022-2023. She noted that the changes in leadership would take effect at the end of the day's proceedings.

2022-2023 BOARD OF CHANCELLORS

Dr. Bello introduced the members of the 2022-2023 Board of Chancellors.
Jacqueline A. Bello, MD, FACR, Chair
Alan H. Matsumoto, MD, FACR, Vice Chair
Howard B. Fleishon, MD, MMM, FACR, President
Frank J. Lexa, MD, MBA, FACR, Vice President
Dana H. Smetherman, MD, FACR, Secretary-Treasurer
Amy L. Kotsenas, MD, FACR, Speaker, ACR Council
Timothy A. Crummy, MD, FACR, Vice-Speaker, ACR Council
Mark D. Alson, MD, FACR
Richard A. Barth, MD, FACR
Lori A. Deitte, MD, FACR
Stamatia V. Destounis, MD, FACR
Richard Duszak, Jr., MD, FACR
Catherine J. Everett, MD, MBA, FACR
William T. Herrington, MD, FACR
John E. Jordan, MD, FACR
Taj Kattapuram, MD
Ania Z. Kielar, MD, FACR
Andre Konski, MD, MBA, MA, FACR
Arun Krishnaraj, MD, MPH
David B. Larson, MD, MBA
Johnson B. Lightfoote, MD, FACR
Mahadevappa Mahesh, MS, PhD, FACR
Mary C. Mahoney, MD, FACR
Mary (Vicki) Marx, MD
Andrew K. Moriarity, MD, FACR
Reginald F. Munden, MD, DMD, MBA, FACR
Gregory N. Nicola, MD, FACR
Lauren P. Nicola, MD
Andrew Rosenkrantz, MD, FACR
Eric Rubin, MD, FACR
William Small, Jr, MD, FACR

Timothy L. Swan, MD, FACR
Christoph Wald, MD, PhD, MBA, FACR
Pamela K. Woodard, MD, FACR
Don C. Yoo, MD, FACR

2021-2022 COUNCIL STEERING COMMITTEE

Dr. Kotsenas introduced the members of the 2022-2023 Council Steering Committee.

Amy L. Kotsenas, MD, FACR, Speaker, ACR Council
Timothy A. Crummy, MD, FACR, Vice-Speaker, ACR Council
Max Amurao, PhD, MBA
Juan Batlle, MD, MBA
Matthew J. Brady, MD
Melissa Chen, MD
Ivan M. DeQuesada, II, MD
Rachel Gerson, MD
Daniel Gridley, MD, FACR
Yasha Gupta, MD
K. Elizabeth Hawk, MD, MS, PhD
Elizabeth A. Ignacio, MD
Nolan J. Kagetsu, MD, FACR
Join Luh, MD, FACR
Natasha Monga, MD
Andrew K. Moriarity, MD
Kristin Porter, MD, PhD
Ashley Prosper, MD
Daniel A. Rodgers, MD
Kurt A. Schoppe, MD
Gaurang V. Shah, MD, FACR
Derrick Siebert, MD

Dr. Kotsenas thanked all for members of the BOC and CSC for their service.

AWARD PRESENTATION

The Global Humanitarian Awards were presented to Kassa Darge, MD, PhD, DTM&P, FSAR, FAIUM and David H. Epstein, MD, FACR.

OPEN MICROPHONE SESSION

Dr. Matthew Hawkins moderated an open microphone session.

ECONOMICS FORUM

Dr. Kotsenas introduced the Economics Forum and thanked Dr. Gregory Nicola, chair of the Commission on Economics for coordinating the session.

MORETON LECTURE

Dr. Crummy introduced Brigette McInnis-Day to present the Moreton Lecture. Mrs. McInnis-Day presented the lecture titled, *Transformational Leadership During Times of Change.*

RECESS
The Council recessed, without objection, at approximately 12:00 p.m.

CALL TO ORDER

The meeting was reconvened at approximately 1:30 pm.

CREDENTIALS REPORT

Dr. Kotsenas invited Dr. Cameron to present the credentials report.

Dr. Cameron queried the Council to determine whether 1/3 of the Council was present. Over 130 Councilors were present representing a quorum.

CONSIDERATION OF REFERENCE COMMITTEE REPORTS

Dr. Kotsenas provided an overview on the procedures for the plenary session and consideration of Reference Committee reports.

The 2022 Reference Committee reports were considered by the Council *(attached)*.

The 2022 Final Council Actions Report *(attached)* reflects the disposition of all resolutions considered by the Council.

ANNOUNCEMENTS

Dr. Kotsenas thanked members of the Reference Committees and their staff for their contributions to the resolution process. Dr. Kotsenas also thanked the Council, Chapter Officers, Members, Guests, the Parliamentarian and ACR staff for making the meeting a success.

ADJOURNMENT

There being no further business to come before the ACR Council, Dr. Kotsenas adjourned the 2022 Annual Meeting of the American College of Radiology.

REFERENCE COMMITTEE I

Michael H. Brown, MD, FACR, *Chair*
Kamran M. Ali, MD, FACR
James B. Bronk, MD, FACR
Patricia J. Mergo, MD, FACR
Natasha Monga, MD
Edina Wang, MD

COMMISSIONS, COMMITTEES & TASK FORCES:

Commission on Body Imaging
Commission on Economics
Commission on General, Small, Emergency and Rural Practice
Task Force on Non-Physician Radiology Providers (NPRP)
Commission on Government Relations
Commission on Quality and Safety
Commission on Radiation Oncology Audit Committee
Budget and Finance Committee Governance Committee

No.	RESOLUTION	TYPE	REFERENCE COMMITTEE RECOMMENDATIONS
1.	ACR Position on Registered Radiologist Assistants Legislation	NEW POLICY	RECOMMEND ADOPTION
2	New Process for Comment and Approval of Practice Parameters and Technical Standards	NEW POLICY	RECOMMEND ADOPTION AS AMENDED
3.	Ten Year Extension of Policies:	POLICY RENEWALS	
	(a) Radiation Oncology 8. ~~Electronic Brachytherapy~~ **Electronically-Generated, Low-Energy Radiation Sources (ELS)**		RECOMMEND ADOPTION
	(b) Public Health and Radiation Protection 4. Disposal of Low-Level Radioactive Waste		RECOMMEND ADOPTION
	(c) Public Health and Radiation Protection 11. Radiation Safety Officer (RSO) Training		RECOMMEND ADOPTION
	(d) Radiological Practice and Ethics 2. ACR Policy on Development of Practice Parameters and Technical Standards n. Maintenance of Competence in ACR ~~Standards~~ **Practice Parameters and Technical Standards**		RECOMMEND ADOPTION
	(e) Radiological Practice and Ethics 2. ACR Policy on Development of Practice Parameters and Technical Standards z. Practice Parameters and Technical Standards: Written with Other Organizations		RECOMMEND ADOPTION
	(f) Radiological Practice and Ethics 2. ACR Policy on Development of Practice Parameters and Technical Standards aa. Collaborative and Conflicting Society Guidelines		RECOMMEND ADOPTION
	(g) Radiological Practice and Ethics 2. ACR Policy on Development of Practice Parameters and Technical Standards bb. Practice Parameters and Technical Standards: Uniform CME Statements		RECOMMEND ADOPTION
4.	ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media	REVISED PP	RECOMMEND ADOPTION
5.	ACR Practice Parameter for Continuing Medical Education (CME)	REVISED PP	RECOMMEND ADOPTION

REFERENCE COMMITTEE I

6.	ACR Practice Parameter on the Physician Expert Witness in Radiology and Radiation Oncology	REVISED PP	RECOMMEND ADOPTION AS AMENDED
7.	ACR Practice Parameter for the Performance of Hysterosalpingography	REVISED PP	RECOMMEND ADOPTION
8.	ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI)	REVISED PP	RECOMMEND ADOPTION AS AMENDED
9.	ACR–**SPR** Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT)	REVISED PP	RECOMMEND ADOPTION
10.	ACR–SPR Practice Parameter for the Performance of the Modified Barium Swallow	REVISED PP	RECOMMEND ADOPTION AS AMENDED
11.	ACR–SPR–STR Practice Parameter for the Performance of Chest Radiography	REVISED PP	RECOMMEND ADOPTION
12.	ACR–SPR–STR Practice Parameter for the Performance of Portable (Mobile Unit) Chest Radiography	REVISED PP	RECOMMEND ADOPTION

ACR STAFF:

Director *Brian Monzon*
Moderator *Tracy Purdie*
Recorder *Shannon Rexrode*
Coordinator *Amy Baldwin*
Assistant *Jorden Davie*
Attorney *Tom Hoffman*
Observer *Valerie Olijar*

REFERENCE COMMITTEE I

Reference Committee I met on Monday, April 25, 2022. The members of this committee were Michael H. Brown, MD, FACR, *Chair*, Kamran Ali, MD, FACR, James Bronk, MD, FACR, Patricia Mergo, MD, FACR, Natasha Monga, MD, and Edina Wang, MD.

The session was attended by approximately 800 members, guests, and staff, in person and virtually.

The Reference Committee recognizes the following reports as informational and I recommend that they be filed.

COMMISSIONS, COMMITTEES & TASK FORCES:

Commission on Body Imaging	*Commission on Government Relations*
Commission on Economics	*Commission on Quality and Safety*
Commission on General, Small, Emergency and Rural Practice	*Commission on Radiation Oncology Audit Committee*
Task Force on Non-Physician Radiology Providers (NPRP)	*Budget and Finance Committee Governance Committee*

The Committee was assigned the following resolutions for consideration:

	Resolution	**Sponsor**
1.	ACR Position on Registered Radiologist Assistants Legislation	Kevin Cregan, MD North Carolina Radiological Society
2.	New Process for Comment and Approval of Practice Parameters and Technical Standards	CSC
3.	Ten Year Extension of Policies: (a) Radiation Oncology 8. ~~Electronic Brachytherapy~~ **Electronically-Generated, Low-Energy Radiation Sources (ELS)** (b) Public Health and Radiation Protection 4. Disposal of Low-Level Radioactive Waste (c) Public Health and Radiation Protection 11. Radiation Safety Officer (RSO) Training (d) Radiological Practice and Ethics 2. ACR Policy on Development of Practice Parameters and Technical Standards n. Maintenance of Competence in ACR ~~Standards~~ **Practice Parameters and Technical Standards** (e) Radiological Practice and Ethics 2. ACR Policy on Development of Practice Parameters and Technical Standards z. Practice Parameters and Technical Standards: Written with Other Organizations (f) Radiological Practice and Ethics 2. ACR Policy on Development of Practice Parameters and Technical Standards aa. Collaborative and Conflicting Society Guidelines (g) Radiological Practice and Ethics 2. ACR Policy on Development of Practice Parameters and Technical Standards bb. Practice Parameters and Technical Standards: Uniform CME Statements	CSC

4.	ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media	CSC
5.	ACR Practice Parameter for Continuing Medical Education (CME)	CSC
6.	ACR Practice Parameter on the Physician Expert Witness in Radiology and Radiation Oncology	CSC
7.	ACR Practice Parameter for the Performance of Hysterosalpingography	CSC
8.	ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI)	CSC
9.	ACR–**SPR** Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT)	CSC
10.	ACR–SPR Practice Parameter for the Performance of the Modified Barium Swallow	CSC
11.	ACR–SPR–STR Practice Parameter for the Performance of Chest Radiography	CSC
12.	ACR–SPR–STR Practice Parameter for the Performance of Portable (Mobile Unit) Chest Radiography	CSC

THE REFERENCE COMMITTEE RECOMMENDS THE FOLLOWING CONSENT CALENDAR FOR ACCEPTANCE:

RECOMMENDED FOR ADOPTION:

Resolution No. 1 **ACR Position on Registered Radiologist Assistants Legislation**

BE IT RESOLVED,

that the official policy of the ACR is that for MARCA (and related legislation pertaining to payments for Registered Radiologist Assistants) the ACR will neither support nor oppose such legislation.

Resolution No. 3 **Ten Year Extension of Policy**

BE IT RESOLVED,

that the following policies of the American College of Radiology be extended for an additional ten-year period:

(a) **F. RADIATION ONCOLOGY**

8. ~~ELECTRONIC BRACHYTHERAPY~~ ELECTRONICALLY-GENERATED, LOW-ENERGY RADIATION SOURCES (ELS)

The ACR state chapters should contact their state regulators to adopt the Suggested State Regulations (SSRs) for electronic brachytherapy developed by the Conference of Radiation Control Program Directors; adopted 2012 (Res. 44).

(b) **H. PUBLIC HEALTH AND RADIATION PROTECTION**

4. DISPOSAL OF LOW-LEVEL RADIOACTIVE WASTE

The American College of Radiology encourages its ~~component~~ chapters to actively support state and regional efforts to find safe, cost-effective, and technically sound methods of disposing of low-level radioactive waste. The American College of Radiology will continue to work with the public and other interested bodies to foster understanding and acceptance of the need for the responsible handling of low-level radioactive waste. The American College of Radiology will continue to join with other interested medical organizations in reaffirming support for the timely development of low level radioactive waste disposal sites in accordance with federal law; adopted 1992, amended 2002, 2012 (Res. 33-b).

(c) H. PUBLIC HEALTH AND RADIATION PROTECTION

11. RADIATION SAFETY OFFICER (RSO) TRAINING

The ACR, in collaboration with the **American Association of Physicists in Medicine (**AAPM**)** and other stakeholders, **will** provide models and educational materials for medical physicists, radiologists, radiation oncologists, and nuclear medicine physicians who provide RSO services; adopted 2012 (Res. 43).

(d) I. RADIOLOGICAL PRACTICE AND ETHICS

2. ACR POLICY ON DEVELOPMENT OF PRACTICE PARAMETERS AND TECHNICAL STANDARDS

n. Maintenance of Competence in ACR ~~Standards~~ **Practice Parameters and Technical Standards**

~~In the absence of strong evidence requiring performance of numbers of procedures, the Commission on Quality and Safety will continue to review the "Maintenance of Competence" section in the practice parameters and technical standards and work to develop methods other than number of procedures that assure competence;~~ **The Practice Parameters and Technical Standards' Maintenance of Competence section will be based on methods and criteria other than number of procedures, whenever possible; procedure volumes will be used only if there is strong evidence that requires use of such volumes. In addition, the Practice Parameters and Technical Standards' Maintenance of Competence section will be written consistent with the 2019 ACR Policy on Imaging Guided Procedures Core Privileges**; adopted 2002, amended 2012 (Res. 12-e).

(e) I. RADIOLOGICAL PRACTICE AND ETHICS

2. ACR POLICY ON DEVELOPMENT OF PRACTICE PARAMETERS AND TECHNICAL STANDARDS

z. Practice Parameters and Technical Standards: Written with Other Organizations
For practice parameters and technical standards written with other medical specialty organizations or societies, the ACR Council will follow the ACR Process for Amending Draft Collaborative Guidelines after submission to the ~~AMCLC~~ **ACR Annual Meeting**; 1992, 2002, amended 2012 (Res. 23-a).

(f) I. RADIOLOGICAL PRACTICE AND ETHICS

2. ACR POLICY ON DEVELOPMENT OF PRACTICE PARAMETERS AND TECHNICAL STANDARDS

aa. Collaborative and Conflicting Society Guidelines

The ACR shall remove from a collaborative guideline or standard the name of any collaborating society that has produced, or produces in the future, an independent guideline or standard (subsequent to the production of the collaborative ACR guideline or standard) that conflicts with the ACR collaborative guideline or standard; adopted 2012 (Res. 21).

(g) I. RADIOLOGICAL PRACTICE AND ETHICS

2. ACR POLICY ON DEVELOPMENT OF PRACTICE PARAMETERS AND TECHNICAL STANDARDS

bb. Practice Parameters and Technical Standards: Uniform CME Statements

ACR practice parameters and technical standards will not include a specific number of required CME hours, except when required by the FDA or other government regulatory bodies. The CME section appearing in every ACR practice guideline or technical standard dealing with CME shall state: "The physician should ~~meet~~ **follow** the ACR Practice Parameter for Continuing Medical Education." The physician should include CME in whatever system or modality the practice guideline or technical standard addresses as is appropriate to ~~his or her~~ **their** needs; adopted 1992, 2002, amended 2012 (Res. 23-b).

Resolution No. 4 **ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media**

Resolution No. 5 **ACR Practice Parameter for Continuing Medical Education (CME)**

Resolution No. 7 **ACR Practice Parameter for the Performance of Hysterosalpingography**

Resolution No. 9 **ACR–SPR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT)**

Resolution No. 11 **ACR–SPR–STR Practice Parameter for the Performance of Chest Radiography**

Resolution No. 12 **ACR–SPR–STR Practice Parameter for the Performance of Portable (Mobile Unit) Chest Radiography**

RECOMMENDED FOR ADOPTION AS AMENDED:

Resolution No. 2 **New Process for Comment and Approval of Practice Parameters and Technical Standards**

BE IT RESOLVED,

that starting with the 2024 Annual Meeting there will be a new process for approval of Practice Parameters and Technical Standards (PP&TS) which will apply to all PP&TS, even those sponsored by multiple organizations, trialed for a period of not less than 2 years; and

BE IT FURTHER RESOLVED,

that all PP&TS will be made available during the field review process for ACR member comment simultaneously, with a common deadline. The comment period will be at least 6 weeks in length and no more than 12 weeks; and

BE IT FURTHER RESOLVED,

a virtual PP&TS meeting open to all ACR Members will be created which will occur at least 3 weeks before the Annual Meeting, with the structure of this meeting mirroring existing reference committee open sessions. Depending on the number of PP&TS up for approval, a small number of dedicated PP&TS reference committee(s) will be formed which will hear testimony on proposed PP&TS language at the dedicated PP&TS meeting; and

BE IT FURTHER RESOLVED,

non PP&TS resolutions will continue to follow the current meeting structure with reference committee hearings at the Annual ACR Meeting; and

BE IT FURTHER RESOLVED,

after hearing testimony at the dedicated, virtual PP&TS meeting, the reference committee(s) will formulate a final draft version of all PP&TS being considered which will be distributed to Council and to co-sponsoring organizations at least one week prior to the Annual Meeting; and

BE IT FUTHER RESOLVED,

the final draft version of the PP&TS will be presented to Council as a consent agenda. Persistent ACR member concerns may be resolved by extraction of an individual PP&TS by an ACR Councilor after a motion. Unextracted PP&TS will be passed with the consent agenda after a simple majority vote by Council; and

BE IT FURTHER RESOLVED,

that extracted PP&TS will go through the reconciliation process again for presentation at the next Annual Meeting unless Council determines, by a simple majority vote, that the PP&TS in question needs to be discussed at the current Annual Meeting due to the importance of having an active/updated PP&TS on the subject; and

BE IT FURTHER RESOLVED,

that should an extracted PP&TS be determined to warrant discussion at the current Annual Meeting, standard parliamentary procedure states that any discussion point not previously brought up during the dedicated, virtual PP&TS meeting is out of order; and

BE IT FURTHER RESOLVED,

extracted PP&TS will revert to the most recently approved version, until superseded by a newer version approved by Council.

BE IT FURTHER RESOLVED,

that at the end of the trial period of not less than two years, the ACR Council Steering Committee will gather specific comments from the leadership of each Collaborative Society involved in the trial PP&TS process.

Resolution No. 6 **ACR Practice Parameter on the Physician Expert Witness in Radiology and Radiation Oncology**
(Lines 76-79)

Resolution No. 8 **ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI)**
(Lines 169)

Resolution No. 10 **ACR–SPR Practice Parameter for the Performance of the Modified Barium Swallow**
(Lines 169-170, 285)

The SPR representative affirms that in their best judgement the proposed changes would be acceptable to SPR.

Reference Committee I wishes to thank the Councilors and visitors for their valuable input in these deliberations.

Respectfully Submitted:

_____

Michael H. Brown, MD, FACR, *Chair*
Kamran M. Ali, MD, FACR
James B. Bronk, MD, FACR
Patricia J. Mergo, MD, FACR
Natasha Monga, MD
Edina Wang, MD.

RESOLUTION NO. 6

BE IT RESOLVED,

that the American College of Radiology adopt the ACR Practice Parameter on the Physician Expert Witness in Radiology and Radiation Oncology

Sponsored By: **ACR Council Steering Committee**

Revised 2017 (Resolution 9)*

ACR PRACTICE PARAMETER ON THE PHYSICIAN EXPERT WITNESS IN RADIOLOGY AND RADIATION ONCOLOGY

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

I. INTRODUCTION

For the purpose of this practice parameter, radiology is defined as diagnostic radiology, interventional radiology, nuclear medicine, radiation oncology, and medical physics. For the scope of this practice parameter, radiologists and radiology oncologists include diagnostic radiologists, interventional radiologists, nuclear medicine physicians, and radiation oncologists. For medical physicists, please see the ACR–AAPM Practice Parameter on the Expert Witness in Medical Physics **[1]**.

Radiologists and radiation oncologists **help with training and assessment of students, residents, and fellows, and** are frequently called upon to serve as medical expert witnesses in a variety of legal proceedings that may include cases of alleged medical malpractice, personal injury, product liability, workers compensation, and criminal law and have an obligation to do so in the appropriate circumstances. This obligation includes not only the review of documents, radiologic images, records of treatments, and/or procedures but also the willingness to give sworn testimony by deposition or in court. The public interest requires readily available, objective, and unbiased medical expert testimony. The expert witness should be qualified for the role and follow clear and consistent guidelines. The American College of Radiology (ACR) recognizes the decisive role of the judge in determining admissibility of expert testimony as well as the difficulty in setting the balance between variations of viewpoints and their reasonableness, which fairness requires (see Note 1 that appears in the "Notes" section after the references).

Medical expert witness testimony is indicated in any legal proceeding in which the court needs an objective physician who is not a party to the case, has no personal interest in the outcome of the case, and has expertise in the matter at hand to help explain the issues.

II. QUALIFICATIONS AND RESPONSIBILITIES OF THE EXPERT WITNESS

The expert witness should be a physician with the following qualifications:

Unless otherwise stipulated by applicable state law, licensure and active engagement at the time of the incident under review and for a reasonable period of time in the practice of the radiologic specialty or subspecialty relating to the testimony.

Certification in Radiology, or Diagnostic Radiology, Therapeutic Radiology, Nuclear Radiology, or Radiation Oncology by the American Board of Radiology, the American Osteopathic Board of Radiology, the American Board of Nuclear Medicine, the Royal College of Physicians and Surgeons of Canada, or the Collège des Médecins du Québec. ~~Participation in Maintenance of Certification (MOC)~~ **Continuing Certification (Maintenance of Certification)** by the relevant board, if they have a time limited board certificate.

Education, training, and practical experience, as well as current knowledge and skill, concerning the subject matter of the case, including in a medical liability case the relevant standard of care.

Should the **proceeding involve a** physician defendant **who is** ~~be~~ required by federal or state statute to fulfill certain educational or practice experience requirements, the expert witness should also meet these same requirements.

III. REQUISITES OF AN EXPERT WITNESS

A. The role of the expert witness is to help the ~~fact~~ finder**s of fact** analyze the issues in dispute necessary to decide the case. The expert witness is expected and should be able to render an opinion regarding the reasonableness of the conduct of the parties in the circumstances at hand. Depending on the legal issues **in question,** ~~tried,~~ this may include

an opinion about a defendant doctor's training and experience; the relevant standard of care; the relevance of particular imaging findings, interventional procedures, or radiation **oncology** ~~therapy~~ treatment to causation of damages; or the adequacy of the technical equipment used.

B.

In a medical liability **proceeding** ~~case~~, the expert opinion should be based on **careful review of** ~~on~~ all relevant clinical and radiologic information available at the time of the incident now under **consideration** ~~review.~~ Information, facts, and results of imaging studies performed after the incident ~~generally~~ should **never** ~~not~~ be used to formulate an opinion. The expert witness should make every effort to avoid being influenced by hindsight and framing biases [2,3]. Mechanisms to mitigate bias have been well studied in the literature [4]. It should be recognized that physicians with different levels of expertise may still practice within the **relevant** standard of care. **Determination of standard of care should take into consideration the relevant circumstances under which the involved physician or facility is operating and not necessarily the practice environment of the expert witness.**

C. Recommended Guidelines of Conduct for the Radiologist and Radiation Oncologist Expert Witness

1. Although the nature of legal proceedings is adversarial, the expert witness must **remain** ~~b e~~ as impartial and objective as possible. **The expert's opinion should not be influenced by the client counsel.**
2. In a medical liability case, the expert witness should be familiar with the relevant standard of care. Care must be taken to distinguish between the expert's personal opinion and the **generally accepted** standard of care **for the site of the incident under consideration.**
3. **Expert witnesses must be provided information including medical records and imaging studies that permit the expert witness to formulate an opinion on whether the defendant physician satisfied relevant legal standard of care. For imaging examinations, original images are preferred over copies. Where a picture defendant physician reviewed computer generated or stored images, the expert witness should replicate viewing conditions that existed when the studies were originally reviewed. The expert witness should attempt to replicate the original viewing conditions [5].**
4. The expert witness should be prepared to explain the basis of **their** ~~an~~ opinion ~~and should take care that proffered testimony will be scientifically valid and applicable **able** to **cite examples in** the facts at issue, can be or has been tested **medical** and **imaging,**~~ **which may include citing relevant literature.** ~~**as to why they hold this point of view.** has withstood or reasonably could withstand a peer review.~~ ~~The~~ **Any** expert ~~witness~~ should **expect to** be ~~familiar with~~ **aggressively challenged by opposing counsel and** be prepared to ~~address the known or potential limitations regarding an opinion, as well as the degree to which that~~ **defend your** opinion. ~~is accepted in the medical community~~
5. Compensation of the expert witness should reflect the time and effort involved. Linking compensation for expert testimony to the outcome of the case (contingency fee) is unethical.
6. The expert witness should strive to minimize all potential sources of conscious and subconscious bias when reviewing case materials. Images and other relevant material presented in a blinded fashion to the expert in a malpractice lawsuit strengthens the credibility of the opinion rendered by the expert.
7. **If the expert witness requested is believed to be helpful enabling a sound development of an opinion, but materials have not been provided, the lack of availability of that requested material should be revealed to the relevant parties and stated for the record of proceedings.**
8. **The expert witness should review serial studies prospectively and in tandem, to more closely approximate the circumstances of the original interpretation. Some formats such as CD-ROMs may not permit this approach and, where appropriate, hard copy images should be requested instead.**

Any individual holding an official capacity with the College who testifies in a legal proceeding must exercise great care to distinguish between his or her personal opinions and the policy positions of the College (see Note 2 that appears in the Notes section after the references).

The expert witness can be held accountable for statements made during a legal proceeding. Expert witness testimony may be reviewed and evaluated by medical boards and professional societies.

ACKNOWLEDGEMENTS

This practice parameter was revised according to the process described under the heading *The Process for Developing ACR Practice Parameters and Technical Standards* on the ACR website (https://www.acr.org/Clinical-Resources/Practice-Parameters-and-Technical-Standards) by the Committee on Practice Parameters – General, Small, Emergency and/or Rural Practice of the ACR Commission on General, Small, Emergency and/or Rural Practice, and the Committee on Practice Parameters – Radiation Oncology of the ACR Commission of Radiation Oncology.

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Wallner K, Elliott K, Merrick G, Herstein P, Rieke J. Malpractice in radiation oncology: redefining the role of the medical expert: In regard to Kagan. *Int J Radiat Oncol Biol Phys* 2005;62:1254-1255.

NOTES

[1]These practice parameters are not meant to apply to percipient witnesses such as a doctor who is a party to the case. However, in some jurisdictions (California, for example) a defendant doctor can be deposed both as a defendant and as an expert [5].

[2]The policies of the College are a matter of public record and, if relevant, may be appropriately cited in testimony. Also, the fact that an individual holds an official position with the College may be an appropriate part of his or her qualifications as an expert witness. However, the College, except pursuant to specific action by the Board of Chancellors, does not take a position on the merits of particular cases. A witness who holds an official capacity with the College must therefore be at pains to make clear that his or her testimony expresses his or her personal views and must not state or imply in a written opinion or deposition or trial testimony that he or she is speaking as a representative of the College or is testifying to the views of the College on the merits of a particular case. (1987, 1997, 2007 - ACR Resolution 36-v).

*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised or approved by the ACR Council.

Development Chronology for this Practice Parameter
2002 (Resolution 43)
Revised 2007 (Resolution 40)
Revised 2012 (Resolution 38)
Amended 2014 (Resolution 39)
Revised 2017 (Resolution 9)

RESOLUTION NO. 8

BE IT RESOLVED,

that the American College of Radiology adopt the ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI)

Sponsored By: **ACR Council Steering Committee**

Revised 2017 (Resolution 10)*

ACR PRACTICE PARAMETER FOR PERFORMING AND INTERPRETING MAGNETIC RESONANCE IMAGING (MRI)

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

I. INTRODUCTION

Magnetic resonance imaging (MRI) is a multiplanar imaging method based on an interaction between radiofrequency electromagnetic fields and certain nuclei in the body (usually hydrogen nuclei) after the body has been placed in a strong magnetic field.[2] MRI differentiates between normal and abnormal tissues, providing a sensitive examination to detect disease. This sensitivity is based on the high degree of inherent contrast due to variations in the magnetic relaxation properties of different tissues, both normal and diseased, and the dependence of the MRI signal on these tissue properties.

II. INDICATIONS AND CONTRAINDICATIONS

A. Indications

The currently accepted MRI techniques and indications for MRI specific to anatomic areas are discussed in various ACR practice parameter documents. It is important that any site offering MRI should have documented procedures, technical expertise, and appropriate equipment appropriate to examine each anatomic area. Because the clinical applications of MRI continue to expand, the techniques and indications enumerated in the reference documents may not be all inclusive.

Each site's procedures should be reviewed and updated at appropriate intervals. The final judgment regarding appropriateness of a given examination for a particular patient is the shared responsibility of the ordering physician or other appropriately licensed health care provider and the radiologist. The decision to use MRI to scan a particular **segment** ~~part~~ of the human body depends on the available MRI software and hardware ~~available~~ and the relative cost, efficacy and availability of alternative imaging methods. The examination should provide ~~produce~~ images with suitable contrast characteristics, spatial resolution, signal-to-noise ratio, and ~~section geometry~~ anatomic coverage appropriate to the specific clinical indications.

B. Contraindications

All patients should be screened for potential contraindications prior to MRI scanning [1,2]. Possible contraindications include, but are not limited to, the presence of ~~most~~ **certain** cardiac pacemakers, ferromagnetic intracranial aneurysm clips, certain neurostimulators, certain cochlear implants, and certain other ferromagnetic foreign bodies or electronic devices **[3-8]. Some implants (certain cardiac and vascular stents and gastrointestinal endoclips) may require a waiting period after insertion prior to MRI scanning. In addition, MRI conditional pacemaker and ICD devices are also in clinical use and can be scanned using the appropriate parameters. A large database inclusive of nearly all medical devices can be accessed at www.mrisafety.com [9]**. ~~Possible contraindications should be listed on a screening questionnaire. All patients should be screened for potential contraindications prior to MRI scanning [1,2]. In most cases this will be accomplished with a screening questionnaire **[10].**~~ Published test results and/or on-site testing of an identical device or foreign body may be helpful to determine whether a patient with a particular medical device, implant, or foreign body, such as a pacemaker, may be safely scanned. ~~It should be noted that there are currently MRI safe pacemaker and ICD devices when the appropriate procedures are followed before, during, and after the MR examination~~. There is no known adverse effect of MRI on the fetus. The decision to scan during pregnancy should be made on an individual basis [11].

[2] See ACR Glossary of MR Terms, 5th edition, 2005

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

A. Physician

A physician must be responsible for all aspects of the study, including, but not limited to, reviewing indications for the examination, specifying the pulse sequences to be performed, interpreting images, generating official interpretations (final reports), and assuring the quality of the images and the interpretations. The physician should also be able to apply current knowledge about the gamut of MRI contrast agents, to include choice of agent, composition, risks ~~(including nephrogenic systemic fibrosis)~~ and benefits, appropriate use, and dosing.

Physicians assuming these responsibilities for MR imaging of all anatomical areas, **except for** ~~with the exception of~~ cardiac imaging, should meet one of the following criteria:

Certification in Radiology, Diagnostic Radiology, Interventional Radiology/Diagnostic Radiology (IR/DR), Nuclear Radiology, or Nuclear Medicine by one of the following organizations: the American Board of Radiology (ABR), the American Osteopathic Board of Radiology **(AOBR),** the Royal College of Physicians and Surgeons of Canada **(Royal College),** or the Collège des Médecins du Québec **(CMQ),** and involvement with the supervision, interpretation, and reporting of ~~300~~ MRI examinations ~~within the past 36 months~~[3].

or

Completion of a diagnostic radiology residency program approved by the Accreditation Council for Graduate Medical Education (ACGME), the Royal College of Physicians and Surgeons of Canada (**Royal College** ~~RCPSC~~), the Collège des Médecins du Québec, or the American Osteopathic Association (AOA) to include active participation in the supervision, interpretation, and reporting of ~~500~~ MRI examinations ~~within the past 36 months~~.

or

Physicians not board certified in radiology or not trained in a diagnostic radiology residency program who assume the above responsibilities for MR imaging (~~to~~ excluding cardiac MRI) should limit themselves to the specific anatomic areas pertinent to their specialty practice and meet the following criteria: Completion of an ACGME approved residency program in the specialty practiced, plus ~~200 hours of~~ Category I CME in MRI to include, but not limited to: MRI physics, recognition and correction of MRI artifacts, safety, instrumentation, and clinical applications of MRI in the relevant subspecialty. Additional criteria include the supervision, interpretation, and reporting of ~~500~~ MRI cases in that specialty area ~~within the past 36 months~~ in a supervised setting. For neurologic MRI, ~~at least 50 of the 500~~ cases must include MR angiography (MRA) of the central nervous system.

Specific qualifications for physicians performing cardiac MRI are described in the ACR–NASCI–SPR Practice Parameter for the Performance and Interpretation of Cardiac MRI **[12].**

Maintenance of Competence

All physicians performing MRI examinations should demonstrate evidence of continuing competence in the interpretation and reporting of those examinations. ~~If~~ Competence is assured primarily **based on** ~~on the basis of~~ continuing experience, ~~a minimum of 100 examinations per year is recommended in order~~ to maintain the physician's skills. Because a physician's practice or location may preclude this method, continued competency can also be assured through monitoring and evaluation that indicate appropriate protocols, acceptable technical success, and accuracy of interpretation.

Continuing Medical Education

The physician's continuing education should be in accordance with the ACR Practice Parameter for Continuing Medical Education (CME) **[13]** in MRI as is appropriate to the physician's practice needs.

[3] Board certification and completion of an accredited radiology residency in the past 24 months will be presumed to be satisfactory experience for the reporting and interpreting requirement.

B. Medical Physicist / MR Scientist

A Qualified Medical Physicist or a Qualified MR Scientist must be responsible for acceptance testing and monitoring of MRI equipment for the purposes of this practice parameter.

A Qualified Medical Physicist is an individual who is competent to practice independently one or more subfields in medical physics. The American College of Radiology (ACR) considers certification, continuing education, and experience in the appropriate subfield(s) to demonstrate that an individual is competent to practice in one or more subfields in medical physics, and to be a Qualified Medical Physicist. The ACR strongly recommends that the individual be certified in the appropriate subfield(s) by ~~the American Board of Radiology (~~ABR~~)~~, the Canadian College of Physics in Medicine **(CAMP),** or the American Board of Medical Physics (ABMP).

The Qualified Medical Physicist should meet the ACR Practice Parameter for Continuing Medical Education (CME) **[13].**

The appropriate subfield of medical physics for this practice parameter is Diagnostic Medical Physics (previous medical physics certification categories including Radiological Physics, Diagnostic Radiological Physics, and Diagnostic Imaging Physics are also acceptable).

Certification by the American Board of Medical Physicists (ABMP) or the Canadian College of Physics in Medicine (CCPM) in Magnetic Resonance Imaging Physics is also acceptable. (ACR Resolution 17, 1996 – revised in 2012, Resolution 42)

A Qualified MR Scientist is an individual who does not hold board certification in an appropriate subfield of medical physics but has obtained a graduate degree in a physical science **or engineering field** involving nuclear magnetic resonance (NMR) or MRI and has ~~at least 3 years of~~ documented experience in a clinical MRI environment [14].

Additional guidance on the initial qualifications, as well as continuing experience and education for the Qualified Medical Physicist or MR Scientist, is provided in the current document "ACR CT, MRI, Nuclear Medicine and PET Accreditation Program Requirements for Medical Physicists/MR Scientists," which can be found at https://www.acr.org/Clinical-Resources/Accreditation **[14].**

The Qualified Medical Physicist or MR scientist must maintain a thorough knowledge of the principles of MRI safety, physics, equipment, and relevant performance testing (see the ACR–AAPM Technical Standard for Diagnostics Medical Physics Performance Monitoring of Magnetic Resonance Imaging (MRI) Equipment) **[15].** The Qualified Medical Physicist or MR scientist must have a working understanding of clinical imaging protocols and methods of image optimization. This proficiency must be maintained by participation in continuing education programs of sufficient frequency to ensure familiarity with current concepts, equipment, and procedures. All activities of the Qualified Medical Physicist or MR Scientist must be performed within the context of pertinent government regulations, including the Food and Drug Administration's guidance for MR diagnostic devices.

The Qualified Medical Physicist or MR scientist must be present during surveys and may be assisted in obtaining test data for performance monitoring by other properly trained individuals. These individuals must be properly trained and approved by the Qualified Medical Physicist or MR scientist in the techniques of performing the tests, the reason for a given test, the function and limitations of the imaging equipment and test instruments, the reason for the tests, and the importance of the test results. Supervision of these individuals should be in accordance with current **American Association of Physicists in Medicine (**AAPM) Professional Policy 18-B [16]. The Qualified Medical Physicist or MR Scientist must review and approve all measurements.

C. Registered Radiologist Assistant (RRA)

An RRA is an advanced level radiographer who is certified and registered as a "Registered Radiologist Assistant"

by the American Registry of Radiologic Technologists (ARRT) after successful completion of an advanced academic program encompassing an American Society of Radiologic Technologists (ASRT) RRA curriculum and a radiologist-directed clinical preceptorship.

Under radiologist supervision, the RRA may perform patient assessment, patient management, and selected examinations as delineated in the ACR Statement "Radiologist Assistant: Roles and Responsibilities" subject to state law (see the ACR Digest of Council Actions Appendix H). The RRA transmits to the supervising radiologist those observations that have a bearing on diagnosis. Performance of diagnostic interpretations (preliminary, final, or otherwise) remains outside the scope of practice of the RRA. RRAs performing invasive or non-invasive procedures should function under radiologist supervision and as part of radiologist-led teams. (Adopted 2006 Resolution 34, 2016 Resolution 1-c, Revised in 2020 Resolution 11).

D. Radiology Technologist

The technologist should participate directly in assuring patient comfort and safety, preparing and positioning the patient for the MRI examination, and obtaining the MRI data in a manner suitable for interpretation by the physician. The technologist should also perform frequent quality control testing in accordance with the MRI manufacturer's recommendations.

The technologist performing MRI should:

1. Be certified by the American Registry of Radiologic Technologists (ARRT) ~~the American Registry of Radiologic Technologists (ARRT),~~ the American Registry of MRI Technologists (ARMRIT) **in MRI**, or the Canadian Association of Medical Radiation Technologists (CAMRT) as an MRI technologist (RTMR).

or

2. Be certified by the ARRT **in Radiography, Radiation Therapy, or Nuclear Medicine** and/or have appropriate state licensure and have ~~6 months of~~ supervised clinical experience in MRI scanning.

or

3. Have an associate's degree in an allied health field or a bachelor's degree and certification in another clinical imaging field~~, as well as~~ and have ~~6 months of~~ supervised clinical MRI scanning **experience**.

To assure competence, the supervising physician should evaluate any technologist who began performing MRI prior to October 1996 and who does not meet the above criteria.

Any technologist practicing MRI scanning should be licensed in the jurisdiction in which he/she practices, if state licensure exists. To assure competence, all technologists must be evaluated by the supervising physician.

IV. SPECIFICATIONS OF THE EXAMINATION

The examination should be performed within parameters currently approved by the FDA. Examinations that use techniques not approved by the FDA may be considered when they are judged to be medically appropriate.

The written or electronic request for a MRI examination should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed

health care provider familiar with the patient's clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

Images should be labeled with the following: (1) patient identification, (2) facility identification, (3) examination date, and (4) image orientation indicated by unambiguous polarity symbols (eg, R, L, A, P, H, F). **Study description, sequence name, parameters, image number, field-of-view (FOV) and slice thickness are recommended.**

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings **[17].**

High-quality patient care requires adequate documentation. There should be a permanent record of the full MRI examination in a suitable archival format. Images should remain retrievable within a reasonable period of time, whether for future clinical, facility, legal, or regulatory needs. Retention of the MRI examination should be consistent both with clinical need and with relevant legal and local health care facility requirements. If intravenous or intra-articular contrast material is administered during the MRI examination, the brand name, route of administration, and administered dose of the contrast agent should be recorded and included in the permanent record of the examination, as should injection of any other drugs (eg, glucagon, **Lasix**). An official interpretation (final report) of the MRI findings must be included in the patient's medical record.

VI. EQUIPMENT SPECIFICATIONS

Specifications and performance of the MRI equipment must meet all state and federal requirements. The requirements include, but are not limited to, specifications of maximum static magnetic field strength, maximum rate of change of magnetic field strength (dB/dt), maximum radiofrequency power deposition (specific absorption rate, or SAR), and maximum acoustic noise levels.

Equipment monitoring should be in accordance with the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging (MRI) Equipment **[15].**

VII. SAFETY GUIDELINES

Safety guidelines, practices, and policies must be written, enforced, and reviewed with documentation at least annually by the supervising physician. These guidelines should take into consideration potential magnetic field interactions of ferromagnetic objects in the MRI environment **[**18**,19].** They should also address potential hazards to the patient (eg, from magnetic field interactions, tissue heating, and induced electrical currents) and potential hazards posed by implanted objects or materials within the patient or other individuals in the MR environment **[4,5].**

A screening program should be implemented to assure appropriate and safe use of MR contrast material and to reduce the risk of nephrogenic systemic fibrosis (NSF) [20-22] **unless a cyclic agent is used [23,24].** For further information on ACR screening recommendations see the ACR Manual on Contrast Media **[25]** and the ACR Guidance Document on MR Safe Practices: 2019 Updates and Critical Information **[11]**. Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis.

In pregnancy, gadolinium-based contrast agents (GBCAs) cross the placental barrier, enter the fetal circulation, and pass via the kidneys into the amniotic fluid. Although no definite adverse effects of GBCA administration on the human fetus have been documented, the potential bioeffects of fetal GBCA exposure are not well understood. GBCA administration should therefore be avoided during pregnancy unless no suitable alternative imaging is possible and the benefits of contrast administration outweigh the potential risk to the fetus (see the ACR–SPR

Practice Parameter for the Safe and Optimal Performance of Fetal MRI **[26]**). **If a gadolinium agent is used in pregnancy, a cyclic agent is recommended because of its extremely high kinetic stability [23,24].**

Only a tiny fraction of a GBCA administered to a lactating **patient** ~~woman~~ is excreted into the breast milk, and only a similarly small portion of the excreted **GBCA** ~~milk~~ is actually absorbed by the infant gut. **It is unlikely that the minute amount of GBCA absorbed by a nursing infant's gastrointestinal tract will be harmful.** Moreover, intravenous administration of a GBCA to neonates and infants is considered safe and performed routinely in clinical practice. Given these observations and the fact that even temporary disruption of breastfeeding can be stressful for both mother and infant, ~~a recommendation that breast-feeding be suspended for 24 hours is considered unnecessary~~ **no delay in resumption of breast feeding after MRI is necessary [27]. If a gadolinium agent is used while lactating, a cyclic agent is also recommended.**

~~When GBCAs are administered to nursing women, a small amount of the contrast agent is excreted in the breast milk. It is unlikely that the minute amount of GBCA absorbed by a nursing infant's gastrointestinal tract will be harmful. If there is concern on the part of the referring physician, radiologist, or patient, the nursing mother can be advised to discard her breast milk for 24 hours after GBCA administration.~~

When contrast and/or sedation are necessary, they must be administered in accordance with institutional policy and state and federal law by a qualified practitioner with training in cardiopulmonary resuscitation **[28]** (see the ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media **[29]** and the ACR-SIR Practice Parameter Minimal and/or Moderate Sedation/Analgesia **[30]**).

Appropriate emergency equipment and medications must be immediately available to treat adverse reactions associated with administered medications and should also be appropriate and comprehensive for the range of ages and sizes in the facility's patient population. Inventory and drug expiration dates must be monitored on a regular basis.

A documented quality control program must be maintained at the MR site. Quality control testing should be conducted by the technologist and/or service engineer with review at least annually by the supervising physician and/or a medical physicist/MR scientist **[31-34].**

VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on Quality Control & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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NOT FOR PUBLICATION, QUOTATION, OR CITATION

RESOLUTION NO. 10

BE IT RESOLVED,

that the American College of Radiology adopt the ACR–SPR Practice Parameter for the Performance of the Modified Barium Swallow

Sponsored By: **ACR Council Steering Committee**

8uAmerican College of Radiology, with more than 30,000 members, is the principal organization of radiologists, radiation oncologists, and clinical medical physicists in the United States. The College is a nonprofit professional society whose primary purposes are to advance the science of radiology, improve radiologic services to the patient, study the socioeconomic aspects of the practice of radiology, and encourage continuing education for radiologists, radiation oncologists, medical physicists, and persons practicing in allied professional fields.

The American College of Radiology will periodically define new practice parameters and technical standards for radiologic practice to help advance the science of radiology and to improve the quality of service to patients throughout the United States. Existing practice parameters and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice parameter and technical standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review and approval. The practice parameters and technical standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice parameter and technical standard by those entities not providing these services is not authorized.

Revised 2017 (Resolution 4)*

ACR–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF THE MODIFIED BARIUM SWALLOW

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

I. INTRODUCTION

The modified barium swallow (MBS) is a proven and useful procedure for evaluating the oral and pharyngeal ~~phases of~~ swallowing **function and airway protection** [1-**6**]. Although it is used primarily for evaluation of function, structural abnormalities may also be revealed and may be a primary cause of swallowing dysfunction. A tailored MBS focusing primarily on function **may be performed** ~~is often performed alone. A complete patient evaluation may also include spot images of the pharynx for structural assessment and an esophagram, as symptoms of dysphagia are often poorly localized.~~ **As symptoms of dysphagia are often poorly localized, a complete evaluation of these symptoms may require spot film images of the pharynx for structural assessment or an esophagram in addition to an MBS. The MBS and t**his practice parameter **focus** on assessment of the **functional swallowing regions including the oral cavity, pharynx, larynx, and pharyngoesophageal junction** ~~pharynx~~. For evaluation of the esophagus, see the ACR Practice Parameter for the Performance of Esophagrams and Upper Gastrointestinal Examinations in Adults **[7]** and the ACR–SPR Practice Parameter for the Performance of Contrast Esophagrams and Upper Gastrointestinal Examinations in Infants and Children **[8]**.

The MBS may be performed because of known or suspected swallowing dysfunction or because of the presence of conditions that are strongly associated with swallowing dysfunction. The MBS should be performed only for a valid medical reason and with the minimum radiation dose necessary to achieve a study of diagnostic quality **[9]**. Additional or specialized examinations may be required to complete the patient's assessment.

The primary purposes of the MBS include: to identify and distinguish the presence, type, and estimated severity of physiologic swallowing impairment; determine the safety of oral intake (airway protection); determine the efficiency of oral intake (clearance); detail the effects of selected frontline interventions (postures, maneuvers, bolus variables) on swallowing physiology, airway protection, and efficiency; identify indications for specific interventions that may be appropriate for the clinical condition of the patient; and develop intake (oral, tube, etc) and diet texture/nutritional management plans in collaboration with the physician and other interdisciplinary team members [10].

Although it is not possible to detect all structural and functional swallowing abnormalities using the MBS, adherence to the following practice parameter will maximize the probability of their detection.

II. INDICATIONS AND CONTRAINDICATIONS

Indications for the MBS include, but are not limited to:

1. Oropharyngeal dysphagia
2. Coughing, choking, or drooling ~~with swallowing~~
3. Known or suspected aspiration **or aspiration** pneumonia
4. Frequent respiratory tract infections
5. Neurologic disorders likely to affect swallowing
6. Myoneural junction disorders likely to affect swallowing
7. **Pulmonary conditions likely to affect swallowing**
8. **Pulmonary conditions possibly related to swallowing dysfunction**
9. Myopathy involving the pharynx and cervical esophagus
10. Masses of the tongue, pharynx, larynx, or retropharyngeal region that may affect swallowing
11. **Preoperative and f**ollow-up posttreatment (operative, radiation, and/or chemotherapy) evaluation of the mouth, pharynx, larynx, ~~or~~ retropharyngeal**, or pharyngo-esophageal junction** area [11-13]
12. Follow-up of known oropharyngeal swallowing dysfunction
13. Follow-up assessment of dietary restrictions and protective maneuvers to limit or prevent aspiration
14. Follow-up assessment of patients recovering from trauma and/or coma
15. Oral feeding **safety** assessment for ventilator dependent patients [14]
16. Poor feeding**, sucking, swallowing** (neonate)
17. Patients with basilar pulmonary fibrosis
18. **After prolonged intubation and/or deconditioning**

For the pregnant or potentially pregnant patient, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation **[15,16]**.

Potential Contraindications

1. **Known or suspected leak from the pharynx or esophagus such as following trauma or surgery. If leak is suspected, a water soluble esophagram should be performed prior to MBS that uses barium contrast agents**
2. **Known or suspected leak from the more distal gastrointestinal (GI) tract**
3. **Known or suspected tracheoesophageal fistula. If suspected, an esophagram should be performed prior to MBS**

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

A. Physician

Examinations must be performed by or under the supervision of a licensed physician at the site and interpreted by a physician with the following qualifications:

Certification in Radiology, Diagnostic Radiology or Interventional Radiology/Diagnostic Radiology (IR/DR) by the American Board of Radiology, the American Osteopathic Board of Radiology, the Royal College of Physicians and Surgeons of Canada, or the Collège des Médecins du Québec.

or

Completion of a residency program approved by the Accreditation Council for Graduate Medical Education (ACGME), the Royal College of Physicians and Surgeons of Canada (RCPSC), the Collège des Médecins du Québec, or the American Osteopathic Association (AOA) and must have ~~spent a minimum of 3 months of~~ documented formal training in the performance and interpretation of gastrointestinal fluoroscopy, including MBS.

and

1. The physician shall have documented training in and understanding of the physics of diagnostic radiology and the equipment needed to produce the images. This should include radiography, fluoroscopy, and digital image processing. In addition, the physician must be familiar with the principles of radiation protection, the hazards of radiation, and radiation monitoring requirements as they apply to both patients and personnel.

and

2. The physician shall have documented training in and understanding of the value of MBS examinations **and oropharyngeal swallowing function** relative to other medical imaging procedures (general radiography, fluoroscopy, CT, ultrasound, MRI, and nuclear medicine) to best evaluate a patient's clinical symptoms.

CME

The physician's continuing medical education should be in accordance with the ACR Practice Parameter for Continuing Medical Education (CME) [17].

B. Registered Radiologist Assistant (RRA)

An RRA is an advanced level radiographer who is certified and registered as a "Registered Radiologist Assistant" by the American Registry of Radiologic Technologists (ARRT) after successful completion of an advanced academic program encompassing an American Society of Radiologic Technologists (ASRT) RRA curriculum and a radiologist-directed clinical preceptorship.

Under radiologist supervision, the RRA may perform patient assessment, patient management, and selected examinations as delineated in the ACR Statement "Radiologist Assistant: Roles and Responsibilities" subject to state law (see the ACR Digest of Council Actions Appendix H). The RRA transmits to the supervising radiologist those

observations that have a bearing on diagnosis. Performance of diagnostic interpretations (preliminary, final, or otherwise) remains outside the scope of practice of the RRA. RRAs performing invasive or non-invasive procedures should function under radiologist supervision and as part of radiologist-led teams. (Adopted 2006 Resolution 34, 2016 Resolution 1-c, Revised in 2020 Resolution 11).

C. Radiologic Technologist

Qualifications of technologists performing GI radiography should be in accordance with the current ACR policy statement for fluoroscopy[2] and with the operating procedures or manuals at the imaging facility. Fluoroscopy technologists assisting in MBS examinations should be thoroughly trained in GI radiography.

Certification by the ARRT or unrestricted state licensure is required.

D. Speech-Language Pathologist

A speech-language pathologist **is usually also involved in the performance and interpretation of MBS studies, in conjunction with the radiologist. This professional** should have specific education and training related to the indications **and to** ~~for and~~ the performance **and interpretation** of the MBS **using validated and standardized methods.** It is recommended that ~~he or she~~ **the individual** hold the Certificate of Clinical Competence in Speech-Language Pathology (CCC-SLP) from the American Speech-Language-Hearing Association. The speech-language pathologist should have knowledge of the patient's medical condition and current cognitive and mental status.

IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for modified barium swallow should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state's scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

A. Patient Selection, Preparation, and Positioning

The patient must have sufficient cognitive awareness to cooperate with the study. ~~The patient should have nothing by mouth for several hours prior to the study and should not smoke or chew gum for the same period of time.~~ The oral, ~~and~~ pharyngeal**, and pharyngoesophageal junction** regions **and functions** are usually evaluated initially in the lateral plane with the patient upright **with gravity assistance to mimic the eating and drinking position**. **The lateral view may be followed by frontal view observations whenever positioning allows to provide evaluation of symmetry of swallowing function. Stable, commercially prepared barium and validated, standard protocols are encouraged to optimize visualization and reproducibility of the MBS and comparison of finding across sites in the care continuum [18-20].** Special chairs are available to assist with patient positioning **if the patient is unable to stand or sit upright unsupported** but are not necessary to perform an adequate study. ~~Patients who cannot be placed upright may be examined with cross-table lateral fluoroscopy or in the lateral decubitus position.~~ For infants, the MBS

[2]The American College of Radiology approves of the practice of certified and/or licensed radiologic technologists performing fluoroscopy in a facility or department as a positioning or localizing procedure only, and then only if monitored by a supervising physician who is personally and immediately available.* There must be a written policy or process for the positioning or localizing procedure that is approved by the medical director of the facility or department/service and that includes written authority or policies and processes for designating radiologic technologists who may perform such procedures. (ACR Resolution 26, 1987 – revised in 2007, Resolution 12-m)
*For the purposes of this parameter, "personally and immediately available" is defined in manner of the "personal supervision" provision of CMS—a physician must be in attendance in the room during the performance of the procedure. Program Memorandum Carriers, DHHS, HCFA, Transmittal B-01-28, April 19, 20

should be performed with the patient upright and sitting supported in a secured chair/seat preferentially designed for oropharyngeal motility studies. **Neonates may be studied on an inclined lateral decubitus, simulating breast-feeding. For patients who cannot be placed upright, a semiupright swallowing study can be performed with the patient placed in the lateral decubitus position on the fluoroscopy table and the table tilted as close to upright as the patient can tolerate.**

B. Personnel

The examination **should** ~~may~~ be performed by ~~a physician alone for diagnostic evaluation or by~~ a physician and a speech-language pathologist for both diagnosis **of the swallowing impairment(s)** and recommendation regarding therapy and technique to promote swallowing with the least risk of aspiration **and most complete oropharyngeal clearance during swallowing.**

The examination may be performed by a physician alone (or an NPRP ~~RRA~~ with physician supervision) for diagnostic evaluation or by a physician (or an NPRP ~~RRA~~ with physician supervision) and a speech-language pathologist for both diagnosis and recommendation regarding therapy.

C. Method of Recording

For functional assessment, the fluoroscopic portion of the examination should be recorded on high-resolution video fluorographic (VF) and/or rapid digital fluorographic imaging [**10**,21]. For morphologic assessment, spot images and/or rapid digital fluorographic imaging with double-contrast or single-contrast technique should be used ~~(single contrast usually suffices in children)~~.

D. MBS Technique

1. Examination
   The examination should include evaluation of oral, ~~and~~ pharyngeal**, laryngeal, and pharyngoesophageal segment** function and morphology in the lateral projection. Evaluation in the frontal projection may be useful **to view symmetry of function and effects of applied compensatory strategies on swallowing safety and bolus clearance. Observation of the esophagus in the frontal projection to ensure unimpeded pharyngo-esophageal drainage may be helpful. If used, the report should specify "Upright emptying was observed." It is important to recognize that the assessment of gravity-assisted pharyngo-esophageal clearance of barium during MBS is a limited assessment and does not imply the esophagus is normal. Depending on patient symptoms and findings (or lack of findings) on MBS, an esophagram may be required to complete the assessment of the patient. [22-25]** ~~to further evaluate an abnormality identified on the lateral projection. An esophagram may be required to complete the assessment of the patient. Evaluation in the frontal projection is not necessary in infants and young children~~. **The examination may need to be terminated prematurely if the patient demonstrates severe aspiration (such as aspiration below the sternal notch) and does not respond to protective or therapeutic maneuvers.**

2. Videofluorographic recording medium
   It is recommended that videofluorographic and/or rapid digital fluorographic recordings **are** ~~is~~ performed while the patient **is administered barium consistencies and volumes customized for the MBS and that approximate the consistencies of liquids and food in an oral diet to detect swallowing impairment. Use of a standardized and validated set of commercially prepared barium consistencies and volumes is recommended to ensure the ability to reproduce or compare repeat evaluation results, risks associated with aspiration of these substances, and infection control issues [26].** ~~swallows a variety of consistencies of barium or barium-impregnated food with varying bolus volumes~~. ~~Assessment includes all phases of swallowing from the preparatory oral phase through the oral transfer phase and pharyngeal phase. The esophageal phase may be assessed on other swallows. The viscosity and volume of each bolus may be varied by the clinical judgment of the speech–language pathologist or the radiologist based on the patient's presenting symptoms.~~ **Introduction or mixing of food substances and barium recipes should be avoided because of inability to reproduce or compare repeat evaluation results, risks associated with aspiration of these**

substances, and infection control issues [10,20]. Fluoroscopic acquisition rates should be continuous or 30 pulses per second whenever possible to provide optimal visualization of rapid movements associated with swallowing and aspiration detection. Lower pulse rates have been shown to reduce detection of swallowing impairment and aspiration [9,27,28]. If aspiration occurs, the patient's response to aspiration and ability to clear the aspirated materials and his or her response to protective and therapeutic maneuvers should be assessed wherever possible.

In some instances, continuous fluoroscopy may not be indicated. For example, in assessing the ability of the patient to protect the airway once fatigue occurs following progressive feedings, interval fluoroscopy should be used. ~~Fluoroscopic screening should be restarted once the patient's swallow appears to slow [15].~~

a. Spot radiographs
Spot radiographs are not needed for all patients. When obtained, double-contrast spot radiographs and/or rapid digital fluorographic images of the pharynx may include lateral views during both suspended respiration and phonation and frontal views during both suspended respiration and modified Valsalva maneuver. Single-contrast radiographs and/or rapid digital fluorographic images may be substituted if warranted by the patient's clinical condition. For pediatric patients, spot radiographs and double contrast examinations are seldom necessary. ~~The examination should be performed with a pulsed fluoroscopy unit using a frame rate sufficient for diagnostic quality and in keeping with the principles of ALARA. Images and/or cine clips may be stored with the image capture feature rather than using full exposures.~~

b. Esophagram
An evaluation of esophageal structure and function is beyond the scope of the MBS, which is focused on assessment of functional swallowing in the areas of the oral cavity, pharynx, larynx, and pharyngo-esophageal junction. For evaluation of the esophagus, see the ACR Practice Parameter for the Performance of Esophagrams and Upper Gastrointestinal Examinations in Adults [7] and the ACR–SPR Practice Parameter for the Performance of Contrast Esophagrams and Upper Gastrointestinal Examinations in Infants and Children [8]. In cases of significant aspiration, the esophagram may be performed with injection of barium directly into the esophagus through a feeding tube, either pre-existing or placed by the radiologist. A dedicated evaluation of the esophagus ~~in children~~ is often part of an upper gastrointestinal study (UGI) and ~~can be performed before the modified barium swallow or~~ at a later time after the MBS, as ingestion of different consistencies of barium impregnated foods may impact the diagnostic quality of the UGI.

3. Tailored examination
The method of examination **may** ~~will often~~ vary based on the patient's history, the clinical questions to be answered, and the findings during the study**; however, standard protocols, assessment, interpretation, and reporting are encouraged [19].** ~~Many institutions tailor the majority of examinations to VF in the lateral projection to assess for the presence or absence of aspiration and the effects of protective maneuvers to limit aspiration.~~ The examination may need to be terminated prematurely if the patient demonstrates **repeated,** severe aspiration (such as aspiration below the sternal notch) and does not respond to protective or therapeutic maneuvers.

4. Protective and therapeutic maneuvers
When aspiration does occur, the effect of maneuvers to limit or prevent aspiration may be assessed. These may include changes in neck or body position or other special maneuvers. If swallowing dysfunction is present, additional compensatory strategies may be assessed to improve swallow physiology [14]. ~~Additional consistencies of food may be assessed based on the patient's usual or expected diet.~~

5. Provocative maneuvers
When the patient's symptoms are not explained by the **standard** ~~basic~~ examination, provocative or helpful maneuvers based on the history may be needed. Changes in **head or** body position may be used to evoke subtle swallowing dysfunction, including **head turn or flexion** ~~the supine and prone oblique positions and head extension~~. Similarly, a change in the position of an infant's head (flexion) may also be useful, once aspiration

has been shown, to determine if head position eliminates aspiration.

In the event of aspiration during the study, frontal chest radiography may be helpful at the end of the examination to document or determine the extent of aspiration.

E. Radiographic Quality Control

Proper functioning of the imaging equipment should be assured prior to beginning the examination. If spot images are obtained, image quality should be checked by a qualified technologist or physician before the patient is dismissed. Images not of diagnostic quality should be repeated as necessary. Provision should be made for recording all available radiation dose data in the patient's medical record. If cumulative air kerma or air kerma-area-product data are not available, the fluoroscopic exposure time and the number of acquired images (radiography or cine) should be recorded in the patient's medical record, according to the ACR–AAPM Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures **[29]**.

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings **[30]**.

When the examination is performed by a radiologist, a supervised resident or fellow, or a qualified supervised NPRP ~~RRA~~ and a speech-language pathologist, the images should be reviewed by the performing team with a discussion of the findings and conclusions agreed upon by them. This should be done out of hearing of the patient. If there are any discordant opinions not resolved by image review, additional imaging should be performed.

Comparison to prior MBS studies should be performed when relevant, particularly when the examination is performed to follow up previously demonstrated abnormalities. Patient identity (using name and/or a unique identifying number) and examination date should be recorded on the VF recording medium. Each institution should develop a policy on retention **and reporting results** of video image**s, which are considered part of the medical record** consistent with applicable state or federal policies. **It is recommended that the radiologist and speech-language pathologist corroborate findings at the conclusion of the examination [10].**

VI. EQUIPMENT SPECIFICATIONS

Examinations should be performed with fluoroscopic and radiographic equipment meeting all applicable federal and state radiation standards. The equipment should provide diagnostic fluoroscopic image quality and recording capability. The equipment should be capable of producing kilovoltage greater than 100 kVp. In selected cases, patient monitoring (eg, pulse oximetry) may be desirable. However, most patients do not require any additional monitoring other than that which may already be in use.

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Radiographic Equipment [18] and the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Fluoroscopic Equipment [19].

VII. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, registered radiologist assistants, radiologic technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff, and to society as a whole, "as low as reasonably achievable" (ALARA) and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure and the diagnostic image quality necessary

to achieve the clinical objective. All personnel that work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection and application of dose limits) and the principles of proper management of radiation dose to patients (justification, optimization and the use of dose reference levels)
http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf

Nationally developed guidelines, such as the ACR's Appropriateness Criteria®, should be used to help choose the most appropriate imaging procedures to prevent unwarranted radiation exposure.

Facilities should have and adhere to policies and procedures that require varying ionizing radiation examination protocols (plain radiography, fluoroscopy, interventional radiology, CT) to take into account patient body habitus (such as patient dimensions, weight, or body mass index) to optimize the relationship between minimal radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used whenever appropriate. If such technology is not available, appropriate manual techniques should be used.

Additional information regarding patient radiation safety in imaging is available at the Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org) websites. These advocacy and awareness campaigns provide free educational materials for all stakeholders involved in imaging (patients, technologists, referring providers, medical physicists, and radiologists).

Radiation exposures or other dose indices should be measured and patient radiation dose estimated for representative examinations and types of patients by a Qualified Medical Physicist in accordance with the applicable ACR technical standards. Regular auditing of patient dose indices should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry, the NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States or the Conference of Radiation Control Program Director's National Evaluation of X-ray Trends. (ACR Resolution 17 adopted in 2006 – revised in 2009, 2013, Resolution 52).

VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on Quality Control & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

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No.	RESOLUTION	TYPE	REFERENCE COMMITTEE RECOMMENDATIONS
13.	Paid Family/Medical Leave in Radiology, Interventional Radiology and Radiation Oncology	NEW POLICY	RECOMMEND ADOPTION AS AMENDED
14.	Environmental Sustainability and Climate Change	NEW POLICY	RECOMMEND ADOPTION AS AMENDED
15.	Ten Year Extension of Policies: (a) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies i. Implementation of the Clinical Practice of Interventional Radiology (IR) and Interventional Neuroradiology (INR) (b) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies v. Interpretation of Radiologic Examinations Not Directly Supervised or Monitored by the Radiologist (c) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies w. Managed Health Care (d) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies x. Medical Staff Privileges, Exclusive Contracts, and Economic Credentialing (e) Technologists and Allied Health Professions 9. Business Management Association (f) Technologists and Allied Health Professions 10. Educational Programs (g) Technologists and Allied Health Professions 19. Radiology Technology Model Scholarship Agreement (h) Third Party Carriers and Compensation 22. Radiologists, Radiation Oncologists, and Self-Referral	POLICY RENEWALS	RECOMMEND ADOPTION
16.	ACR–SIR Practice Parameter for Endovascular Management of the Thrombosed or Dysfunctional Dialysis Access	REVISED PP	RECOMMEND ADOPTION
17.	ACR–SIR–SPR Practice Parameter for the Performance of Arteriography	REVISED PP	RECOMMEND ADOPTION
18.	ACR–SIR–SPR Practice Parameter for the Creation of a Transjugular Intrahepatic Portosystemic Shunt (TIPS)	REVISED PP	RECOMMEND ADOPTION

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19.	ACR–ASNR–ASSR–SIR–SNIS Practice Parameter for the Performance of Vertebral Augmentation	REVISED PP	RECOMMEND ADOPTION
20.	**ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography (CT) in the Evaluation and Classification of Traumatic Brain Injury**	NEW PP	RECOMMEND ADOPTION
21.	ACR–ASNR–SPR Practice Parameter for the Performance of functional Magnetic Resonance Imaging (fMRI) of the Brain	REVISED PP	RECOMMEND ADOPTION
22.	ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography (CT) Perfusion in Neuroradiologic Imaging	REVISED PP	RECOMMEND ADOPTION
23.	ACR–ASNR–ASSR–SPR Practice Parameter for the Performance of Computed Tomography (CT) of the Spine	REVISED PP	RECOMMEND ADOPTION
24.	ACR–ASNR–SPR Practice Parameter for the Performance of Intracranial Magnetic Resonance Perfusion Imaging	REVISED PP	RECOMMEND ADOPTION

ACR STAFF:

Director	*Christine Waldrip*	Assistant	*Elspeth Gates*
Moderator	*Christina Berry*	Attorney	*Gloria Romanelli*
Recorder	*David O'Brien*	Coordinator	*Shavouna Farmerie*

REFERENCE COMMITTEE II

Reference Committee II met on Monday, April 25, 2022. The members of this committee were Sammy Chu, MD, FACR, *Chair,* Ivan M. DeQuesada II, MD, Atul K. Gupta, MD, FACR, Kirang Patel, MD, Mary H. Scanlon, MD, FACR, and Derrick Siebert, MD.

The session was attended by approximately 800 members, guests, and staff, in person and virtually.

The Reference Committee recognizes the following reports as informational and I recommend that they be filed.

COMMISSIONS, COMMITTEES & TASK FORCES:

Commission on Human Resources
Commission on Informatics & the Data Science Institute
Commission on International Relations
Commission on Interventional Radiology & Cardiovascular Imaging
Commission on Neuroradiology
Journal of the American College of Radiology (JACR)

The Committee was assigned the following resolutions for consideration:

	Resolution	**Sponsor**
13.	Paid Family/Medical Leave in Radiology, Interventional Radiology and Radiation Oncology	Elizabeth Kagan Arleo, MD, FACR, Councilor-at-large, ACR Kirti Magudia, MD, PhD, Councilor-at-large, ACR Susan Ackerman, MD, FACR, Councilor, AAWR Kristin Porter, MD, PhD, Councilor, Alabama Academy of Radiology Lucy Spalluto, MD, MPH, Councilor, Tennessee Radiological Society Candice Johnstone, MD, MPH, FACR, Councilor, Wisconsin Radiological Society Board of Chancellors Council Steering Committee ACR Young and Early Career Professional Section ACR Resident and Fellow Section Alabama Academy of Radiology Arizona Radiological Society California Radiological Society Council of Affiliated Regional Radiation Oncology Societies District of Columbia Metropolitan Radiological Society Kentucky Radiological Society Maine Radiological Society Maryland Radiological Society Massachusetts Radiological Society Minnesota Radiological Society Missouri Radiological Society New York State Radiological Society North Carolina Radiological Society Radiological Society of Puerto Rico Rhode Island Radiological Society Utah State Radiological Society Virginia Radiological Society
14.	Environmental Sustainability and Climate Change	ACR Young and Early Career Physician Section California Radiological Society

District of Columbia Metropolitan Radiological Society
Illinois Radiological Society
Massachusetts Radiological Society
North Carolina Radiological Society
Radiological Society of Puerto Rico
Vermont Radiological Society

15. Ten Year Extension of Policies: CSC
    (a) Radiological Practice and Ethics
        5. Miscellaneous Radiologic Practice and Ethics Policies
            i. Implementation of the Clinical Practice of Interventional Radiology (IR) and Interventional Neuroradiology (INR)
    (b) Radiological Practice and Ethics
        5. Miscellaneous Radiologic Practice and Ethics Policies
            v. Interpretation of Radiologic Examinations Not Directly Supervised or Monitored by the Radiologist
    (c) Radiological Practice and Ethics
        5. Miscellaneous Radiologic Practice and Ethics Policies
            w. Managed Health Care
    (d) Radiological Practice and Ethics
        5. Miscellaneous Radiologic Practice and Ethics Policies
            x. Medical Staff Privileges, Exclusive Contracts, and Economic Credentialing
    (e) Technologists and Allied Health Professions
        9. Business Management Association
    (f) Technologists and Allied Health Professions
        10. Educational Programs
    (g) Technologists and Allied Health Professions
        19. Radiology Technology Model Scholarship Agreement
    (h) Third Party Carriers and Compensation
        22. Radiologists, Radiation Oncologists, and Self-Referral

16. ACR–SIR Practice Parameter for Endovascular Management of the Thrombosed or Dysfunctional Dialysis Access CSC

17. ACR–SIR–SPR Practice Parameter for the Performance of Arteriography CSC

18. ACR–SIR–SPR Practice Parameter for the Creation of a Transjugular Intrahepatic Portosystemic Shunt (TIPS) CSC

19. ACR–ASNR–ASSR–SIR–SNIS Practice Parameter for the Performance of Vertebral Augmentation CSC

20. **ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography (CT) in the Evaluation and Classification of Traumatic Brain Injury** CSC

21. ACR–ASNR–SPR Practice Parameter for the Performance of functional Magnetic Resonance Imaging (fMRI) of the Brain CSC

22. ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography (CT) Perfusion in Neuroradiologic Imaging CSC

23. ACR–ASNR–ASSR–SPR Practice Parameter for the Performance of Computed Tomography (CT) of the Spine CSC

24. ACR–ASNR–SPR Practice Parameter for the Performance of Intracranial Magnetic Resonance Perfusion Imaging CSC

THE REFERENCE COMMITTEE RECOMMENDS THE FOLLOWING CONSENT CALENDAR FOR ACCEPTANCE:

RECOMMENDED FOR ADOPTION:

Resolution No. 15 Ten Year Extension of Policy

BE IT RESOLVED,

that the following policies of the American College of Radiology be extended for an additional ten-year period:

(a) I. RADIOLOGICAL PRACTICE AND ETHICS

5. MISCELLANEOUS RADIOLOGIC PRACTICE AND ETHICS POLICIES

i. Implementation of the Clinical Practice of Interventional Radiology (IR) and Interventional Neuroradiology (INR)

The ACR works with SIR and SNIS to continually enhance and promote the growth and sustainability of IR and INR clinical services within the practice of radiology and within the health care system.

~~The ACR created a Task Force to define and prioritize the business needs of IR and INR clinical practices, and develop implementation and marketing tactics with respect to optimizing clinical practices in radiology. The task force should have appropriate representation from the ACR, SIR, SNIS, and other stakeholders.~~

The ACR Radiology Leadership Institute (RLI) should consider the necessity of a longitudinal patient care model for IR and INR in designing its curriculum and include the appropriate course content to address that need.

The ACR, in partnership with the SIR and SNIS, should embark upon an educational campaign to promote and demonstrate the value of IR and INR clinical practices to patients, physicians, allied health providers, radiology practices, public and private third-party payors, **government agencies, legislative representatives** and health care organization leaders; including but not limited to web-based information, printed materials, audio/visual media, and targeted conferences.

The ACR works with the SIR and SNIS to disseminate to radiology practices the existing support tools that facilitate the implementation of optimal IR and INR clinical practices; adopted 2012 (Res. 9).

(b) I. RADIOLOGICAL PRACTICE AND ETHICS

5. MISCELLANEOUS RADIOLOGIC PRACTICE AND ETHICS POLICIES

v. Interpretation of Radiologic Examinations Not Directly Supervised or Monitored by the Radiologist.

The ACR will continue to monitor the legal, ethical, professional liability and state licensure aspects of medical imaging interpretation when off site within a state and particularly in other states remote from the practical site.

Interpretation of these cases should be in compliance with the ACR—AAPM—SIIM Technical Standard for Electronic Practice of Medical Imaging, the ACR Practice Guideline for Communication of Diagnostic Findings, and the Report of the ACR Task Force on Teleradiology Practice (2013); adopted 1992, 2002, 2012, amended 2014 (Res. 10-a).

(c) I. RADIOLOGICAL PRACTICE AND ETHICS

5. MISCELLANEOUS RADIOLOGIC PRACTICE AND ETHICS POLICIES

w. Managed Health Care

The American College of Radiology actively advises radiologists that they need to become informed of their legal rights and obligations before they enter into any health care contract. ~~The American College of Radiology will provide guidance to radiologists on the legal implications of such contracts.~~ The American College of Radiology will continue to gather data regarding radiologists' participation in new payment models; adopted 1992, 2002, amended 2012 (Res.1-h).

(d) I. RADIOLOGICAL PRACTICE AND ETHICS

5. MISCELLANEOUS RADIOLOGIC PRACTICE AND ETHICS POLICIES

x. Medical Staff Privileges, Exclusive Contracts, and Economic Credentialing

Hospital Medical Staff Bylaws

The ACR expresses concern over hospital efforts to make changes in medical staff bylaws which reduce or eliminate fair hearing rights. The ACR will make available model medical staff bylaws and sources of appropriate legal counsel to represent hospital medical staffs; adopted 1992, amended 2002, 2012 (Res.1-i).

(e) J. TECHNOLOGISTS AND ALLIED HEALTH PROFESSIONS

9. BUSINESS MANGEMENT ASSOCIATION

The ACR urges all radiologists and radiation oncologists to encourage their business managers **and administrators** to become or remain members of the Radiology Business Management Association or the Society of Radiation Oncology

Administrators. Recognizing that these associations will benefit radiology, the ACR continues to support their broadening membership bases and attendance at educational seminars; 1982, 1992, 2002, amended 2012 (Res. 1-j).

(f) J. TECHNOLOGISTS AND ALLIED HEALTH PROFESSIONS

10. EDUCATIONAL PROGRAMS

Educational programs in Radiologic Technology seeking to demonstrate or develop innovation in the educational process should document the need and justification for such a program; structure the program so that the currently established essentials are not

diminished; and submit the plans for such programs to the appropriate Joint Review Committee and/**or other** certifying agency for evaluation and review prior to initiation; adopted 1980, 1990, 2012 (Res. 12-g).

(g) J. TECHNOLOGISTS AND ALLIED HEALTH PROFESSIONS

19. RADIOLOGY TECHNOLOGY MODEL SCHOLARSHIP AGREEMENT

The ACR encourages radiology practices, local societies, state chapters, and other radiological organizations to establish radiologic technologists scholarship programs. The ACR suggests an updated model for such scholarships to be used as the practice deems necessary; 1992, amended 2002, 2012 (Res. 1-k).

(h) L. THIRD PARTY CARRIERS AND COMPENSATION

22. RADIOLOGISTS, RADIATION ONCOLOGISTS, AND SELF-REFERRAL

The American College of Radiology adopts the following policy on self-referral: The practice of physicians referring patients to health care facilities in which they have a financial interest is not in the best interest of patients. This practice of self-referral may also serve as an improper economic incentive for the provision of unnecessary treatment or services. Even the appearance of such conflicts or incentives can compromise professional integrity. Disclosing referring physicians' investment interests to patients or implementing other affirmative procedures to reduce, but not completely eliminate, the potential for abuse created by self-referral is not sufficient.

In accordance with these views, the American College of Radiology supports current and future federal and state legislation and regulatory action designed to prohibit self-referral or restrict its influence on patient care decisions.

The American College of Radiology believes that radiologists and radiation oncologists should make efforts to restructure the ownership interests in existing imaging or radiation therapy facilities, if not already done, because self-referral may improperly influence the professional judgments of those physicians referring patients to such facilities; 1992, 2002, amended 2012 (Res. 33-d).

Resolution No. 16 **ACR–SIR Practice Parameter for Endovascular Management of the Thrombosed or Dysfunctional Dialysis Access**

Resolution No. 17 **ACR–SIR–SPR Practice Parameter for the Performance of Arteriography**

Resolution No. 18 **ACR–SIR–SPR Practice Parameter for the Creation of a Transjugular Intrahepatic Portosystemic Shunt (TIPS)**

Resolution No. 19 **ACR–ASNR–ASSR–SIR–SNIS Practice Parameter for the Performance of Vertebral Augmentation**

Resolution No. 20 **ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography (CT) in the Evaluation and Classification of Traumatic Brain Injury**

Resolution No. 21 **ACR–ASNR–SPR Practice Parameter for the Performance of functional Magnetic Resonance Imaging (fMRI) of the Brain**

Resolution No. 22 **ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography (CT) Perfusion in Neuroradiologic Imaging**

Resolution No. 23 **ACR–ASNR–ASSR–SPR Practice Parameter for the Performance of Computed Tomography (CT) of the Spine**

Resolution No. 24 **ACR–ASNR–SPR Practice Parameter for the Performance of Intracranial Magnetic Resonance Perfusion Imaging**

RECOMMENDED FOR ADOPTION AS AMENDED:

Resolution No. 13 **Paid Family/Medical Leave in Radiology, Interventional Radiology and Radiation Oncology**

BE IT RESOLVED,

that the American College of Radiology (ACR) recommends that diagnostic radiology, interventional radiology, radiation oncology, medical physics, and nuclear medicine practices, departments and training programs strive to provide 12 weeks of paid family/medical leave in a 12-month period for its attending ~~and trainee~~ physicians, medical physicists, and members in training as needed.

Resolution No. 14 **Environmental Sustainability and Climate Change**

BE IT RESOLVED,

that the ACR will join the Medical Society Consortium on Climate and Health, an organization with dozens of member medical societies which have come together to advance the goals of sustainability and climate change action[6]; and

BE IT FURTHER RESOLVED,

that the ACR will create a task force on radiology's environmental impact and climate change mitigation and adaptation strategies for radiology. This ACR task force will ~~study~~ collaborate with other interested stakeholders to develop a resource for radiology~~'s~~ practice self-assessment of environmental ~~footprint (including supply chains), shifting disease burdens and imaging utilization patterns related to climate change, and resilience~~ impact of radiology ~~practices and departments~~ applicable to ~~climate-related events~~ the diverse practices of ACR members, as well as the ACR itself. ~~Based on this information~~ Also, the task force will identify measures to address and mitigate the deficiencies found in the self-assessment, and disseminate these measures to the ACR members. ~~establish recommendations regarding the need for research, policy, education, and quality improvement initiatives dedicated to energy efficiency, waste reduction, decarbonizing diagnostic and interventional radiology imaging services, and improving resilience of radiology services to climate-related impacts. The findings and recommendations of this~~ The task force will ~~be~~ present~~ed in~~ an interim report in December 2022 and will ~~a final~~ report its progress to the ACR Council at the 2023 annual meeting.

Reference Committee II wishes to thank the Councilors and visitors for their valuable input in these deliberations.

Respectfully Submitted:

_____

Sammy Chu, MD, FACR, *Chair*
Ivan M. DeQuesada II, MD
Atul K. Gupta, MD, FACR
Kirang Patel, MD
Mary H. Scanlon, MD, FACR
Derrick Siebert, MD

REFERENCE COMMITTEE III

Suzanne L. Palmer, MD, FACR, *Chair*
Evelyn Y. Anthony, MD, FACR
Ariadne DeSimone, MD, MPH
Rachel Gerson, MD
Betsy Jacobs, MD, FACR
Joshua G. Tice, MD

COMMISSIONS, COMMITTEES & TASK FORCES:

Commission on Patient- and Family-Centered Care
Commission on Pediatric Radiology
Commission on Publications and Lifelong Learning
Commission on Research
Commission on Research on Harvey L. Neiman Health Policy Institute
Commission on Ultrasound
Commission for Women and Diversity
Bylaws Committee
Ethics Committee
Judiciary Committee

No.	RESOLUTION	TYPE	REFERENCE COMMITTEE RECOMMENDATIONS
25.	Partnership Track Associates and Substantial Changes in Practice Structure or Ownership	NEW POLICY	RECOMMEND ADOPTION
26.	Reinstating the Statement on Medical Staff Privileges, Economic Credentialing and Support for State Legislation	NEW POLICY	RECOMMEND ADOPTION
27.	Exclusive Contrast (Res. 2f 2021 Response)	NEW POLICY	RECOMMEND ADOPTION
28.	Ten Year Extension of Policies: (a) General 9. ACR Advocacy Networks (b) Chapters 5. Young and Early Career Professional Section (YPS) (c) Finances 1. Membership Dues a. Collection of Chapter Dues (d) Advertising 2. Expansion of Public Information Efforts Regarding the Role of Radiology in the Provision and Economics of Health Care (e) Education 2. Resident and Fellowship Training Programs d. Radiation Oncology Residency Matching Program (f) Education 4. Miscellaneous Education Policies c. Subspecialty Certification (g) Legislative – Government 2. Funding (h) Workforce 4. Workforce Studies (see also Workforce in Radiologic Technology) (i) Workforce 5. ~~Shortage of Investigators~~ **Importance of Radiology Research**	POLICY RENEWALS	RECOMMEND ADOPTION RECOMMEND ADOPTION RECOMMEND ADOPTION RECOMMEND ADOPTION RECOMMEND ADOPTION RECOMMEND ADOPTION RECOMMEND ADOPTION RECOMMEND ADOPTION
29.	**ACR–AIUM–SRU Practice Parameter for the Performance of Penile Ultrasound**	**NEW PP**	RECOMMEND ADOPTION

REFERENCE COMMITTEE III

30.	ACR–AIUM–SIR–SRU Practice Parameter for the Performance of Physiologic Evaluation of Extremity Arteries	REVISED PP	RECOMMEND ADOPTION
31.	ACR–AIUM–SPR–SRU Practice Parameter for the Performance of Transcranial Doppler Ultrasound	REVISED PP	RECOMMEND ADOPTION
32.	ACR–AIUM–SPR–SRU Practice Parameter for the Performing and Interpreting of Diagnostic Ultrasound Examinations	REVISED PP	RECOMMEND ADOPTION
33.	ACR–AIUM–SPR–**SSR**–SRU Practice Parameter for the Performance of the Musculoskeletal Ultrasound Examination	REVISED PP	RECOMMEND ADOPTION AS AMENDED
34.	ACR–AIUM–SPR–SRU Practice Parameter for the Performance and Interpretation of Diagnostic Ultrasound of the **Thyroid and** Extracranial Head and Neck	REVISED PP	RECOMMEND ADOPTION AS AMENDED
35.	ACR–SABI–SPR–SSR Practice Parameter for the Performance of Magnetic Resonance Imaging (MRI) of the Wrist	REVISED PP	RECOMMEND ADOPTION
36.	ACR–NASCI–SPR Practice Parameter for the Performance of Quantification of Cardiovascular Computed Tomography (CT) and Magnetic Resonance Imaging (MRI)	REVISED PP	RECOMMEND ADOPTION AS AMENDED
37.	ACR–ASSR–SPR–SSR Practice Parameter for the Performance of Spine Radiography	REVISED PP	RECOMMEND ADOPTION

ACR STAFF:

Director *Dina Hernandez*
Moderator *Barbara Rivers*
Recorder *Nya Lowden*
Coordinator *Joyce Kidwell*
Assistant *Nicole Vega*
Attorney *Gloria Romanelli*
Observer *Sara Baker*

REFERENCE COMMITTEE III

Reference Committee III met on Monday, April 25, 2022. The members of this committee were Suzanne L. Palmer, MD, FACR, *Chair*, Evelyn Y. Anthony, MD, FACR, Ariadne DeSimone, MD, MPH, Rachel Gerson, MD, Betsy Jacobs, FACR, MD, and Joshua G. Tice, MD.

The session was attended by approximately 800 members, guests, and staff, in person and virtually.

The Reference Committee recognizes the following reports as informational and I recommend that they be filed.

COMMISSIONS, COMMITTEES & TASK FORCES:

Commission on Patient- and Family-Centered Care
Commission on Pediatric Radiology
Commission on Publications and Lifelong Learning
Commission on Research
Commission on Research on Harvey L. Neiman Health Policy Institute
Commission on Ultrasound
Commission for Women and Diversity
Bylaws Committee
Ethics Committee
Judiciary Committee

The Committee was assigned the following resolutions for consideration:

	Resolution	**Sponsor**
25.	Partnership Track Associates and Substantial Changes in Practice Structure or Ownership	BOC
26.	Reinstating the Statement on Medical Staff Privileges, Economic Credentialing and Support for State Legislation	CSC
27.	Exclusive Contrast (Res. 2f 2021 Response)	CSC
28.	Ten Year Extension of Policies:	CSC

(a) General
9. ACR Advocacy Networks
(b) Chapters
5. Young and Early Career Professional Section (YPS)
(c) Finances
1. Membership Dues
a. Collection of Chapter Dues
(d) Advertising
2. Expansion of Public Information Efforts Regarding the Role of Radiology in the Provision and Economics of Health Care
(e) Education
2. Resident and Fellowship Training Programs
d. Radiation Oncology Residency Matching Program
(f) Education
4. Miscellaneous Education Policies
c. Subspecialty Certification
(g) Legislative – Government
2. Funding
(h) Workforce
4. Workforce Studies (see also Workforce in Radiologic Technology)
(i) Workforce

5. ~~Shortage of Investigators~~ **Importance of Radiology Research**

29.	**ACR–AIUM–SRU Practice Parameter for the Performance of Penile Ultrasound**	CSC
30.	ACR–AIUM–SIR–SRU Practice Parameter for the Performance of Physiologic Evaluation of Extremity Arteries	CSC
31.	ACR–AIUM–SPR–SRU Practice Parameter for the Performance of Transcranial Doppler Ultrasound	CSC
32.	ACR–AIUM–SPR–SRU Practice Parameter for the Performing and Interpreting of Diagnostic Ultrasound Examinations	CSC
33.	ACR–AIUM–SPR–**SSR**–SRU Practice Parameter for the Performance of the Musculoskeletal Ultrasound Examination	CSC
34.	ACR–AIUM–SPR–SRU Practice Parameter for the Performance and Interpretation of Diagnostic Ultrasound of the **Thyroid and** Extracranial Head and Neck	CSC
35.	ACR–SABI–SPR–SSR Practice Parameter for the Performance of Magnetic Resonance Imaging (MRI) of the Wrist	CSC
36.	ACR–NASCI–SPR Practice Parameter for the Performance of Quantification of Cardiovascular Computed Tomography (CT) and Magnetic Resonance Imaging (MRI)	CSC
37.	ACR–ASSR–SPR–SSR Practice Parameter for the Performance of Spine Radiography	CSC

THE REFERENCE COMMITTEE RECOMMENDS THE FOLLOWING CONSENT CALENDAR FOR ACCEPTANCE:

RECOMMENDED FOR ADOPTION:

Resolution No. 25 **Partnership Track Associates and Substantial Changes in Practice Structure or Ownership**

BE IT RESOLVED,

that the ACR recommends transparency and professionalism in the hiring process; and

BE IT FURTHER RESOLVED,

that the ACR recommends that partnership track associates should receive at least some proportional monetary compensation and should be included in discussions related to substantial changes in practice structure or ownership as legally permissible; and

BE IT FURTHER RESOLVED,

that the ACR recommends that in the event of a substantial change in or control of ownership or structure of the practice, any restrictive covenant in an associate's current employment contract should be waived; and

BE IT FURTHER RESOLVED,

that the ACR contributes legal and government relations resources to suggest model language for state legislative initiatives to effectuate the above statutory changes to restrictive covenants; and

BE IT FURTHER RESOLVED,

that the ACR requests that its delegation to the American Medical Association (AMA) submit a similar resolution for consideration by the AMA House of Delegates.

Resolution No. 26 **Reinstating the Statement on Medical Staff Privileges, Economic Credentialing and Support for State Legislation**

BE IT RESOLVED,

that the ACR reinstates as policy the following statement on medical staff privileges, economic credentialing and support for state legislation:

Medical Staff Privileges
The American College of Radiology believes that all physicians who are members of the hospital medical staff have the same rights. Principles including procedural due process should be applicable to physicians providing services to managed care organizations, health care maintenance organizations, and other third-party payers.

In the absence of an exclusive contract, hospital governing boards should abridge a physician's privileges only upon a recommendation of the medical staff after the completion of a peer review process for reasons related to professional competence, adherence to appropriate standards of medical care, health status or other parameters agreed on by the medical staff.

Economic Credentialing
The College opposes the use of economic credentialing, which is the use of economic criteria unrelated to quality of care or professional competency in determining an individual's qualifications for initial or continuing hospital medical staff membership or privileges. Properly negotiated and freely entered exclusive contracts should be based primarily on ensuring high-quality, 24-7 care for all hospital patients and thus are not a form of economic credentialing even when they may affect the privileges of other physicians seeking to perform radiological procedures at that facility.

Because the hospital medical staff is an independent, self-governing entity that has the primary responsibility for assuring quality patient care within the hospital, the College believes that it is the responsibility of the medical staff to ensure the integrity of the credentialing and privileging processes.

Support for State Legislation
The American College of Radiology supports efforts to enact legislation at the state level that prohibits the practice of any form of economic credentialing and exclusive contracting decisions that deprive physicians of their due process rights; 1991, 2001, amended 2011 (Res. 47-j).

Resolution No. 27 **Exclusive Contracts (Res. 2f 2021 Response)**

BE IT RESOLVED,

that the College recognizes that exclusive contracts may be an appropriate and beneficial method in ensuring high quality, 24-hour care for hospital patients. However, groups may need to collaborate with other providers to improve or expand the services they offer and strengthen contracts with their hospitals. Therefore, groups holding exclusive contracts should be open to exploring relationships (e.g. sub-contracts, affiliations, etc.) that may benefit patients in their community, and whenever appropriate, may allow independent IR physicians limited admitting and treating privileges so as to optimize continuity of patient care.

Resolution No. 28 **Ten Year Extension of Policy**

BE IT RESOLVED,

that the following policies of the American College of Radiology be extended for an additional ten year period:

(a) **A. GENERAL**

9. ACR ADVOCACY NETWORKS

~~The ACR encourages all chapters and practices to develop and support advocacy networks and coordinate their efforts through the Radiology Advocacy Group of the Government Relations Commission. The ACR encourages other radiology, radiation oncology, nuclear medicine, interventional radiology and medical physics societies to work with the ACR and the ACR Radiology Advocacy Group to optimize our collective advocacy efforts. The ACR encourages chapters to add an advocacy network position on their Executive Committees/Boards;~~ **The ACR will continue to assist state chapters with their state government relations issues.**

The ACR encourages all chapters and practices to:

(i) develop and support advocacy networks;

(ii) coordinate their advocacy through the Radiology Advocacy Network of the Government Relations Commission

The ACR encourages all chapters to:

(i) establish or maintain a state government relations program to meet the demands of increased legislative and regulatory activity;

(ii) to add and maintain an advocacy network position on their Executive Committees/Boards

The ACR encourages other radiology, radiation oncology, nuclear medicine, interventional radiology and medical physics societies to:

(i) work with the ACR and the ACR Radiology Advocacy Network to optimize our collective advocacy efforts.

adopted 2012 (Res. 20).

(b) B. CHAPTERS

5. YOUNG AND EARLY CAREER PROFESSIONAL SECTION (YPS)

The ACR shall have a Young and Early Career Professional Section (YPS). A young or early career professional shall be defined as a Member who is age 40 or younger, or who is within the first 8 years of practice after completion of training.

The YPS shall be led by an executive committee elected by the Section. The elected Chair and Vice Chair (Chair-Elect) of the YPS executive committee shall serve as councilors during their respective terms leading the YPS, to represent the voice of young and early career professionals of the ACR. The ACR will make available, to each chapter, an additional alternate council seat earmarked for a young or early career professional. The ACR will provide $1,000 per chapter to those chapters that designate an additional young or early career professional Council member.

The ACR encourages state chapters to facilitate greater involvement by young and early career professionals. The YPS shall work in coordination with the Commission on Membership and Communications to increase membership and volunteerism in the ACR by young and early career professionals and ACR Commissions and Committees will be encouraged to have representation from this important and unique demographic group.

The YPS shall provide an annual report to the ACR Council regarding its activities, and provide progress reports upon request to the Board of Chancellors, Council Steering Committee, and Commission on Membership and Communications.; adopted 2012, amended 2017 (Res. 35).

(c) F. FINANCES

1. MEMBERSHIP DUES

a. Collection of Chapter Dues

All ACR dues and chapter dues may at the option of the chapter be collected by the ACR and the chapter dues be forwarded to the chapter secretary-treasurer as is the current procedure with new members. The ACR will assess the individual chapters involved for the cost of this service; adopted 1982, 1992, 2002, 2012 (Res. 1-b).

(d) H. ADVERTISING

2. EXPANSION OF PUBLIC INFORMATION EFFORTS REGARDING THE ROLE OF RADIOLOGY IN THE PROVISION AND ECONOMICS OF HEALTH CARE

The American College of Radiology will continue to educate the public and all stakeholders about the role of radiology (including radiation oncology, nuclear medicine, interventional radiology, and medical physics) in the health care system and

the cost effectiveness of appropriately utilized radiologic services; 1992, 2002, amended 2012 (Res. 1-c).

(e) A. EDUCATION

2. RESIDENT AND FELLOWSHIP TRAINING PROGRAMS

d. Radiation Oncology Residency Matching Program

~~The American College of Radiology supports the concept of a matching program for radiation oncology and encourages one hundred percent participation of all radiation oncology training programs.~~ The American College of Radiology supports the use of the National Residency Matching Program as the vehicle for radiation oncology residency matching; 1992, 2002, amended 2012 (Res. 33-a).

(f) A. EDUCATION

4. MISCELLANEOUS EDUCATION POLICIES

c. Subspecialty Certification

The American College of Radiology endorses the following statement of the American Board of Medical Specialties Annual Report & Reference Handbook–1992 (page 57) which states:

"There is no requirement or necessity for a diplomate in a recognized specialty to hold special certification in a subspecialty of that field in order to be considered qualified to include aspects of that subspecialty within a specialty practice. Under no circumstances should a diplomate be considered unqualified to practice within an area of a subspecialty solely because of lack of subspecialty certification.

Specialty certification in a subspecialty field is of significance for physicians preparing for careers in teaching, research, or practice restricted to that field. Such special certification is recognition of exceptional expertise and experience and has not been created to justify a differential fee schedule or to confer other professional advantages over other diplomates not so certified."

The American College of Radiology endorses the following statement from the American Board of Medical Specialties Annual Report and Reference Handbook–1992 (pages 52-53) which states:

"It should be emphasized that there is no specific requirement for a diplomate in a recognized specialty to hold certification in a subspecialty of that field in order to include aspects of that subspecialty within the range of privileges"; 1992, 2002, amended 2012 (Res. 12-b).

(g) C. LEGISLATIVE – GOVERNMENT

2. FUNDING

The ACR in conjunction with the Academy of Radiology Research will continue to lobby federal agencies and Congress to adequately fund the National Institute of

Biomedical Imaging and Bioengineering and the Biomedical Imaging Program within the National Cancer Institute, **as well as the Advanced Research Projects Agency for Health (ARPA-H) of the National Institutes of Health**; 2002, amended 2012 (Res. 12-c).

(h) E. WORKFORCE

4. WORKFORCE STUDIES (SEE ALSO WORKFORCE IN RADIOLOGIC TECHNOLOGY)

The ACR reaffirms its support for the conduct of periodic workforce studies of physicians, medical physicists, allied health workers in radiology**,** ~~and~~ technologists**, and non-physician radiology providers (NPRPs)**; 1981, 1992, 2002, amended 2012 (Res. 1-d).

(i) E. WORKFORCE

5. ~~SHORTAGE OF INVESTIGATORS~~ IMPORTANCE OF RADIOLOGY RESEARCH

We recognize the importance of research to the future of radiology. The ACR shall promote, encourage, and participate in partnership with other radiological organizations to educate radiologists, radiology chairs, other academic department chairs, and deans regarding the importance of radiology research; 2002, amended 2012 (Res. 12-d).

Resolution No. 29 **ACR–AIUM–SRU Practice Parameter for the Performance of Penile Ultrasound**

Resolution No. 30 **ACR–AIUM–SIR–SRU Practice Parameter for the Performance of Physiologic Evaluation of Extremity Arteries**

Resolution No. 31 **ACR–AIUM–SPR–SRU Practice Parameter for the Performance of Transcranial Doppler Ultrasound**

Resolution No. 32 **ACR–AIUM–SPR–SRU Practice Parameter for the Performing and Interpreting of Diagnostic Ultrasound Examinations**

Resolution No. 35 **ACR–SABI–SPR–SSR Practice Parameter for the Performance of Magnetic Resonance Imaging (MRI) of the Wrist**

Resolution No. 37 **ACR–ASSR–SPR–SSR Practice Parameter for the Performance of Spine Radiography**

RECOMMENDED FOR ADOPTION AS AMENDED:

Resolution No. 33 **ACR–AIUM–SPR–SSR–SRU Practice Parameter for the Performance of the Musculoskeletal Ultrasound Examination**
(Lines 609-610)

The AIUM, SPR and SSR representatives affirms that in their best judgement the proposed changes would be acceptable to AIUM, SPR and SSR. The representative from SRU was not available to affirm the proposed changes would be acceptable to SRU. The proposed changes are subject to ratification by AIUM, SPR, SSR and SRU.

Resolution No. 34 **ACR–AIUM–SPR–SRU Practice Parameter for the Performance and Interpretation of Diagnostic Ultrasound of the Thyroid and Extracranial Head and Neck**
(Lines 288-289)

The AIUM and SPR representatives affirms that in their best judgement the proposed changes would be acceptable to AIUM and SPR. The representative from SRU was not available to affirm the proposed changes would be acceptable to SRU. The proposed changes are subject to ratification by AIUM, SPR and SRU.

Resolution No. 36 **ACR–NASCI–SPR Practice Parameter for the Performance of Quantification of Cardiovascular Computed Tomography (CT) and Magnetic Resonance Imaging (MRI)**
(Lines 12-15, 517-526 & 1687-1700)

The NASCI and SPR representatives affirm that in their best judgement the proposed changes would be acceptable to NASCI and SPR; subject to ratification by NASCI and SPR.

Reference Committee III wishes to thank the Councilors and visitors for their valuable input in these deliberations.

Respectfully Submitted:

_____

Suzanne L. Palmer, MD, FACR, *Chair*
Evelyn Y. Anthony, MD, FACR
Ariadne DeSimone, MD, MPH
Rachel Gerson, MD
Betsy Jacobs, MD, FACR
Joshua G. Tice, MD

RESOLUTION NO. 33

BE IT RESOLVED,
that the American College of Radiology adopt the ACR–AIUM–SPR–SSR–SRU Practice Parameter for the Performance of the Musculoskeletal Ultrasound Examination

Sponsored By: **ACR Council Steering Committee**

Revised 2017 (Resolution 31)*

ACR–AIUM–SPR–SSR–SRU PRACTICE PARAMETER FOR THE PERFORMANCE OF THE MUSCULOSKELETAL ULTRASOUND EXAMINATION

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

I. INTRODUCTION

The clinical aspects contained in specific sections of this practice parameter (Introduction, Indications, Specifications of the Examination, and Equipment Specifications) were developed collaboratively by the American College of Radiology (ACR), the American Institute of Ultrasound in Medicine (AIUM), the Society for Pediatric Radiology (SPR), Society of Skeletal Radiology (SSR) and the Society of Radiologists in Ultrasound (SRU). Recommendations for physician requirements, written request for the examination, procedure documentation, and quality control vary between the 4 organizations and are addressed by each separately.

This practice parameter has been revised to assist practitioners performing a musculoskeletal (MSK) ultrasound examination. Although it is not possible to detect every abnormality, adherence to the following practice parameter will maximize the probability of detecting most abnormalities ~~that occur~~.

II. INDICATIONS

Indications for musculoskeletal ultrasound include, but are not limited to:

1. Pain or dysfunction
2. Soft tissue or bone injury
3. Tendon, ligament **or fascial** pathology
4. Arthritis, synovitis, or crystal deposition disease
5. ~~Intra-articular bodies~~
5. Joint effusion **and intra-articular bodies**
6. ~~Nerve~~ **Neurovascular** entrapment, injury, neuropathy, mass, or subluxation
7. Evaluation of soft tissue masses, swelling, or fluid collections
8. Detection of foreign bodies in the superficial soft tissues
9. Planning and **guidance** ~~guiding~~ for an invasive procedure
10. Congenital or developmental anomalies
11. Postoperative or postprocedural evaluation
12. Joint laxity, stiffness, decreased range of motion **or misalignment**
13. ~~Sensory deficits or paresthesias~~
14. ~~Motor weakness~~

The above is a comprehensive list of general indications for musculoskeletal ultrasound; however, specific and unique indications pertaining to specific joints will be listed in the corresponding sections.

Musculoskeletal ultrasound should be performed when there is a valid medical reason. There are no absolute contraindications.

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR–SPR–SRU Practice Parameter for Performing and Interpreting Diagnostic Ultrasound Examinations **[1].**

A. Physician

A physician must be available for consultation with the sonographer on a case-by-case basis. Ideally the physician should be on-site and available to participate actively in the ultrasound examination when required. It is recognized, however, that geographic realities may not permit the presence of an on-site physician in all locations. In this case, a supervising physician should be available for quality assurance and sonographer supervision via a picture archiving and communication system (PACS).

IV. ~~WRITTEN REQUEST FOR THE EXAMINATION~~ SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for a musculoskeletal ultrasound examination should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

A. General Principles

Depending on the clinical request and the patient's symptoms, the ultrasound examination may involve a complete assessment of a joint or an anatomic region, or it may be limited to a specific anatomic structure. Examinations of joints, such as the elbow, hip, knee, and ankle, can be divided into four regions (anterior, medial, lateral, and posterior).

A complete examination includes evaluation of the joint and synovium, cortical outline of underlying bones, muscles, tendons and tendon sheaths, ligaments and fascia, capsule, and any additional abnormalities visible in the region. Color and power Doppler may be useful in detecting hyperemia or neovascularity within the tendon and/or tendon sheath, joint, or surrounding structures. Doppler flow is considered a key imaging finding for some pathologic conditions in musculoskeletal ultrasound. The equipment must be optimized for relevant Doppler sensitivity.

Images should always be obtained with the ultrasound beam perpendicular to the region of interest to minimize artifact. When applicable, relevant structures should be interrogated in more than 1 plane, at least 2 orthogonal planes. Patient positioning for specific examinations may vary depending on the structure being examined, the patient's clinical condition, and the operator's preference to obtain required short axis and long axis images. Dynamic evaluation is an important aspect of all musculoskeletal exam protocols to test for mobility, subluxation/dislocation, or impingement.

Transducer movements and manipulation are critical to provide accurate ultrasound images in musculoskeletal ultrasound. Heel-toe and tilting maneuvers help in avoiding anisotropy artifact by changing the angle of insonation while maintaining contact with the skin surface. Sometimes compression with the transducer may be performed to evaluate for solid versus cystic/fluid filled structures and/or to elicit symptoms (sonopalpation).

B. Specifications of the Shoulder Examination

A shoulder examination is ~~most commonly~~ **requested** ~~indicated~~ to evaluate for rotator cuff pathology such as a partial- or full-thickness tear, calcific tendinitis, or tendinosis **in adults, and joint-centered pathology in children**. Other indications include evaluation **of** ~~for~~ biceps tendon pathology, including tendon instability, subacromial-subdeltoid hypertrophy/bursitis, ~~joint effusion,~~ acromioclavicular arthritis, paralabral cyst, and nerve compression.

~~Patients should be examined in the sitting position when possible, preferably on a rotating stool. Examination of the shoulder should be tailored to the patient's clinical circumstances and range of motion. Color and power Doppler assessment may be useful in detecting hyperemia within the subacromial-subdeltoid bursa, the biceps tendon sheath, joint synovium, or surrounding structures.~~

~~The long head of the biceps tendon should be examined with the forearm in supination.~~ ~~resting on the thigh or with the arm in slight external rotation.~~ The **long head of the biceps** tendon is examined in a transverse plane (short axis) **within the bicipital groove** ~~where it emerges from under the acromion~~ and to the musculotendinous junction distally. The insertions of the pectoralis major tendon on the humerus can be evaluated at the same time, when indicated. Longitudinal views (long axis) should also be obtained. ~~These views should be used to detect effusion, synovial hypertrophy, or intra-articular loose bodies within the bicipital tendon sheath.~~ **Tendon position within the bicipital groove should be commented upon.** ~~and to determine whether the tendon is properly positioned within the bicipital groove, subluxated, dislocated, or torn. Power or color Doppler should also be used to detect hyperemia in the tendon sheath, which may indicate tenosynovitis.~~ **Dynamic evaluation may be performed in the short axis to evaluate for tendon subluxation or dislocation.**

~~The rotator cuff should be examined for signs of full- or partial-thickness tear, tendinosis, and/or calcification. Both long axis and short axis views should be obtained.~~

~~To examine the subscapularis tendon, the elbow at the side while the arm in external rotation.~~ The subscapularis is imaged from the musculotendinous junction to the insertion on the lesser tuberosity of the humerus **in long and short axis planes**. Dynamic evaluation **in the long axis plane** ~~as the patient~~ is helpful to evaluate ~~dynamic biceps tendon subluxation or~~ **possible** subcoracoid impingement. ~~and assess the integrity of the subscapularis tendon.~~

~~To examine the supraspinatus tendon, the arm is extended posteriorly, and the palmar aspect of the hand can be placed against the superior aspect of the iliac wing with the elbow flexed and directed toward midline (instruct the patient to place the hand in the ipsilateral back pocket).~~

~~To the supraspinatus and infraspinatus tendons along their long axes, it is important to orient the transducer approximately 45 degrees between the sagittal and coronal planes. The transducer then should be moved anteriorly and posteriorly parallel to this imaging plane while continually adjusting to its angle to remain perpendicular to the investigated tendon.~~

~~To~~ **When** scan**ning** the supraspinatus and infraspinatus tendons along their long axes, it is important to orient the transducer **in an oblique plane.** Short axis views of the tendons should **also** be obtained by rotating the transducer 90 degrees to the long axis. **Correct short axis positioning may be confirmed by visualizing the coracohumeral ligament in long axis medially, then moving laterally along the shoulder**. **Additionally, a short axis view of the long head biceps in the rotator interval can serve as a landmark for appropriate orientation to the supraspinatus and infraspinatus tendons in short axis.** ~~The tendons are visualized by sweeping medially to the acromion and laterally to their insertions on the greater tuberosity of the humerus~~. When necessary, the more posterior aspect of the infraspinatus and teres minor tendons can be examined by placing the transducer **posteriorly** at the level of the glenohumeral joint.~~ below the scapular spine while the forearm rests on the thigh with the hand supinated. Internal and external rotation of the arm is helpful to identify the infraspinatus muscle and tendon and to detect small joint effusions. To visualize the teres minor tendon, the medial edge of the transducer should be angled slightly inferiorly. The teres major tendon can also be identified in short axis by placing the transducer in a longitudinal plane at the surgical neck of the humerus where it inserts and scanning medially along the inferior border of the scapula.~~

~~Throughout~~ **During** the examination of the rotator cuff, the cuff should be **frequently** compressed with the transducer to detect nonretracted tears. ~~When evaluating for rotator cuff tears, comparison with the contralateral side may be useful.~~ Dynamic evaluation of the rotator cuff ~~also~~ **during shoulder abduction** is useful ~~in certain circumstances - for example~~ to evaluate the rotator cuff for **subacromial or subligamentous** impingement. Tear length (partial-thickness tear) or the degree of retraction of the cuff (full-thickness tear) should be measured on longitudinal views, and tear width should be measured on short axis views. **Tear depth should also be assessed.**

A partial-thickness tear should ~~further~~ be described as **originating from the** bursal **or** articular **side**, or intrasubstance, and its thickness should be **assessed** ~~measured~~. It is also useful to measure the distance between the intra-articular portion of the biceps tendon and the anterior edge of the tear on short axis views; most degenerative tears ~~are located~~ **begin** ~~in the crescent of the cuff,~~ approximately 15 mm from the intra-articular portion of the biceps tendon [2]. In patients with a rotator cuff tear, the supraspinatus, infraspinatus, and teres minor muscles should be examined for fatty infiltration and atrophy, because these findings ~~are associated with a poorer~~ **may influence** postoperative outcome. Comparison with the contralateral rotator cuff muscles is often helpful **to confirm** ~~in confirming~~ muscle atrophy and fatty infiltration **except when muscle atrophy is the result of a diffuse systemic process**. Rotator cuff thickness and echogenicity should also be evaluated; a thick, hypoechoic cuff indicates tendinosis. **The postoperative (rotator cuff after repair) rotator cuff may be hypoechoic and/or heterogenous in the early healing period, but that appearance may resolve over a period of time [3].**

~~During the rotator cuff examination,~~ **T**he subacromial-subdeltoid bursa should be examined for the presence of synovial hypertrophy **or effusion**. Power or color Doppler should also be used to detect hyperemia. **Bursal bunching and snapping in the setting of subcoracoid, subacromial, and subligamentous impingement can be assessed with dynamic examination.** ~~It is also important to evaluate.~~ **Glenohumeral joint effusion is best assessed via a posterior approach. Glenohumeral effusion typically lacks Doppler flow and can be displaceable, whereas synovial thickening can contain Doppler flow and is not or only minimally compressible. Posterior labral abnormalities should also be evaluated using this approach.** ~~The posterior glenohumeral joint **should be evaluated** for effusion, synovitis, or labral abnormalities. This can be accomplished by placing the transducer in a transverse plane at the level of the joint space.~~ If symptoms warrant, the suprascapular notch and spinoglenoid notch may also be evaluated for a paralabral cyst. The acromioclavicular joint should be evaluated for arthritis, infection, or trauma by placing the transducer at the apex of the shoulder, over the acromion and distal clavicle [4-**7**].

Ultrasound is very useful ~~in evaluating~~ **as the first line screening for** infants **and young toddlers** with **clinically suspected** glenohumeral dysplasia. **It serves as an alternative to MRI, which provides a more global assessment, providing complementary information without the need for patient sedation**. These infants are **typically** examined **in the seated position on the caregiver's lap, facing away from the sonographer. Alternatively, the children can also be scanned** in a decubitus position~~, and older children are examined seated~~. ~~The~~ **Each** shoulder**, both symptomatic and normal sides,** is scanned **via** ~~from~~ a posterior approach to evaluate the **morphology and alignment** ~~relationship~~ between the humeral head and glenoid ~~as well as the shape of the posterior glenoid~~. Both static and dynamic images are obtained with the shoulder in neutral **position and in** full ~~scanned through the full range of~~ internal **and** ~~to~~ external rotation. Posterior subluxation is **evaluated qualitatively** ~~assessed visually~~ and **quantitatively,** ~~by measuring~~ **with the latter involving use of** the α angle **and humeral head translation.** ~~which is~~ **The** α angle **is formed** between **a line drawn along** the posterior margin of the scapula and **a** ~~the~~ line drawn tangentially to the **posterior cortex of** humeral head and posterior edge of the glenoid. ~~The normal value of the~~ **An** α angle **of** ~~is~~ 30 degrees or less **is considered normal**. **Humeral head translation measures the percentage of the humeral head that is displaced posterior to the axis of the scapula. The normal value for humeral head translation is 50% or less. Muscle atrophy is characterized by asymmetric decreased thickness and bulk when compared to the contralateral normal side. In infants with equivocal radiographs, t**he clavicle and proximal humerus **can** ~~are also~~ **be** evaluated for **displaced** fractures **secondary to birth trauma** [8] **or nonaccidental trauma. In the latter scenario, the proximal humerus can be assessed for Salter Harris fractures**. **However, it is worth noting that nondisplaced fractures and incomplete fractures involving the cortex that is inaccessible by ultrasound can be subtle and missed, respectively**. **These can be assessed using follow-up radiographs. In infants with Erb's palsy and history of shoulder dystocia, ultrasound is useful for mapping out injuries to the brachial plexus, associated muscle denervation injuries and glenohumeral subluxation [9]**. **Ultrasound can be helpful intraoperatively to confirm glenohumeral reduction.**

C. Specification of an Elbow Examination

~~An elbow examination may be indicated to evaluate for synovial hypertrophy or synovitis, crystal deposition, loose bodies, joint effusion, tendinosis or tendon tear, ligamentous abnormality, bursitis, or nerve pathology. In newborns and young infants, ultrasound may be used to evaluate for epiphysiolysis of the distal humerus [10-13].~~

~~The patient is seated with the arm extended and the hand in supination, resting on a table, and the examiner sitting in front of the patient. The elbow may also be examined with the patient supine and the examiner on the same side as the elbow of interest.~~ Examination **of the elbow** is divided into 4 regions: anterior, medial, lateral, and posterior. ~~The examination may involve a complete assessment of 1 or more of the 4 regions or be limited to a specific structure, depending on the clinical presentation. Color and power Doppler may be useful in detecting hyperemia within the joint or surrounding structures.~~

1. Anterior
   The anterior joint space and other recesses of the elbow are assessed for **joint or bursal** effusion, synovial hypertrophy, and intra-articular bodies. Longitudinal and transverse scanning of the anterior humeroradial joint, the humeroulnar joint, and both the coronoid and radial fossae is performed to assess the articular cartilage and cortical bone. The annular recess of the neck of the radius is scanned dynamically with forearm pronation and supination. The same dynamic assessment can be made for the biceps brachii tendon and its attachment to the radial bicipital tuberosity. When evaluating the distal biceps tendon from an anterior approach, the arm should be maximally supinated and extended. The distal biceps tendon can also be evaluated from a medial approach with the elbow flexed and the forearm supinated [14] **or via a lateral approach [15] using the brachioradialis as an acoustic window. The insertion can also be imaged during dynamic scan with a posterior approach**. Evaluation of the brachialis muscle, the adjacent radial and brachial vessels, and the median and radial nerves can also be performed as clinically warranted.

2. Lateral
   ~~To evaluate the~~ Lateral elbow **evaluation** ~~the patient extends the arm and places both palms together, or if the patient is supine the forearm is placed across the abdomen. This position~~ allows assessment of the lateral epicondyle ~~and~~ the attachments of the common extensor tendon **and** ~~as well as the more~~ the proximal attachments of the extensor carpi radialis longus and brachioradialis. ~~The hand is then pronated, with the transducer on~~ **Scanning** the posterolateral aspect of the elbow ~~to scan~~ **allows evaluation of** the lateral collateral ligament complex. The radial nerve, including its deep branch entering the supinator **muscles (posterior interosseous nerve),** is also evaluated.

3. Medial
   ~~To evaluate the medial elbow, the hand is placed in supination, or if the patient is supine the upper limb is placed in abduction and external rotation to expose the medial side of the elbow.~~ **Medial elbow scanning includes evaluation of t**he medial epicondyle, common flexor tendon, and ulnar collateral ligament ~~are scanned in both planes~~ **[16,17**]. The ulnar nerve is visualized in the cubital tunnel region between the olecranon process and medial epicondyle. ~~Static examination of the ulnar nerve may be facilitated by placing the elbow in an extended position.~~ Dynamic subluxation and dislocation of the ulnar nerve **and adjacent medial head of the triceps muscle** are assessed by imaging with flexion and extension of the elbow. Dynamic examination with valgus stress is performed to assess integrity of the ulnar collateral ligament. During valgus stress testing, the elbow ~~must~~ **may have to** be ~~slightly~~ flexed **at variable angles** to disengage the olecranon from the olecranon fossa.

4. **Posterior**
   To evaluate the posterior elbow, ~~the palm is placed down on the table, or if the patient is supine the forearm is placed across the abdomen, with~~ the elbow **is** flexed to 90 degrees. The posterior joint space, triceps brachii tendon, olecranon process, and olecranon bursa are assessed [18-20].

In infants, who have not yet developed any elbow ossification centers, radiographic distinction between elbow dislocation and transphyseal fracture-displacement is challenging. Ultrasound can be helpful in this situation, made even more useful by comparison imaging of the contralateral, normal side. Placing the transducer in the longitudinal plane anteriorly or anterolaterally on the elbow can confirm the normal radiocapitellar alignment in the absence of a dislocation. It can assess for disruption at the level of the humeral physis too. Similarly, ultrasound can identify the components of a lateral condyle fracture when the distal humeral epiphysis is not yet ossified and fracture components are radiographically occult.

D. Specifications of the Wrist Examination

A ~~hand and~~ wrist examination may be indicated to evaluate a focal abnormality such as a tumor (tenosynovial giant cell tumor of the tendon sheath, peripheral nerve sheath tumor, or lipoma), ganglion, epidermal inclusion cyst, foreign body, or ~~isolated~~ tendon injury. Tenosynovitis, nerve entrapment syndromes, and peripheral nerve disorders such as carpal tunnel syndrome can also be evaluated. In the patient with suspected inflammatory arthritis, the hands and wrists should be evaluated for synovial hypertrophy, joint effusion, bony erosions, tenosynovitis, crystal deposition, and tendon rupture. ~~Power or color Doppler should also be used to detect active inflammation (synovitis).~~

~~To evaluate the hands and wrists, the patient is usually seated on a stool or chair if possible, with hands resting on a table. Color and power Doppler may be useful in detecting hyperemia within the joint or surrounding structures.~~

The examination may include a complete assessment of 1 or more of the 4 anatomic regions described below or may be limited to a specific anatomic structure, depending on the clinical presentation.

1. Volar~~/Radial~~
   Transverse and longitudinal images should be obtained from the volar wrist crease to the thenar muscles. The transducer will require angulation **changes** to compensate for the normal contour of the wrist **and to minimize anisotropy**. The flexor retinaculum, flexor digitorum profundus, ~~and~~ superficialis tendons and the adjacent flexor pollicis longus tendon should be identified within the carpal tunnel. Dynamic imaging with flexion and extension of the fingers will demonstrate the normal motion of these tendons. The median nerve normally lies superficial to these tendons and deep to the flexor retinaculum. The distal portion of the median nerve tapers and divides into multiple branches for the hand. The palmaris longus tendon lies superficial to the retinaculum**, if present.**

2. **Radial**
   On the radial side of the wrist, the flexor carpi radialis longus tendon lies within its own canal. It is important to evaluate the region of the flexor carpi radialis and the radial artery for occult ganglion cysts, which can originate from the radiocarpal joint capsule, scapho-trapezial joint, or flexor carpi radialis tendon sheath itself. All of the tendons can be followed to their sites of insertion if clinically indicated.

3. Ulnar
   Placing the transducer transversely on the ulnar styloid and moving distally will allow visualization of the triangular fibrocartilage complex (TFCC) in its long axis. Dynamic imaging with radial deviation may be helpful in assessing the integrity of the TFCC. The transducer is then **rotated** ~~moved~~ 90 degrees to view the short axis of the TFCC. The ulnomeniscal homologue may be seen just deep to the extensor carpi ulnaris tendon. The extensor carpi ulnaris tendon should be viewed in supination and pronation to assess for subluxation. In the setting of inflammatory arthritis, the extensor carpi ulnaris should be evaluated for tenosynovitis and rupture. **On the ulnar side, branches of the ulnar nerve and artery lie within the ulnar tunnel. The flexor carpi ulnaris tendon and pisiform bone border the ulnar aspect of the tunnel.**

4. Dorsal
   Because the dorsal structures are very superficial, ~~and~~ a high frequency transducer ~~and~~**, even using a stand-off,** ~~large amounts of~~ gel is necessary to optimize the examination and prevent compression of small vessels when using color or power Doppler. The extensor retinaculum divides the dorsal aspect of the wrist into 6 compartments, which accommodate 9 tendons. These tendons are examined in their short axes initially and then in their long axes statically and dynamically, the latter being performed with flexion and extension of the fingers. The tendons can be followed to their sites of insertion when clinically indicated. Moving the transversely positioned transducer distal to Lister's tubercle identifies the dorsal aspect of the scapholunate ligament, a potential site of symptomatic ligament tears and ganglion cysts **that may be evaluated with and without stress maneuvers**. The remaining intercarpal ligaments are not routinely assessed.

E. **Specifications of Hand Ultrasound**

In patients with suspected inflammatory arthritis, the dorsal radiocarpal, distal radioulnar, midcarpal, metacarpophalangeal, and, if symptomatic, the ~~proximal~~ interphalangeal joints are evaluated from the volar and dorsal aspects in both the longitudinal and transverse planes for effusion, synovial hypertrophy, **synovial hyperemia,** and bony erosions **[21,22**]. ~~Other joints of the wrist and hand are similarly evaluated as clinically indicated [23,24].~~**This component of the examination can be extended as clinically warranted to evaluate the flexor/extensor tendons and their pulleys for injuries and/or tenosynovitis. In the event of trauma, ultrasound can be used to detect avulsion fractures that may be associated with tendon injuries. Specific to the thumb, the ulnar collateral ligament may be evaluated with and without stress maneuvers.**

F. Specifications of a Hip Examination

~~A hip examination may be indicated to evaluate for tendinosis, a tendon or muscle injury, bursitis, hip effusion or synovitis, labral abnormality, pseudotumor (in patients with total hip arthroplasty), "snapping hip," hernia, bursitis, focal soft tissue mass, or focal nerve pathology.~~

Depending on the patient's body habitus, a lower frequency transducer may be required to scan the hip. However, the operator should use the highest possible frequency that provides adequate penetration. **The examination is divided into 4 regions: anterior, medial, lateral, and posterior.** ~~The examination may involve a complete assessment of 1 or more of the 4 anatomic regions of the hip described below or may be limited to a specific anatomic structure, depending on the clinical presentation. Color and power Doppler may be useful in detecting hyperemia within the joint or surrounding structures.~~

1. Anterior
   In the supine position, a sagittal oblique plane parallel to the long axis of the femoral neck is used for evaluating the femoral head and neck and for detecting joint effusion or synovitis. The lower extremity should be rotated externally. The sagittal **and axial** planes are ~~is~~ used to ~~evaluate~~ **visualize** the **anterior** labrum, the iliopsoas tendon and bursa, the femoral vessels, and the sartorius and rectus femoris **tendon origins [25].** ~~muscles. The above structures are then scanned in the transverse plane, perpendicular to the original scan plane.~~ When an extra-articular cause of anterior "snapping hip" is suspected, dynamic scanning is performed over the region of interest using the same movement that the patient describes as precipitating the snap**, usually precipitated by hip flexion and external rotation.** This snap commonly occurs **anteriorly, as the** ~~just proximal to where the~~ iliopsoas tendon **crosses over the acetabular eminence** ~~abruptly moves anteriorly over the acetabulum~~ [26]. **Recent literature adds that the interchange of the muscle belly and the tendon is more likely the cause of a snap rather than the tendon snapping over the underlying acetabular eminence [26].**

2. Lateral
   In the lateral decubitus position with the symptomatic side up, transverse and longitudinal scans of the greater trochanter, greater trochanteric bursae, gluteus medius, gluteus maximus, gluteus minimus, iliotibial band, and tensor fasciae latae should be performed. **Sonopalpation of the greater trochanter can be performed when assessing for trochanteric bursitis.** An iliotibial band or gluteus maximus muscle that snaps over the greater trochanter can be assessed in this position using dynamic flexion extension **of the hip**.

3. Medial
   The hip is placed in external rotation with 45-degree knee flexion (frog-leg position). The distal iliopsoas tendon, because of its oblique course, may be better seen in this position. The adductor muscles and their origins from the pubic tubercle are imaged in their long axes with the probe in a sagittal oblique orientation. ~~with~~**S**hort axis images are obtained perpendicular to this plane. In addition, the pubic bone and symphysis, ~~and~~ the distal rectus abdominis, **and adductor** ~~insertion~~ **origin** should be evaluated **for musculotendinous or aponeurotic injury [27].**

4. **Posterior**
   The patient is prone with the lower extremities extended. Transverse and longitudinal views of the glutei, hamstring **tendons**, and sciatic nerve are obtained. The glutei are imaged obliquely from their origins to the greater trochanter (gluteus medius and minimus) and linea aspera (gluteus maximus). The sciatic nerve is scanned in its short axis starting at its exit at the greater sciatic foramen, deep to the gluteus maximus. It can be followed distally, midway between the ischial tuberosity and the greater trochanter, lying superficial to the quadratus femoris muscle [28]. **The hamstring tendons can be assessed in transverse and long axis for the presence of tears and tendinosis. The ischial bursa is not typically seen unless an effusion or thickening is present in the setting of bursitis.**

~~For information on the neonatal hip~~ **For further detail on the examination of the pediatric hip for hip dysplasia**, see the ACR–AIUM–SPR–SRU Practice Parameter for the Performance of the Ultrasound Examination for Detection and Assessment of Developmental Dysplasia of the Hip **[29].**

G. Specifications of a Prosthetic Hip Examination

The **prosthetic** hip is assessed for joint effusions, extra-articular fluid collections**, iliopsoas bursitis,** or soft tissue masses **and/or necrosis** ~~(pseudotumor).~~ (**adverse local tissue reaction).** Ultrasound guidance may be requested to evaluate for fluid aspiration in the clinical scenario of a possible prosthetic joint infection. The region of the greater trochanter and iliopsoas is evaluated for fluid collections or tendon abnormalities, such as tendinosis or tear of the iliopsoas, gluteus medius, ~~and~~ or gluteus minimus tendons [30,31]. To assess for pseudotumor, the anterior, medial, lateral, and posterior hip structures should be evaluated for joint and extra-articular fluid collections and soft tissue masses [32,33]. **In patients with suggestive symptoms, ultrasound can provide guidance for diagnostic injections to assess for possible psoas tendon impingement.**

H. Specifications of a Knee Examination

~~A knee examination may be indicated to evaluate for tendon or muscle rupture/tear or tendinosis, joint effusion, crystal deposition disease, periarticular cystic lesions, meniscal tear, bursitis, ligamentous tear, or nerve pathology.~~ The examination **of the knee** is divided into 4 regions. The examination may involve **an** ~~complete~~ assessment of 1 or more of the 4 regions of the knee described below or may be limited to a specific anatomic structure, depending on the clinical presentation. ~~Color and power Doppler may be useful in detecting hyperemia within the joint or surrounding structures.~~

1. Anterior
   The patient is supine with the knee flexed to 30 degrees. Longitudinal and transverse scans of the quadriceps and patellar tendons, patellar retinacula, and suprapatellar recess are obtained. **A portion of t**he distal femoral trochlear cartilage can be assessed with the transducer placed in the suprapatellar space in the transverse plane ~~and~~ with the knee in maximal flexion. ~~Longitudinal views of the cartilage over the medial and lateral femoral condyles are evaluated as indicated.~~ The prepatellar, superficial, and deep infrapatellar bursae are also evaluated using adequate gel to prevent inadvertent compression of the bursae by the transducer. **Suprapatellar recess may be evaluated for detection of joint effusion.**

2. Medial
   During the ultrasound examination, the patient remains supine with slight flexion of the knee and hip and with slight external rotation of the hip. ~~Alternatively, the patient may be placed in the lateral decubitus position. The medial joint space is examined.~~ The medial collateral ligament, the pes anserine tendons and bursa, and the medial patellar retinaculum are scanned in both planes. The anterior horn and body of the medial meniscus may be identified in this position, particularly with valgus stress. If meniscal pathology is suspected either clinically or by ultrasound, further imaging with MRI **is recommended. Alternatively, if there are contraindications to MRI,** CT arthrography **can be performed** ~~if there are contraindications to MRI is recommended if clinically indicated~~.

3. Lateral
   The patient remains supine with the ipsilateral leg internally rotated ~~or in a lateral decubitus position. A pillow may be placed between the knees for comfort~~. The popliteus tendon, biceps femoris tendon, fibular collateral ligament, and iliotibial band are scanned. The lateral patellar retinaculum can also be assessed in this position ~~(as well as in the anterior position)~~. The joint line is scanned for lateral meniscal pathology, with var**us** stress applied as needed. **The common peroneal nerve can be localized in the popliteal fossa or identified posterior to the biceps femoris tendon and followed as it courses around the fibular neck.**

4. Posterior
   The patient lies prone with the leg extended. The popliteal fossa, semimembranosus **muscle,** ~~and~~ medial and lateral gastrocnemius muscles, tendons, and bursae are assessed. To confirm the diagnosis of a **popliteal** ~~Baker~~ cyst, the subgastrocnemius component of the semimembranosus-gastrocnemius bursa should be visualized between the medial head of the gastrocnemius and semimembranosus tendon. In addition, the posterior horns of both menisci **may** ~~can~~ be evaluated. The **tibial insertion of the** posterior cruciate ligament may be identifiable in a sagittal oblique plane in this position [34,35].

I. Specifications of an Ankle ~~and Foot~~ Examination

~~The examination of the ankle and foot may be indicated to evaluate a focal abnormality such as plantar fasciitis, plantar fibromatosis, Morton's neuroma, ganglion cyst, or tenosynovial giant cell tumor of the tendon sheath but may also be used to evaluate for muscle, tendon, or ligament tear/rupture; tendinosis; tenosynovitis; joint effusion; and nerve pathology~~. Ultrasound examination of the ankle is divided into 4 regions (anterior, medial, lateral, and posterior). The examination may involve an ~~complete~~ assessment of 1 or more of the 4 regions described below or be limited to a specific anatomic structure, depending on the clinical presentation. ~~Color and power Doppler may be useful in detecting hyperemia within the tendon sheath, joint, or surrounding structures.~~

1. Anterior
   ~~The patient lies supine with the knee flexed and the plantar aspect of the foot flat on the table.~~ The anterior **extensor** tendons are assessed in long axis and short axis planes from their musculotendinous junctions to their distal insertions. From medial to lateral, this tendon group includes the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius tendons (the latter being congenitally absent in some patients). The anterior joint recess is scanned for effusion, intra-articular bodies, synovial hypertrophy, and synovitis. The anterior joint capsule is attached to the anterior tibial margin and the neck of the talus. ~~, and~~ The hyaline cartilage of the talus appears as a thin hypoechoic line **paralleling subchondral bone**. ~~The anterior inferior tibiofibular ligament of the syndesmotic complex is assessed by moving the transducer proximally over the distal tibia and fibula, superior and medial to the lateral malleolus, and scanning in an oblique plane [36].~~

2. Medial
   ~~The patient is placed in a lateral decubitus position with the medial ankle facing upward.~~ The tibialis posterior, flexor digitorum longus, and flexor hallucis longus tendons (located in this order from anterior to posterior) are initially scanned in the short axis plane proximal to the medial malleolus to identify each tendon. They are then assessed in long axis ~~and short axis~~ planes from their proximal musculotendinous junctions in the supramalleolar region to their distal insertions. To avoid anisotropy, the angulation of the transducer must be adjusted continuously, ~~for the ultrasound beam to remain perpendicular to the tendons~~ **especially** as they curve under the medial malleolus. The tibial nerve can be scanned by identifying it between the flexor digitorum tendon anteriorly and the flexor hallucis longus tendon posteriorly, at the level of the malleolus. The tibial nerve can then be followed ~~proximally and also distally~~ **along its course** to assess the medial and lateral plantar nerves. The flexor hallucis longus may also be scanned in the posterior position, medial to the Achilles tendon. The deltoid ligament is scanned longitudinally from its attachment to the medial malleolus to the navicular, talus, and calcaneus.

3. Lateral

~~The patient is placed in a lateral decubitus position with the lateral ankle facing upward~~. The peroneus **(fibularis)** brevis and longus tendons are identified proximal to the lateral malleolus in their short axis planes and can be assessed in long axis and short axis planes from their proximal (supramalleolar) musculotendinous junctions to their distal insertions. The peroneus longus can be followed in this manner to the cuboid groove, where it turns to course medially along the plantar aspect of the foot to insert on the base of the first metatarsal and medial cuneiform. ~~This latter aspect of the tendon can be scanned in the prone position, as clinically indicated.~~ The peroneus brevis tendon is followed to its insertion on the base of the fifth metatarsal. The peroneus brevis and longus tendons can be assessed for subluxation in real time by asking the patient to dorsiflex and evert the ankle. Circumduction of the ankle can also be a helpful maneuver. **The overlying retinaculum can be assessed for thickening or integrity.** The lateral ligament complex is examined ~~by placing the transducer on the tip of the lateral malleolus in the following orientations: anterior and posterior horizontal oblique for the~~ **including the anterior inferior tibiofibular ligament,** anterior and posterior talofibular ligaments, and ~~posterior vertical oblique for~~ the calcaneofibular ligament. Dynamic testing of the ligaments can be performed as clinically indicated **by applying varus stress**.

4. Posterior

The patient is prone with feet extending over the end of the table. A rolled towel **under the ankles** may also be helpful ~~under the ankles~~. The Achilles tendon is scanned in the long axis and short axis planes from the musculotendinous junctions (medial and lateral heads of the gastrocnemius and soleus muscles) to the site of insertion on the posterior surface of the calcaneus. Dynamic scanning with plantar and dorsiflexion may aid in the evaluation of tears. The plantaris tendon lies along the medial aspect of the Achilles tendon and **typically** inserts on the posteromedial calcaneus. ~~It should be noted that~~ This tendon may be absent as a normal variant. **Of note, it** is often intact in the setting of a full-thickness Achilles tendon tear. The retrocalcaneal bursa, between the Achilles and superior calcaneus, is also assessed and a small amount of fluid may be normally seen in this bursa. Assessment for a superficial retro-Achilles bursa is facilitated by floating the transducer on ultrasound gel and evaluating for fluid within the subcutaneous tissues. The plantar fascia is scanned in both long axis and short axis planes from its proximal origin on the medial calcaneal tubercle distally where it divides and merges into the soft tissues.

J. Specifications of a Foot Examination

1. Digital

In patients with suspected inflammatory arthritis, the metatarsophalangeal joints and, if symptomatic, the proximal interphalangeal joints are evaluated from the plantar and dorsal aspects in both the longitudinal and transverse planes for effusion, synovial hypertrophy, synovial hyperemia, and bony erosions. Other joints of the foot are similarly evaluated as clinically indicated **[37].**

2. Interdigital

The patient is supine with the foot dorsiflexed 90 degrees to the ankle. Either a dorsal or plantar approach can be used. The latter will be described here. The transducer is placed longitudinally on the plantar aspect of the first interdigital space, and the examiner applies digital pressure on the dorsal surface. The transducer is moved laterally with its center at the level of the metatarsal heads. The technique is repeated for the remaining interspaces and then repeated in the transverse plane. When a Morton's neuroma is clinically suspected, pressure can be applied to reproduce the patient's symptoms. In addition, manual medial and lateral compression of the forefoot with plantar imaging transverse to the metatarsals (Mulder's maneuver) will often displace a neuroma in a plantar direction **along with a palpable click,** improving visibility. The intermetatarsal bursa lies on the dorsal aspect of the interdigital nerve. **C**are must be taken to correctly identify a neuroma and differentiate it from the bursa, [38,39] **which typically flattens with compression**.

K. Specifications of a Peripheral Nerve Examination

Nerves have a fascicular pattern with hypoechoic longitudinal neuronal fascicles interspersed with hyperechoic

interfascicular connective tissue and epineurium, best appreciated when imaged in short axis. Nerves course adjacent to vessels and are readily distinguished from the surrounding tendons with a dynamic examination, during which the nerve demonstrates relatively little movement **and less anisotropy** compared with the adjacent tendons. Nerves may become more hypoechoic as they pass through fibro-osseous tunnels, as the fascicles become more compact.

Examination in the short axis plane is usually preferred to assess the course of the nerve because it may be difficult to separate the nerve itself from the surrounding tendons and muscles on a longitudinal scan. Assessment at the level of fibro-osseous tunnels may require dynamic examination. A statically subluxated or dislocated nerve is readily identifiable on ultrasound, but an intermittently subluxating or dislocating nerve requires dynamic examination. Perhaps the most commonly subluxating nerve is the ulnar nerve within the cubital tunnel region (see elbow examination). Entrapment neuropathies also typically occur within fibro-osseous tunnels (eg, cubital and **ulnar** ~~Guyon's~~ tunnels for the ulnar nerve, carpal tunnel for the median nerve, fibular neck for the common peroneal [fibular] nerve, and the tarsal tunnel for the tibial nerve). Adjacent pathology of tendons, soft tissues, and bone can be ~~readily~~ evaluated to determine the **possible** ~~potential underlying~~ cause of the nerve dysfunction. In addition, congenital abnormalities (eg, accessory muscles or vessels), can be assessed [40].

The sonographic appearance of peripheral nerve sheath tumors can be variable, although most share the common features of being hypoechoic and homogeneous, with posterior acoustic enhancement and peripheral nerve continuity [41].

L. Specifications of a Soft Tissue Mass Examination

The mass should be scanned in both long axis and short axis planes. Ultrasound is an excellent method to differentiate solid from cystic masses. The mass should be measured in 2 ~~3~~ orthogonal dimensions with its relationship to surrounding structures, particularly joints, neurovascular bundles, and tendons, determined. Compressibility of the lesion should be evaluated. Color or power Doppler evaluation will help **differentiate solid from cystic masses, and to determine if a** ~~to delineate whether the~~ mass has internal vascularity [42]. **Dynamic evaluation helps in evaluation of mobility relative to adjacent structures. An attempt should be made to differentiate between superficial soft tissues masses and deep soft tissue masses by commenting on their location in relation to the deep investing fascia.**

M. Specifications of Interventional Musculoskeletal Ultrasound

Ultrasound is an ideal modality for image guidance of musculoskeletal interventional procedures. The usual standards for interventional procedures apply (ie, review prior imaging, appropriate **informed** consent, ~~anesthetic,~~ sterile conditions**, and a local anesthetic**). Ultrasound provides direct visualization of the needle **or interventional device**, monitors the ~~needle~~ trajectory, and shows the position of the needle/**device** within the target area. Direct visualization ~~of the needle~~ allows the practitioner to avoid ~~significant~~ **damage to** intralesional and extralesional vessels, adjacent nerves, or other structures at risk.

Prior to any procedure, an ultrasound examination is performed to characterize the target area and its relationship to surrounding structures. Color or power Doppler is useful to delineate any vessels within the target zone **and to assess for potential infection in the overlying tissues. If significant hyperemia is noted in superficial tissues along the target pathway, an alternative procedure or pathway should be reconsidered to avoid introducing an infection into deeper tissues, particularly if the target position is intra-articular.**

Ideally the shortest pathway to the region of interest should be selected, with consideration given to regional neurovascular structures and optimization of needle visualization. A needle guide can be used or the procedure can be performed free-hand. Slight "to and fro" movement (ie, jiggling) of the needle may be beneficial in visualizing the needle. When possible, the needle should be aligned longitudinally with the plane of the transducer at its center. When biopsying a partially necrotic mass, color Doppler should be used to identify areas of vascularity, ~~this~~ **which** indicates viable tissue and increases the chance for an adequate histologic specimen**.**

N. Specifications for Ultrasound Examination for ~~Detecting~~ **Detection of** Foreign Bodies

Most foreign bodies are **hyperechoic compared with the surrounding soft tissues and are associated** with an acoustic shadow (wood) or comet tail artifact (glass, metal). Retained foreign bodies can cause a surrounding **hypoechoic** soft tissue inflammatory reaction/**granulation tissue** or abscess formation. Once a foreign body is detected, ultrasound can be used to demonstrate its location and relationship to adjacent structures **and help guide removal**. A high frequency linear array transducer as well as a generous amount of gel should be used to scan superficial foreign bodies. Deeper foreign bodies may require a lower frequency transducer. Color and power Doppler are useful in detecting surrounding hyperemia. When available, 3-D imaging may be useful in localization [43].

V. DOCUMENTATION

Reporting should be in accordance with ACR Practice Parameter for Communication of Diagnostic Imaging Findings **[44].**

Adequate documentation is essential for high-quality patient care. There should be a permanent record of the ultrasound examination and its interpretation. Comparison with prior relevant imaging studies may prove helpful. Images of all appropriate areas, both normal and abnormal, should be recorded. Variations from normal size should generally be accompanied by measurements. Images should be labeled with the patient identification, facility identification, examination date, and image orientation. An official interpretation (final report) of the ultrasound examination should be included in the patient's medical record. Retention of the ultrasound examination images should be consistent both with clinical need and with relevant legal and local health care facility requirements. Video clips of structures of interest in transverse and longitudinal (or orthogonal planes) may be obtained to supplement static images.

VI. EQUIPMENT SPECIFICATIONS

Equipment performance monitoring should be in accordance with the ACR-AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Real Time Ultrasound Equipment **[45].**

Musculoskeletal ultrasound should be performed with high-resolution linear array transducers with a broad bandwidth. Transducer frequencies will vary depending on the structure being imaged and body habitus; lower frequencies **(6-9 MHz)** are typically required for deeper structures and higher frequencies for superficial structures. The most common **higher** transducer frequencies used range between 12 and 18 MHz. **Newer transducers have a frequency range up to 24 MHz that help in evaluation of smaller, superficial structures like pulleys, tendons, and nerves**. Color and power Doppler are valuable in assessing hyperemia and inflammation, vascularity of a soft tissue mass, differentiating cystic from solid lesions and in assisting with ultrasound-guided biopsy**, injection,** and aspiration procedures [46]. Doppler frequencies should be set to optimize flow detection. Tissue harmonic imaging, compound imaging, and extended field of view may all be useful in musculoskeletal ultrasound.

VII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on Quality Control & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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NOT FOR PUBLICATION, QUOTATION, OR CITATION

RESOLUTION NO. 34

BE IT RESOLVED,
that the American College of Radiology adopt the ACR–AIUM–SPR–SRU Practice Parameter for the Performance and Interpretation of Diagnostic Ultrasound of the Thyroid and Extracranial Head and Neck

Sponsored By: **ACR Council Steering Committee**

American College of Radiology, with more than 30,000 members, is the principal organization of radiologists, radiation oncologists, and clinical medical physicists in the United States. The College is a nonprofit professional society whose primary purposes are to advance the science of radiology, improve radiologic services to the patient, study the socioeconomic aspects of the practice of radiology, and encourage continuing education for radiologists, radiation oncologists, medical physicists, and persons practicing in allied professional fields.

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Revised 2018 (Resolution 25)*

ACR–AIUM–SPR–SRU PRACTICE PARAMETER FOR THE PERFORMANCE AND INTERPRETATION OF DIAGNOSTIC ULTRASOUND OF THE THYROID AND EXTRACRANIAL HEAD AND NECK

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

I. INTRODUCTION

The clinical aspects contained in specific sections of this practice parameter (Introduction, Indications, Specifications of the Examination, and Equipment Specifications) were developed collaboratively by the American College of Radiology (ACR), the American Institute of Ultrasound in Medicine (AIUM), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU). Recommendations for physician requirements, written request for the examination, procedure documentation, and quality control vary between the 4 organizations and are addressed by each separately.

This practice parameter is intended to assist practitioners performing sonographic evaluation of the extracranial head and neck, including evaluation of the thyroid gland, parathyroid glands, parotid glands, submandibular glands, lymph nodes, and adjacent soft tissues. Sonographic evaluation of the major vasculature of the neck is addressed in a separate practice parameter. Occasionally, an additional and/or specialized examination with another modality may be necessary. Although it is not possible to detect every abnormality, adherence to the following practice parameters will maximize the probability of detecting most abnormalities that occur in the extracranial head and neck.

II. INDICATIONS

Indications for an **ultrasound (US) examination of the** thyroid and **extracranial** ~~parathyroid~~ head and neck ~~ultrasound (US) examination~~ include, but are not limited to [1]:

1. Evaluation of the location and characteristics of palpable neck masses **and thyroid nodules**

2. Evaluation of abnormalities detected by other imaging examinations, such as ~~a~~ thyroid nodule**s and/**or other neck mass**es that satisfy criteria for a thyroid ultrasound that are** detected on CT, PET, **PET**/CT, MRI, or ~~seen on~~ other ultrasound **examinations** (eg, carotid **duplex** ~~ultrasound~~) [1]

~~3. Evaluation for causes of relevant laboratory abnormalities, such as abnormalities of thyroid or parathyroid function~~

3. Evaluation of the presence, size, ~~and~~ location, **and sonographic features** of the thyroid gland [2]

4. Evaluation of congenital hypothyroidism, including search for and characterization of orthotopic and/or ectopic thyroid tissue [3,4]

5. Evaluation of patients at high risk for thyroid malignancy

6. Imaging of previously detected thyroid nodules that meet criteria for follow-up ~~imaging~~ [5]

~~7. Evaluation for regional nodal metastases in patients with proven or suspected thyroid carcinoma prior to thyroidectomy [6]~~

~~8. Evaluation for recurrent disease or regional nodal metastases after total or partial thyroidectomy for thyroid carcinoma [7]~~

7. Evaluation of the thyroid gland for ~~malignancy~~ **suspicious focal pathology** prior to neck surgery for ~~nonthyroid~~ **nonthyroidal** disease [8]

8. Evaluation of the thyroid gland for **suspicious focal pathology** ~~malignancy~~ prior to radioiodine ablation of the gland **for hyperthyroidism**

9. Evaluation for regional nodal metastases in patients with proven or suspected thyroid carcinoma prior to surgical or other management [6]

10. Evaluation for recurrent locoregional metastatic disease and/or nodal metastases after lobectomy, ~~or~~ **hemi- or total** thyroidectomy for thyroid carcinoma [5]

11. Evaluation of known or suspected thyroid cancer (usually papillary microcarcinoma not undergoing surgical resection) that is being monitored periodically with ultrasound active surveillance/active monitoring for disease progression (eg, increase in **nodule** ~~lesion~~ size, ~~or~~ development of nodal metastatic disease**, or extrathyroidal extension**)

~~12. Assessment of the location, number, and size of enlarged parathyroid glands in patients with known or suspected hyperparathyroidism, or who have undergone previous parathyroid surgery or ablative therapy with recurrent signs or symptoms of hyperparathyroidism [9,10]~~

12. Guidance for aspiration ~~or~~ biopsy **or other interventional procedure performed on** ~~of~~ thyroid abnormalities or other **neck** masses ~~of the neck, or for other interventional procedures~~ [11,12]

13. Evaluation for causes of relevant laboratory abnormalities, such as abnormalities of parathyroid or thyroid function, elevation of thyroglobulin, hypercalcemia, etc

14. Assessment of the location, number, and size of enlarged parathyroid glands in patients with known or suspected hyperparathyroidism, including patients who have undergone previous parathyroid surgery or ablative therapy who have recurrent signs or symptoms of hyperparathyroidism [9,10]

15. Localization of autologous parathyroid gland implants

16. Evaluation of masses of the parotid and submandibular glands [13,14]

17. Evaluation of nonneoplastic conditions of the parotid and submandibular glands, including, but not limited to, sialolithiasis, infection, and autoimmune processes [15-17]

18. Nodal evaluation, including staging, evaluation of response to therapy, and monitoring after therapy, in select patients with head and neck malignancies, including, but not limited to, head and neck primary squamous cell carcinoma, primary salivary malignancy, and melanoma [18-20]

19. Evaluation for supraclavicular nodal metastasis in patients with lung cancer or other infraclavicular primary malignancies at risk for metastasis [21,22]

20. Nodal evaluation in pediatric patients with cervical lymphadenopathy, including, but not limited to, evaluation for necrosis and abscess formation in the setting of acute ~~lymphadenititis~~ **lymphadenitis** [23,24]

21. Imaging of **ultrasound** ~~sonographically~~ **detectable** ~~accessible~~ vascular **abnormalities** ~~anomalies~~ (such as vascular tumors and vascular malformations) of the head and neck [25]

22. Evaluation of torticollis in neonates and infants [26] or

23. **Evaluation of adult and** ~~other~~ pediatric **head and neck soft tissue masses** ~~conditions~~ including, but not limited to, thyroglossal duct cyst, branchial cleft cyst, lymphatic malformation, thymic ectopia/cyst, hemangioma, primary neck masses, including neurogenic tumors (neuroblastoma, schwannoma, neurofibroma), rhabdomyosarcoma, leukemia/lymphoma**,** metastatic disease (rhabdomyosarcoma, neuroblastoma, thyroid cancer, **etc**) [27], and phlebectasia [28]

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR–SPR–SRU Practice Parameter for Performing and Interpreting Diagnostic Ultrasound Examinations **[29]**

IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for an extracranial head and neck ultrasound examination should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

Sonographic evaluations of the neck may be comprehensive ~~(including all of the structures described below)~~ or may be problem focused, as appropriate for the patient and clinical scenario. **Whenever possible, comparison should be made with prior sonograms and/or other appropriate imaging studies.**

A. Thyroid Evaluation

The examination should be performed with the neck ~~in hyperextension, with~~ **in** as much **hyper**extension as tolerated by the patient**, with or without a towel or other support under the neck or shoulders**. Upright positioning may be helpful in patients who cannot tolerate neck hyperextension in the supine position. The right and left lobes of the thyroid ~~gland~~ should be imaged in ~~the~~ longitudinal and transverse planes. Recorded images ~~of the thyroid~~ should include transverse images of the superior, mid, and inferior portions of the right and left thyroid lobes; longitudinal images of the medial, mid, and lateral portions of both lobes; and a transverse image of the isthmus. The size of each thyroid lobe should be recorded in 3 dimensions: anteroposterior (AP), transverse, and longitudinal. The thickness (AP measurement) of the isthmus on the transverse view should be recorded. **Color** Doppler ~~examination~~ can be used to supplement ~~the~~ grayscale evaluation of either diffuse or focal **thyroid** abnormalities ~~of the thyroid~~. It is often necessary to extend imaging to include the soft tissue**s** above the isthmus, for example, to evaluate a ~~possible~~ pyramidal lobe of the thyroid, ~~to evaluate congenital abnormalities such as~~ a thyroglossal duct cyst, or ~~to investigate any superior~~ palpable abnormality. **Similarly, it is important to visualize components of the gland that extend toward or into the superior mediastinum. In this effort, use of tightly curved array transducers may be helpful. The roles of strain and shear-wave elastography and contrast-enhanced ultrasound (CEUS), although potentially helpful, have not been established definitively.**

Thyroid abnormalities should be imaged in a way that allows for reporting and documentation of the following:

1. ~~The~~ Localized or diffuse ~~nature of any thyroid abnormalit~~**ies**~~, including assessment of overall~~ **parenchymal echotexture** ~~gland~~ **(eg, homogeneous versus heterogeneous) and, if relevant,** vascularity **(hyperemia) of the thyroid parenchyma should be noted** [30,31].

2. **There are multiple thyroid nodule risk-stratification systems (RSSs) in existence. Images of thyroid nodules should be acquired such that relevant focal nodules can be classified based on whatever RSS is used by the interpreting physician. For example, the ACR Thyroid Imaging, Reporting and Data System (TI-RADS) RSS employs the following sonographic features: composition (solid and/or cystic components); echogenicity; size (in AP, transverse, and longitudinal dimensions); margins (smooth, ill-defined, irregular, or demonstrating extrathyroidal extension); nodule orientation (eg, taller than wide); and presence and type of echogenic foci and/or calcifications [11,32,33]. Although the ultrasound features that determine risk in children are the same as those used in adults, to date, none of the RSSs have been specifically endorsed for the pediatric population [12,34,35].**

~~The sonographic features of any focal thyroid abnormality with respect to composition (degree of solid/or cystic components), echogenicity, shape, size (in AP, transverse, and longitudinal dimensions), margins (smooth, or irregular), , presence and type of echogenic foci and/or calcifications (if present), other relevant sonographic patterns and extra-thyroidal extension of lesion [11,32,33]. The ACR Thyroid Imaging, Reporting and Data System (TI-RADS) provides a lexicon for describing features of focal thyroid abnormalities with an associated management strategy [12,34,35].~~

Examination of relevant neck compartments for adenopathy may be helpful in determining the need for biopsy in the setting of thyroid nodules. ~~A~~ **C**omprehensive evaluation of **central and lateral compartment** cervical lymph nodes is ~~needed~~ **strongly recommended** for patients with known or suspected thyroid cancer ~~for whom surgery is planned~~ [36,37]. This comprehensive evaluation may occur at the time of the initial thyroid ultrasound, the time of an ultrasound-guided biopsy, or as a separate ~~preoperative~~ ultrasound evaluation **to assist in potential surgical or other management decisions**. Institutions are encouraged to have consistent practices to ensure that patients receive a comprehensive nodal evaluation when indicated (see section V.B.).

In patients who have undergone ~~complete or partial~~ **lobectomy, hemithyroidectomy (lobectomy and isthmectomy), or** thyroidectomy, the thyroid bed should be imaged in transverse and longitudinal planes **and abnormal** ~~any~~ **solid or cystic** masses ~~or cysts~~ ~~in the region of the bed~~ should be measured and reported. **Again, examination of relevant neck compartments and the adjacent soft tissue is important to look for locoregional metastatic disease in the setting of prior thyroid malignancy.**

Patients with known or suspected thyroid malignancy who are undergoing active surveillance or active monitoring with ultrasound must be evaluated for progression (eg, interval increase in surveillance nodule size, development of extrathyroidal extension, multifocal disease, or locoregional nodal metastases) [38-41].

~~Whenever possible, comparison should be made with prior sonograms and other appropriate imaging studies.~~

B. Cervical Lymph Node Evaluation

Sonographic examination of ~~the~~ cervical lymph nodes may be comprehensive or focused, as appropriate for the patient and clinical scenario. ~~Therefore,~~ **Specific nodes that are imaged** ~~anatomic locations examined~~ and the extent of imaging documentation will vary based on the clinical indication. **Please see above for nodal evaluation with respect to thyroid-related indications.** The size and location of ~~any~~ abnormal lymph nodes should be documented, and ~~note should be made of any~~ suspicious **nodal morphology including, but not limited to,** ~~features such as~~ calcification, cysts ~~areas,~~ ~~absence of central hilum, round shape,~~ **focal echogenic areas that are unrelated to a fatty hilum,** and abnormal blood flow **should be documented** [42]. **Round shape and absence of an echogenic hilum, although reported in malignant nodes, are findings with poor specificity in thyroid cancer [43,44].** Location of ~~the~~ abnormal lymph node**(s)** should be documented with annotations **and**/or enough visual information to **be able to** describe the location according to the image-based nodal classification system developed by the American Joint Committee on Cancer and the American Academy of Otolaryngology – Head and Neck Surgery, or in a fashion that allows the referring clinician to convert the location of abnormal nodes to that system [45]. Node evaluation should be performed at centers with experienced personnel. **Lymph node size varies with nodal compartment (eg, level 2 nodes are often larger than other lateral compartment nodes), and nodal size is often less important in the evaluation of malignancy than nodal morphology. Enlarged cervical nodes can be seen in lymphoma and other malignancies but are often reactive and are seen in acute and chronic infectious and inflammatory disease processes such as postviral syndromes and Hashimoto's thyroiditis.**

In the pediatric population, cervical lymph node **size**, echotexture, vascularity, and potential nodal suppuration or abscess formation evaluation ~~is often~~ ~~performed as part of the evaluation~~ **are important in the evaluation** of acute lymphadenitis. ~~Lymph node size, echotexture, and vascularity should be documented, and note should be made of nodal suppuration or abscess formation~~ [23,24].

C. Parathyroid Evaluation

~~Examination for suspected parathyroid enlargement should include images of the typical parathyroid gland locations, such as posterior to and just inferior to the thyroid gland. An E~~**Parathyroid ultrasound helps guide surgical planning by localizing enlarged parathyroid glands in patients with primary hyperparathyroidism and helping to predict single versus multiple gland enlargement. Examination for suspected parathyroid enlargement due to adenomas, hyperplasia, or, extremely rarely, parathyroid carcinomas should include images posterior to and just inferior to the right and left thyroid lobes, typical parathyroid gland locations. In addition to typical locations, enlarged parathyroid glands and parathyroid adenomas may be ectopic, and the examination may need to be extended to include imaging from the hyoid to the sternum and along the carotid sheath. Abnormalities of the thyroid and cervical nodes should be documented because concomitant thyroid and/or cervical node pathology may be contraindications to minimally invasive parathyroidectomy** [9,10,46].

The examination should be performed with the neck hyperextended and should include longitudinal ~~and transverse~~ images from the **right and left** carotid arteries to the midline ~~bilaterally~~, **as well as transverse images** ~~extending~~ from the carotid artery bifurcation superiorly to the thoracic inlet inferiorly. **Normal parathyroid glands are often not visualized using available sonographic technology; however, enlarged parathyroid glands may be detected. Gentle compression with the ultrasound transducer, asking the patient to swallow during real-time imaging, and the addition of color Doppler imaging (to evaluate for polar rather than central blood flow that is more typical of lymph nodes) are imaging techniques that may make it easier to identify enlarged parathyroid glands. Parathyroid glands may be located below the clavicles or in the mediastinum, and angling smaller footprint, tightly curved array transducers inferiorly from the sternal notch can aid in diagnosis of enlarged inferior parathyroid glands.** ~~As Parathyroid glands may be hidden below the clavicles in the lower neck and upper mediastinum, and may also be retrotracheal in location, it may be helpful to have the patient swallow during the examination with constant real-time observation. Doppler ultrasound may be helpful. The upper mediastinum may be imaged with an appropriate transducer by and angling inferiorly under the sternum from the sternal notch.~~ **Approximately 1% to 3% of parathyroid adenomas may be retrotracheal; instructing the patient to swallow and/or turn their head to the opposite side may be helpful in identifying these ectopic parathyroid glands.** Rarely, parathyroid adenomas may ~~also~~ be intrathyroidal. ~~Although the normal parathyroid glands are usually not visualized using available sonographic technology, enlarged parathyroid glands may be visualized.~~ When parathyroid abnormalities are visualized, their **number, size, measurements in 3 dimensions, and** location **and relationship to the thyroid gland, if applicable, should be documented**~~, size, and number should be documented, and measurements should be made in three dimensions. The relationship of any visualized parathyroid gland(s) to the thyroid gland should be documented, if applicable~~ [8,47].

~~Whenever possible, comparison should be made with other appropriate imaging studies.~~

D. Parotid and Submandibular Evaluation

Sonographic evaluation of the major salivary glands may be comprehensive or focused, as appropriate for the patient and clinical scenario. The parotid and submandibular glands are evaluated in 2 planes, although anatomic limitations due to the mandible and external ear often require oblique planes. A lower frequency transducer may be helpful to visualize the deep aspects of the parotid gland. **Color** Doppler may be added, when appropriate, for the evaluation of diffuse or focal abnormalities. **Overall echotexture (eg, homogeneous or heterogeneous) and m**easurements of the parotid and submandibular glands **should** ~~can~~ be performed, when appropriate, such as **in the** evaluation of autoimmune disease or gland asymmetry. Salivary ductal dilation and calculi should be reported. When possible, a dilated salivary gland duct should be traced to the level of obstruction. Description of focal abnormalities**/masses** within the salivary glands should include size in 3 dimensions, ~~as previously described~~, margins, echogenicity, composition, and internal blood flow. ~~Abnormal appearing~~ Intraparotid lymph nodes **and their morphologic appearance (normal or abnormal)** should be reported [48].

E. Sonographic Guidance of Head and Neck Procedures

Sonographic guidance may be used for aspiration and/or biopsy of thyroid/parathyroid/salivary **gland** abnormalities, lymph nodes, ~~or~~ **and** other masses of the head and neck or for other interventional procedures **including, but not limited to, preoperative localization and ultrasound-guided treatment of masses with various ablation methods** [49].

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings **[50].**

Adequate documentation is essential for high-quality patient care. There should be a ~~permanent~~ record of the ultrasound examination and its interpretation. Comparison with prior relevant imaging studies may prove helpful. Images of all appropriate areas, both normal and abnormal, should be recorded. Variations from normal size should generally be accompanied by measurements. Images should be labeled with the patient identification, facility identification, examination date, and image orientation. An official interpretation (final report) of the ultrasound examination should be included in the patient's medical record. Video clips of structures of interest in transverse and longitudinal (or orthogonal planes) may be obtained to supplement static images. ~~Retention of the ultrasound examination images should be consistent both with clinical need and with relevant legal and local health care facility requirements.~~

VI. EQUIPMENT SPECIFICATIONS

Equipment performance monitoring should be in accordance with the ACR-AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Real Time Ultrasound Equipment **[51].**

Extracranial head and neck ultrasound studies ~~should be primarily~~ **are usually** conducted with a linear transducer. The equipment should be adjusted to operate at the highest clinically appropriate frequency, realizing that there is a trade-off between resolution and beam penetration. For most patients, mean frequencies of 10 to 14 MHz or greater are preferred, although some patients may require a lower-frequency transducer for depth penetration. For evaluation of deep or large structures, a curved transducer may be necessary. For **morphologic evaluation of** small**,** superficial lesions, higher frequency transducers, ~~particularly those~~ with a small footprint, may be necessary. Additionally, a ~~curved~~ **small-footprint, tightly curved array** ~~linear~~ transducer may be helpful for evaluation of the inferior aspect of the central neck to evaluate for inferior central or upper mediastinal adenopathy and inferior parathyroid glands (Section V-C). Resolution should be of sufficient quality to evaluate the internal morphology of visible lesions. Doppler frequencies should be set to optimize flow detection. Diagnostic information should be optimized while keeping total sonographic exposure as low as reasonably achievable.

VII. QUALITY CONTROL IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on Quality Control & Improvement, Safety, Infection Control*, *and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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RESOLUTION NO. 36

BE IT RESOLVED,

that the American College of Radiology adopt the ACR–NASCI–SPR Practice Parameter for the Performance of Quantification of Cardiovascular Computed Tomography (CT) and Magnetic Resonance Imaging (MRI)

Sponsored By: **ACR Council Steering Committee**

2017 (Resolution 21)*

ACR–NASCI–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF QUANTIFICATION OF CARDIOVASCULAR COMPUTED TOMOGRAPHY (CT) AND MAGNETIC RESONANCE IMAGING (MRI)

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

I. INTRODUCTION

This practice parameter was revised collaboratively by the American College of Radiology (ACR), the North American Society for Cardiovascular Imaging (NASCI), and the Society for Pediatric Radiology (SPR).

Cardiac computed tomography (CT) and magnetic resonance imaging (MRI) ~~and computed tomography (CT)~~ are important noninvasive methods for the assessment of ischemic and nonischemic cardiomyopathies, pericardial disease, cardiac masses, and **valvular** and congenital heart disease. In addition, CT angiography (CTA) and MR angiography (MRA) are well-established noninvasive cross-sectional imaging methods for the detection and assessment of vascular anatomy and a variety of vascular pathologies.

Previous ~~published~~ practice parameters from the ACR have provided practitioners with the educational tools to perform ~~MRA, CTA, and~~ cardiac CT and MR ~~and CT imaging~~, CTA, and MRA. ~~However,~~ This parameter deals with ~~continued improvements in~~ the ~~fidelity of advanced CT and MRI scanners and increasingly available advanced imaging methods, there is a clear need for new guidelines on the~~ quantitative aspects of CT and ~~MRI~~ MR for cardiovascular imaging.

~~Given the rapid development of quantitative cardiovascular CT and MRI, it is anticipated that future versions of this document will evolve as advanced quantification methods are widely adopted into clinical practice.~~

II. INDICATIONS

Indications for quantification of CT and MRI include, but are not limited to, the following quantitative applications:

1. Characterization and grading of vascular stenosis
2. Measurement of vessel wall thickness
3. Characterization of aneurysmal disease
4. Evaluation of vascular morphology prior to surgical intervention
5. Flow measurement with phase-contrast MRI (PC-MRI)
~~6. Flow characterization with contrast enhanced time-resolved MRA~~
6. Characterization of **cardiac** ~~myocardial~~ morphology and function
7. Assessment of pressure gradients across focal **vessel or valvar** stenosis using PC-MRI
8. Assessment of volume of myocardial infarction (MI) in ischemic heart disease
9. Assessment of volume of **resting and stress-induced** hypoperfused myocardium with perfusion imaging
10. ~~Extent of myocardial fibrosis/infiltration~~ **Assessment of myocardial tissue** in nonischemic cardiomyopathy ~~for assessment of risk of fatal arrhythmias~~

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI) **[1]** and the ACR Practice Parameter for Performance and Interpreting Diagnostic Computed Tomography (CT) **[2]**.

IV. SPECIFICATIONS OF THE EXAMINATION

General Aspects of Quantitative Cardiovascular Imaging with CTA and MRA

1. Morphological evaluation

    a. Cardiac gating

    Proper cardiac gating of CT and MR imaging is critical for the generation of diagnostic images for the evaluation of cardiovascular morphology and function. There are 2 techniques for synchronizing the electrocardiogram (ECG) signal with the cardiac cycle: prospective and retrospective [3].

~~With~~ Prospective cardiac gating ~~the~~ acquisition is triggered by the R wave and is paused for image acquisition during a specific phase of the cardiac cycle. This has the advantage of offering selective imaging during a specific cardiac phase to reduce motion blurring, optimizing visualization of a vascular structure and, as in the case of coronary CTA, reducing patient exposure to ionizing radiation.

Retrospective **cardiac** gating acquires data throughout the cardiac cycle **over multiple beats** ~~so that no portion of the cardiac cycle is excluded~~. This technique is more **prone** ~~sensitive~~ to arrhythmia-**related artifacts**, although **this effect is reduced** with ~~current~~ arrhythmia software~~, this effect can be minimized~~ **and the latest generation scanners due to improved temporal resolution.**

b. Measurements:

i. Distance **and cross-sectional diameter** measurements

Many cardiovascular imagers use standard multiplanar imaging and assess individual vessels using multiplanar reconstructions (MPR) perpendicular to the vessel axis in orthogonal planes. This is typically done in an interactive fashion with various segments of the vessels being evaluated sequentially for areas of plaque and stenosis. ~~For CTA and MRA~~ **Alternatively**, a widely used approach for morphological evaluation and measurement is to use curved ~~planar images~~ **multiplanar reconstructions (curved MPR),** derived from the volumetric data set. ~~One option is delineating the centerline of the vessel to create a curved planar reconstruction of the arterial segment in question.~~ Vendor software allows deconvolution of the vessel, permitting a curved planar view that can be displayed in both cross-sectional and longitudinal projections. An accurate cross-sectional diameter and area measurement of the normal vessel can be obtained using this projection. Measurements of coronary artery diameter can be obtained within a precision of approximately 0.6 mm on CTA and to approximately 1 mm on MRA. Length measurements can be derived **from** curved **MPR** views ~~planar on multiplanar reformatted~~. Pitfalls include inaccurate placement of the centerline by automated software **that can cause artifactual stenoses.** This most often occurs in small vessels such as the coronary arteries or calf vessels. On MRA, gradient nonlinearity can cause in-plane and out-of-plane image distortion that leads to incorrect vessel measurements.

~~A centerline that is eccentric or incorporates mural calcification or thrombus does not accurately represent the lumen of the vessel. Artifactual stenoses may be produced by an improper centerline. Thus, it is important that the centerline be verified by an experienced observer to avoid this pitfall.~~
~~Alternatively, many cardiovascular imagers use standard multiplanar imaging and assess the individual vessels using multiplanar reformats (MPR) perpendicular to the vessel axis in orthogonal planes.~~
~~Cross sectional diameter measurements~~

Cross-sectional diameter measurements ~~are~~ **can be** performed using ~~an MPR perpendicular to the vessel axis in orthogonal planes~~ **a curved MPR.** If an area of dilatation or stenosis is suspected, the area can be quantified using reference measurements from adjacent **closest normal vessel or within a 1 cm distance.** ~~normal vessel sections. A common practice is to compare luminal diameter that is deemed normal by taking measurements 1 cm proximal to the abnormal vessel section and another measurement 1 cm distal to the stenosis or dilatation on the longitudinal straightened curved planar images. The average diameter of these 2 measurements is used as the reference normal diameter of the vessel.~~

The diameter of the abnormal segment is divided by the reference normal diameter to arrive at a percentage of stenosis or dilatation (percentage stenosis or dilatation equals abnormal segment [millimeters] referenced to the normal segment). Workstation software is available to automate this calculation, or it may be calculated manually. In practice, it may be difficult to confidently identify one or more reference normal areas because of diffuse calcified and noncalcified plaque. If only one reference normal area can be defined (either proximal or distal), this area can be used as a single reference segment with the caveat that it may slightly overestimate or underestimate the true extent of the stenosis or dilatation.

ii. Cross-sectional area, volume, and angle measurements

Stenosis: Stenosis of the arteries is far more common than dilation and is usually due to negative remodeling and atherosclerosis but can also be secondary to other causes such as vasculitis, dissection, or congenital. Measurements of stenoses are done from the inner wall to the opposite inner wall of the vessel lumen. In evaluating stenoses on CTA, it is important to distinguish calcification from the opacified lumen to properly define the stenosis and minimize the effects of blooming artifacts. This can be particularly problematic in the evaluation of the small vessels, such as the coronary arteries and anterior tibial artery. MRA is used less frequently for small vessels to characterize stenosis and dilation because of its spatial resolution. An advantage of MRI is that calcification is not readily visible, and therefore, blooming effects seen with CTA do not impact MRA. For this reason, MRA can be an alternative in severe vascular calcification.

Atherosclerosis: When atherosclerotic plaque is present, its precise anatomic location, severity, and length of stenosis should be reported. The severity of stenosis is graded as a percentage of diameter reduction; the diameter of the stenotic segment is divided by an adjacent normal diameter to determine the percentage of stenosis (or dilatation). However, in smaller (peripheral or visceral) vessels, limitations in spatial resolution may preclude accurate use of percentage reduction, and qualitative analysis is used (mild, moderate, or severe). Coronary CTA has its own standardized grading system, with CAD-RADS being the most widely used: 0% (no visible stenosis), 1% to 24% (minimal stenosis), 25% to 49% (mild stenosis), 50% to 69% (moderate stenosis), 70% to 99% (severe stenosis), and 100% (occluded) [4]. **In addition, with CTA, the plaque characteristics are typically reported as noncalcified, calcified, or partially calcified.**

Fractional flow reserve by CT (FFRct) is an increasingly used and FDA-approved clinical tool that complements the coronary CTA source data by providing a calculated flow assessment of the coronary arteries. In selected cases of intermediate stenosis, FFRct can improve specificity of coronary CTA and markedly improve clinical decision making. FFRct values should be evaluated in the clinical context and categorized as follows: I. >0.8, stenosis: not hemodynamically significant; II. 0.80 to 0.76, stenosis: borderline hemodynamically significant; and III. ≤0.75, stenosis: hemodynamically significant. Borderline hemodynamically significant stenosis needs further risk stratification [5].

Vasculitis: MRA and CTA have the unique advantage of not only evaluating for luminal narrowing but also allowing direct visualization of the vessel wall. MRI typically provides superior soft tissue contrast that can aid the detection of mural inflammation and edema [6] **and aid in more precise delineation of the vessel wall boundaries, although CTA generally has higher spatial resolution and the benefit of shorter examination times. An abnormally thickened artery wall may indicate the presence of vasculitis. In general, the aortic wall should be no thicker than approximately 2 mm, although it differs by age and sex [7].**

Dissection: It is important to recognize and report:

- **The classification of aortic dissection based on location and extent of the flap**
- **Aortic size (length and width) and the size of true and false lumen**
- **Dilatation of the aortic diameter and further extension of the dissection flap**
- **Location and number of fenestrations as well as the relative size and density of the false and true lumen may be helpful in determining the possible need for treatment**
- **The extent of a penetrating ulcer and possible involvement into nearby branches**

Pulmonary veins (PVs): PV stenosis is a well-known complication of ablation procedure that has been widely used to treat atrial fibrillation (AF) and usually ablates the atrial myocardium inside the PVs to disconnect an abnormal interaction with the left atrium (LA) [8]. **CT of PVs has been the most**

commonly used modality to detect postprocedure stenoses, but MRI is alternatively used. Because the PV size varies throughout the cardiac cycle and the difference between maximum and minimum diameter is 15% ± 8% [8], **ECG-gated CTA acquisitions are preferred with images evaluated during late systole. Preprocedural CTA or MRA for the cross-sectional measurement of PV ostia is beneficial for selecting the optimal circular catheter.** Furthermore, because 38% of patients with AF have variant anatomy of PVs, evaluating the number and location of PVs is useful in ascertaining that all PV orifices are evaluated during the procedure.

Dilatation (ectasia, aneurysm): Dilatation of the arteries is often due to positive remodeling and atherosclerosis, although multiple other causes exist, including vasculitis**, connective tissue diseases,** and trauma. ~~In general,~~

An aneurysm is defined by dilatation of an artery to greater than 1.5 times the diameter of the adjacent normal segment. **Measurements of an aneurysm's cross-sectional area can be calculated from longitudinal straightened MPR and are generally done from one outer wall to the opposite outer wall (from the adventitial side of the vessel wall). Angle measurement are very helpful for follow-up of thoracoabdominal aortic aneurysms and iliac artery aneurysms after endovascular repair** [9]. **Mentioning how we measured in the report helps consistency with future or prior comparison studies.**

~~Stenosis is far more common and is usually due to negative remodeling and atherosclerosis but can also be secondary to other causes such as vasculitis and dissection. Because of the limited spatial resolution (approximately 0.35 mm^3) for CTA of at least 64–slice, 9 to 10 voxels typically span the entire diameter of a proximal coronary artery lumen, for example. Each pixel represents approximately 10% of the luminal diameter. Thus, overly precise reporting of stenoses is often not appropriate. Generally, a percentage range is used. A typical spectrum might include a stenosis grading of less than 25%, 25% to 50%, 50% to 75%, or greater than 75%. Alternatively, more recent guidelines for coronary CTA suggest the following grading system: 0% (no visible stenosis), 1% to 24% (minimal stenosis), 25% to 49% (mild stenosis), 50% to 69% (moderate stenosis), 70% to 99% (severe stenosis), 100% (occluded). Standardized reporting of coronary CTA with corresponding recommendations is in development and may provide a framework for a further study~~.

In baseline and follow-up imaging studies, it is helpful to make aortic measurement at conventional locations to facilitate comparison. It is typical to make double-oblique short-axis measurements at the following locations:

- **Aortic annulus (if valve replacement is being considered)**
- **Sinuses of Valsalva**
- **Sinotubular junction**
- **Ascending thoracic aorta at the level of the right pulmonary artery**
- **Transverse aortic arch between the left common carotid and subclavian artery origins**
- **Aortic isthmus (site adjacent to the ductus ligament insertion)**
- **Descending thoracic aorta at the level of the right pulmonary artery**
- **Diaphragmatic hiatus**
- **Celiac plexus and/or superior mesenteric artery origin**
- **Renal artery origin**
- **Infrarenal abdominal aorta midway between renal artery origins and the aortic bifurcation**
- **Aortic bifurcation**
- **Common iliac arteries**

~~Common iliac~~ ~~This can be particularly problematic in the evaluation of the anterior tibial artery. It is also a common problem in the interpretation of a coronary CTA. The most common, simple solution is to use a lower window center setting and a wider window width. Most vendors provide software with preset window and level settings that optimize evaluation of calcified arteries. It may also be useful to assess the extent of calcification in both the longitudinal and transverse curved planar reconstructions. MRA is used less~~

~~frequently to characterize dilation and stenosis because of its spatial resolution. However, an approach similar to that described above can be used with MRA. Calcification is not readily visible on MRI, and therefore blooming effects seen with CTA do not impact MRA. For this reason MRA is often used in peripheral vascular disease, particularly in the setting of severe vascular calcification.~~

~~Measurements of an aneurysm's cross-sectional area can be calculated from longitudinal straightened curved planar reconstructed images using the techniques described in section IV.A.1.c above, and many vendors provide this software. Nevertheless, it is not commonly used because most studies of the accuracy of CTA have correlated it with quantitative catheter-based angiography, which relies on unidimensional measurements. Volume and angle measurement are not commonly performed for CTA and MRA but are very helpful for follow-up of thoracoabdominal aortic aneurysms, iliac artery aneurysm after endovascular repair [11], and endovascular repair.~~

c. **Attenuation (region-of-**interest characterization ~~(CT only~~)

Attenuation measurement of the arterial wall can be obtained for **diagnosis** ~~plaque characterization. Generally~~ **of intramural hematoma, acute hemorrhage within intraluminal (or mural) thrombus, and atherosclerotic plaques. On CT,** a region of interest (ROI) is placed on the **arterial** wall, and a Hounsfield unit (HU) measurement is obtained that represents an average pixel value. **On MRI, hyperintensity on intrinsic T1-weighted sequences can also be used to depict methemoglobin in the acute and subacute hematoma.**

~~This measurement can be performed on unenhanced gated CT study, often a calcium-scoring examination,~~

When there is suspicion of intramural hematoma, a crescent-shaped high attenuation in the aortic wall can be seen in noncontrast study representing acute hemorrhage, but it is important to repeat the measurements after intravenous (IV) contrast because intramural hematoma does not enhance [10]**. Within the intraluminal thrombus, the presence of focal hyperdensity (CT) or hyperintensity on intrinsic T1-weighted sequence (MR) may suggest acute hemorrhage and potential impending rupture**. **Also, a fissure or dissection within the intraluminal thrombus may predict a higher risk of rupture**. **In both intramural hematoma and intraluminal thrombus, the extent (both length and width) and** ~~it has also been attempted with CTA. Optimally~~ **branch vessel involvement should be noted.**

In atherosclerotic plaques, **optimally,** it should be possible to categorize ~~plaques~~ as primarily calcified, fibrous, or fatty in density. **Because it is** difficult to confidently differentiate fibrous and fatty **atherosclerotic plaques in small vessels, the plaques can also be** characterized as calcified, noncalcified, or **partially calcified [11]**.

~~Although studies correlating CTA with intravascular ultrasound have shown some ability to distinguish among these 3 plaque densities, in clinical practice it is often plaques. This limitation likely arises from partial volume averaging and variability of HU measurements among different vendors. Thus, plaque is generally It is also important to quantify HU measurements in the aorta when they are elevated. Crescent-shaped high attenuation in the aortic wall is seen in intramural hematoma, but it is important to repeat the measurements after IV contrast is administered because intramural hematoma does not enhance, and an alternative diagnosis (eg, vasculitis) should be sought if there is enhancement .~~

The presence of high-risk features in the coronary artery plaques, such as low density (HU < 30), positive remodeling, spotty calcification, or napkin ring signs, is associated with acute coronary syndrome [12].

2. Velocity and flow quantification: PC-MRI

Velocity and flow quantification with MRI are achieved using phase-contrast imaging [13-15]. PC-MRI exploits the fact that moving tissue (ie, blood) acquires a phase shift in the presence of velocity encoding gradients. This phase shift is directly proportional to the velocity of the blood as it moves through a magnetic field.

~~With PC-MRI, 2 measurements are typically acquired: the first with a positive bipolar gradient, the second with a negative bipolar gradient. The resultant image is a subtracted phase map image. Signal from stationary tissue is eliminated. while The only signal that remains originates from moving tissue (ie, blood) and is directly proportional to its velocity.~~

~~PC-MRI can be implemented as a breath-hold technique or with free-breathing. Breath-holding may be preferred within the thorax or abdomen because of the effects of respiratory motion, but it has been suggested that breath-held PC-MRI may underestimate some measurements, such as pulmonary regurgitation, compared to PC-MRI obtained during free breathing. Prospective cardiac gating may be preferred with breath-held PC-MRI because of its more consistent acquisition, although either cardiac gating approach is acceptable. The principal drawback of breath-holding is the restricted acquisition time, which may compromise temporal resolution. Free-breathing PC-MRI permits a longer acquisition, which allows higher temporal resolution, although image quality may be reduced because of respiratory motion artifact. Free-breathing PC-MRI may be preferable in uncooperative patients or in the pediatric population. Real-time PC-MRI can be used as an alternative, if available.~~

The most important parameter for PC-MRI is the velocity encoding variable (V_{enc}). The V_{enc} is generally given in cm/sec and is the highest and lowest detectable velocity measured by that PC-MRI pulse sequence. The closer the V_{enc} is to the actual velocity, the more accurate the measurement. If the V_{enc} is lower than the maximum velocity being measured, then aliasing will occur. If the V_{enc} is significantly higher than the actual velocity, then signal intensity is reduced and the noise floor is relatively higher, which may reduce the accuracy **and sensitivity** of the flow measurement. **Velocity flow is measured by accurately drawing an ROI that includes the entire lumen of the vessel being evaluated** [16]. **Peak velocity is the pixel with the highest signal intensity in the direction of interest within the ROI. Average velocity represents the average of all the pixels within the ROI.**

~~Since V_{enc} is inversely proportional to the amplitude of the magnetic gradient, the lower the velocity being measured and the higher the gradient strength required.~~

V_{enc} is most commonly encoded in a single direction during a PC-MRI acquisition (ie, unidirectional PC-MRI). The direction of the V_{enc} variable can be altered depending on what is being measured, and this will determine slice prescription. In-plane PC-MRI is where the V_{enc} direction is encoded within the plane of the image, either anterior-posterior direction, left-right direction, or superior-inferior direction. In-plane PC-MRI is useful for determining flow direction such as when characterizing the eccentricity of an aortic regurgitant jet on a 3-chamber cardiac orientation. Through-plane PC-MRI is where the V_{enc} is encoded through the plane of the slice. This technique is commonly used for measuring velocity and flow, and it is important that the through plane imaging slices be directly orthogonal to the flow being measured. V_{enc} can be also encoded in 3 directions (x, y, and z) during a single acquisition (~~ie, tridirectional PC-MRI~~) **ie, 4-D flow) [17]**. ~~Since more time is needed to acquire the additional directions, imaging times are long and therefore temporal resolution may be compromised with a breath-hold acquisition~~ The **4D-flow CMR data can be co-registered with cine images and displayed with color coded velocity information. This overlay allows visualization of complex flow patterns associated with cardiovascular disease. Time-resolved contrast-enhanced MRA may be helpful for identifying collaterals and the presence of flow reversal** [18,19]**.**

Most current noninvasive angiographic techniques rely solely on the morphologic assessment of the vasculature. Phase-contrast MRA assesses the hemodynamic consequences of an arterial lesion. Phase-contrast flow quantification is a valuable, versatile tool in the noninvasive evaluation of flow characteristics within almost any vascular bed. It accurately depicts quantitative flow profiles of velocity, volume, rate, and direction.

Pressure gradients across an arterial stenosis are used to determine its hemodynamic significance and therapy. Peak flow velocity is determined on PC-MRI. Pressure gradients across short/focal stenosis can then be approximated using a modified Bernoulli equation, $\Delta P = 4V^2$, where ΔP is the peak pressure gradient in millimeters of mercury and V is the peak blood flow velocity in meters per second.

Phase-contrast MR sequences can be used for both flow quantification for valvular insufficiency and peak

and average velocities quantification for valvular stenosis. Aortic insufficiency is usually graded by regurgitant volume (volume of regurgitant flow across the valve per heartbeat) or regurgitant fraction (regurgitant volume divided by forward stroke volume [SV]). Quantification of stenotic valves measures peak and average velocities across the valve on phase-contrast images. These velocities are converted into pressure gradients with the modified Bernoulli equation: $\Delta P = 4V^2$ (as described above). A mean gradient greater than 50 mm Hg or peak velocity greater than 4.5 m/sec is defined as severe aortic stenosis.

In cardiac imaging, phase-contrast MR can be used for functional assessment of flow through the aortic and pulmonic valve. A unique evaluation in patients with suspected or known congenital heart disease for a left-to-right shunt is to use the pulmonary (Qp) to systemic (Qs) blood flow ratio (Qp/Qs ratio) [20,21]**. This measures the volume of blood flow between the pulmonary (ie, right heart) and systemic (ie, left heart) circulations. In healthy individuals, the blood flow is equal, and the resultant Qp/Qs ratio is 1. In patients with an underlying left-to-right shunt lesion (ie, atrial septal defect, ventricular septal defect, or partial anomalous pulmonary venous return), there is shunting of blood from the left to the right heart and a Qp/Qs ratio greater than 1. When the Qp/Qs ratio is less than 1, this represents right to left shunting. Symptomatic patients often present when the shunting becomes moderate (ie, Qp/Qs >1.5) or large (ie, Qp/Qs >2.2). The Qp/Qs ratio is most commonly measured using MRI. It can be determined by comparing the measured flow over the cardiac cycle on cine PC-MRI performed perpendicular to both the main pulmonary artery and the ascending thoracic aorta. In patients with suspected systemic to pulmonary collateral flow, the pulmonary flow can be estimated using the pulmonary venous return, and the systemic flow can be estimated using the caval return. The degree of systemic-to-pulmonary collateral flow affects immediate postoperative outcomes and can be intervened upon prior to surgery** [22-**25**]**.**

In addition, phase-contrast MR can quantify the volume of mitral valve regurgitation. The most frequent method to quantify the mitral regurgitation volume is left ventricular SV minus aortic forward flow in phase-contrast [26,27].

~~a. Direction~~

~~In its most basic application, PC-MRI can be used to visualize flow direction. This can be achieved with in-plane PC-MRI where the imaging slice is chosen to match the region of interest. Precise selection of V_{enc} is less important for this application as long as the V_{enc} is above the peak velocity being measured. Accurate slice orientation is essential, especially in regions where position may be affected by respiratory variations (eg, in a portal venous system).~~

~~b. Velocity~~

~~Through-plane PC-MRI is used for accurate measurement of velocity. It is essential that the through-plane slice be positioned directly orthogonal to the flow so that the true velocity is being measured and not a vector component of the true velocity. In-plane PC-MRI may be useful for planning the setup of the through-plane slice. For example, a sagittal oblique in-plane PC-MRI of a thoracic aortic coarctation will depict the direction of the high-velocity jet inferior to the stenosis so that the through plane slice can be prescribed directly orthogonal to the flow jet. Preliminary in-plane PC-MRI has the added advantage of providing an assessment of actual velocity so that the V_{enc} can be increased on the through-plane slice if aliasing occurs. In order to ensure true orthogonal positioning, the through-plane slice should or must be set up from at least 2 different orientations. In-plane velocity measurements can also be used for estimation of peak velocity but care must be taken to ensure that the imaging plane is indeed aligned with the direction of the flow, which often may be eccentric and/or moving, as in the case of a valve. Velocity is measured by drawing a ROI that includes the entire lumen of the vessel being evaluated~~

~~Pressure gradients (mmHg) across a focal stenosis can be estimated using the modified Bernoulli equation, $P=4V^2$, where V is the peak velocity in m/sec. If the peak velocity is measured at multiple points along a vessel, such as above and below a coarctation, then the pressure gradient between those points can be estimated. It is important to note that the modified Bernoulli equation does not apply for long segment stenoses. In some instances, highly turbulent flow may result in intravoxel dephasing that results in the absence of signal, which results in inaccurate peak flow determination using PC-MRI. Finally, assessment of the shape of the velocity-time curve may be helpful in conditions where there is dampened flow, such as in pulmonary hypertension.~~

~~c. Flow~~

~~Blood flow can be calculated from the velocities measured by PC-MRI. It is optimal to acquire the velocity measurements directly orthogonal to the direction of flow; therefore, using in-plane PC-MRI to set up the through-plane slice is very helpful. For correct calculation of flow, the ROI needs to be accurately drawn within the flow region since the ROI area will determine the final flow value. It is essential that spatial resolution is set to match the vessel of interest. If spatial resolution is too low, flow and velocity will be underestimated because of partial volume effects. Similarly, temporal resolution (ie, time per frame) must be adequate for measuring flow in the vessel of interest. For example, high flow vessels such as the thoracic aorta require higher temporal resolution.~~

~~3. Time resolved angiography~~

~~a. Technical aspects~~

~~Time-resolved angiography refers to rapid frame rate angiography where images are acquired per unit of time such that sequential filling and draining of vascular structures can be assessed. Time-resolved angiography can be carried out using either MRI or CT. Time-resolved MRA (TR-MRA) refers to ultrafast MRA in which 3-dimensional (3-D) data sets are acquired every 1 to 3 seconds. In order to speed up the acquisition, conventional MRA is implemented with acceleration strategies such as parallel imaging or view sharing (ie, TRICKS, TWIST). If TR-MRA is implemented as a 2-D acquisition, then frame rates of several images per second can be achieved. Time-resolved angiography with CT usually involves acquiring a single slice or stack of slices (with multi-detector CT) every second as a contrast bolus is injected and is the preferred method for bolus timing with CT.~~

~~b. Applications~~

~~TR-MRA, in its most basic use, can be used as a bolus timing acquisition for measuring contrast transit times for conventional MRA. TR-MRA can also be used to visualize, in real-time, the passage of a bolus of contrast through different portions of the circulation. For example, TR-MRA may be the method of choice for imaging the pulmonary vasculature because it depicts sequential filling of pulmonary arteries, pulmonary veins, and thoracic aorta, which has particular utility for assessing congenital heart disease or aortic dissection. The passage of a contrast bolus can also be quantified by placing ROIs in different vessels to measure its time to peak enhancement. For example, the absolute transit time between the pulmonary trunk and thoracic aorta is elevated in conditions such as pulmonary hypertension and congestive heart failure. Similarly, relative contrast transit times between different vascular territories can be expressed as ratios. Contrast transit times between the left heart and right heart can be calculated in order to better characterize intra-cardiac and extra-cardiac shunts.~~

3. Quantitative techniques specific to cardiac MRI and CT

~~Echocardiography, notably~~ Transthoracic echocardiography remains the primary screening tool for evaluating cardiac morphology and function [28]. However, evaluation with echocardiography relies on operator skill, and variability in scanning technique may contribute to ~~intraobserver interobserver~~ **intra-** and **interobserver** variation [29]. Such variation is notably higher with echocardiography than with MRI. ~~Moreover,~~ The IV administration of contrast agents enables the determination of myocardial perfusion and myocardial delayed enhancement on MRI and more recently on CT.

Many of the measurement standards used for clinical cardiac CT and MRI are derived from those of echocardiography [30]. It is important to note that specific thresholds of measurement for healthy individuals vary based on body habitus, race, sex, and age [31-36]. Moreover, imaging technique itself can result in differences in measurement. For example, the actual pulse sequence used for cardiac MRI (ie, fast gradient echo versus steady state free precession) may affect left ventricular measurements **[37-39]**, although field strength (1.5T versus 3T) does not appear to have any significant influence [40-42].

Cardiac-gated MRI and CT can provide images of the heart chambers throughout the entire cardiac cycle, thereby enabling quantitative measurement of myocardial wall thickness and mass, chamber sizes, and myocardial function that are similar and arguably more reproducible than that achieved by transthoracic echocardiography. The IV administration of contrast agents enables the determination of myocardial perfusion and myocardial late gadolinium enhancement (LGE) on MRI.

c. Myocardium

i. Wall thickness:

Myocardial wall thickness is traditionally measured on end-diastolic images. ~~End-diastole can be defined at the onset of the P-wave but is preferably defined as the frame after mitral valve closure or the frame in the cardiac cycle in which the cardiac dimension is largest.~~ In healthy adults, end-diastolic left ventricular thickness is typically between 6 and 12 mm [43]. To minimize volume averaging effects, image acquisition is typically performed in a plane perpendicular to the wall being measured. For the left ventricle (LV), this is typically performed on short axis images. Special regions such as the apex are better suited for evaluation on 2-chamber and 4-chamber ~~long-axis~~ views. The basal anteroseptal segment is best evaluated on a 3-chamber view.

ii. Myocardial mass (left ventricular mass):

The myocardial mass of the LV can be determined by measuring end-diastolic LV myocardial volume and multiplying this by the specific gravity of myocardium (1.05 g/mL) [33].The myocardial volume of the LV can be determined by summing the area of the myocardium from a stack of images that covers the entirety of the LV and multiplying this by the thickness of each slice (and slice gap if present). **The decision of how much of the ventricular outflow tract to include (ie, how close to the ventriculoarterial valve each endocardial contour tracing extends) varies. Some investigators exclude the left and right ventricular outflow tracts, although others draw endocardial contours up to the aortic and pulmonic valve planes. The planimetry measurement between endocardial and epicardial tracings represents the myocardial area. There is variability in how endocardial contours are drawn. Whether one includes or excludes the papillary muscles and ventricular trabeculae from the blood pool volume is a matter of choice. In normal patients or in those with coronary artery disease, it has been shown that inclusion or exclusion of the papillary muscles in ventricular volume measurements has no significant difference in e**nd-diastolic volume (**EDV) or** end-systolic volume (**ESV) measurements for most examinations.**

~~The difference between endocardial and epicardial tracings represents myocardium. The area of the myocardium can be calculated by subtracting the area of the LV's chamber (endocardial tracing) from the area of the LV (epicardial tracing). Note that the papillary muscles are typically excluded from the endocardial border (ie, included within the volume of the chamber) as.~~

The exclusion of the papillary muscles reduces postprocessing time requirements by obviating a separate trace of the papillary muscles [44]. However, in some specific cases, such as in patients with hypertrophic cardiomyopathy, it may be useful to perform an additional trace of the papillary muscles and include their mass in the LV myocardial volume [45]. In hypertrophic cardiomyopathy, the papillary muscles are relatively larger, and their exclusion would underestimate overall myocardial mass as well as overestimate the LV diastolic volume and underestimate the LV ejection fraction (EF) [45].

Because of the variety in the method of measurements that existed among readers, it is recommended that these methods of tracing in any specific lab be clear and similar, at least among cardiac imagers in one lab for the purpose of comparison and follow-up of their patients. The cardiac imager may follow the major society guidelines for the various methods of measurement [46].

iii. Myocardial segmentation and nomenclature:

S**ince 2002, the American Heart Association** [47] **has recommended a standard reporting nomenclature for cardiac imaging studies (nuclear medicine, echocardiography, MRI, and CT) that is based on a 17-segment heart model in which the myocardial segments are defined by their location relative to the long axis (basal, mid, or apical) and circumferential location at each**

location. There are 6 segments (anterior, anteroseptal, inferoseptal, inferior, inferolateral, and anterolateral) at both the basal and midventricular levels, 4 segments (anterior, septal, inferior, and lateral) at the apical level, and the apical cap to compose the total 17 segments of the LV.

This segmental nomenclature is intended for regional descriptions of cardiac wall motion, myocardial perfusion, and ~~myocardial~~ **myocardium LGE.**

d. Cardiac chamber**s:**

i. **Ventricles:**

Ventricular **internal diameter and** volumes can be measured linearly using short and long axis dimensions ~~but are more commonly measured in terms of~~ **or through chamber tracing, respectively. In cardiac CT, the ventricular** volume **can only be accurately calculated in retrospective gated studies including sufficient phases.** When quantifying the LV using 2-D ~~(2-D)~~ linear measurements, the LV's internal diameters are measured **in systole and diastole in the basal to mid-cavity** from the endocardium of the ~~anteroseptum~~ **anteroseptal wall** to the endocardium of the inferolateral wall [48]~~ at the midventricular level~~. Left and right ventricular volumes can be best measured using a modified Simpson method whereby the ventricular chamber volume is determined by the sum of the endocardial area multiplied by the slice distance using short axis or long axis images [49]. ~~CT provides added flexibility for postprocessing in that ventricular~~ **Left ventricular** volume calculations can **often** be made quickly using ~~the volumetric data and using advanced region growing~~ **artificial intelligence** postprocessing software ~~based on density~~ for ~~fast,~~ **automated** ~~accurate~~ determination of chamber contours [50]. ~~It is often helpful to index these.~~ **These** values **can be indexed** to body surface area (BSA) ~~(BSA)~~ or to calculate the ratio of right ventricle (RV) to LV size as an assessment of RV enlargement [**51**,52].

~~LV and RV measurements can be important particularly in the growing number of adult patients with congenital heart disease who require lifelong CT and/or MRI surveillance.~~

ii. Atria:

~~There are few CT and MRI studies reporting~~ **The** normal **measurements of the LA** and right ~~atrial measurements.~~ **atrium (RA) are dependent upon the modality used to assess volumes.** Echocardiographic standards **using 2-D biplane measurements generally underestimate volumes.** ~~however, suggest that the~~ Limited data exists on the standardization of normative values [REFS A-E]. End-systolic measurements should be performed for both LA and RA linear and volumetric measurements. LA linear measurements are typically performed in the anterior-posterior (or left ventricular outflow tract) view, while RA linear measurements are performed on the 4-chamber view. For LA volumetric measurements, the pulmonary veins should be excluded. Cardiac MR is considered the gold standard for atrial volumetric ~~**however, echocardiographic data are easily obtainable, and the** normal left atrial **LA** anterior-posterior dimension is less than 4.0 cm during **in** end-systole and that the **is ≤4.0 cm in men and ≤3.8 cm in women, whereas the area is ≤20 cm^2, and the RA** normal **area is ≤18 cm^2** [30]. **However, cardiac MR is considered the gold standard for left atrial volumetric measurements and function [53,54]. Cardiac MR–derived biplane measurements also have a good correlation with full-volume methods. Cardiac CT is considered more accurate than 2-D echocardiography, and volumes correlate well with MRI [55].**

~~minor axis (ie, transverse) right atrial dimension is less than 4.5 cm [34]. However, the atria, especially the right atrium, are often oblong or unusually shaped, making specific diameter measurements less useful as a determination of enlargement. However, atrioventricular valvular dysfunction (eg, mitral or tricuspid insufficiency or stenosis) will often be present with atrial enlargement.~~

e. Myocardial function:

i. Ventricular ~~ejection fraction~~ **function**:

The evaluation of cardiac function can provide valuable prognostic information on ischemic heart disease. The EF predicts outcome better than the number of vessels involved [56], **and prognosis after MI is closely related to the degree of LV contractile dysfunction** [57].

~~EF[%] = 100 × [EDV – ESV]/EDV, in which EDV is end-diastolic volume and ESV is end-systolic volume. EDV and ESV are determined using the modified Simpson method described above by drawing endocardial tracings on short axis slices of the heart, from the atrioventricular valve plane (base of the heart) to the apex, at end-diastole and end-systole. Because the length of the ventricle is shorter at end-systole than in end-diastole, it is often necessary to trace an endocardial contour on an additional end-diastolic slice. Inclusion or exclusion of the papillary muscles may result in clinically relevant differences in EDV and ESV values in patients with specific pathologies such as hypertrophic cardiomyopathy.~~

Volumetric and EF measurements by MRI and CT have been shown to be very comparable [50,58]. An individual physician, or by consensus an imaging laboratory, should establish a convention by which **endocardial and** epicardial contours will be drawn in all patients. By establishing this standard, one will have confidence in the accuracy, reproducibility, and stability of functional measurements when measuring cardiac function in patients returning for repeat examinations.

~~The ventricular chambers are bounded by the atrioventricular valves (ie, mitral or tricuspid valves) and the ventriculoarterial valves (ie, aortic or pulmonic valves). The atrioventricular valve plane defines the base of the ventricular chamber and is therefore a well-defined boundary of the ventricle. The decision of how much of the ventricular outflow tract to include (ie,~~

Ventricular EF is defined by the following equation [32,48,49]: **EF [%] = 100 × [EDV – ESV] / EDV. EDV and ESV are determined using the modified Simpson method by drawing endocardial tracings (as described above), preferably on short axis slices of the heart, from the atrioventricular valve plane (base of the heart) to the apex, at end diastole and end systole.**

In addition to EDV and ESV, the following functional parameters are easily calculated from the same short axis image data after drawing endocardial contours:

- Stroke volume (SV = EDV – ESV) **and stroke volume index (SVI= SV/ BSA)**
- Ejection fraction (EF [%] = 100 × [EDV – ESV]/ EDV)
- Cardiac output (CO = SV × heart rate)
- Cardiac index (CI = CO / body surface area (BSA) = SV x heart rate / BSA)
- Myocardial mass (grams), which is determined when epicardial borders are drawn on end-systolic slices in addition to the endocardial contours
- End-diastolic volume index (EDVI = EDV/BSA)
- End-systolic volume index (ESVI = ESV/BSA)

Indexing of measurements ~~(eg, cardiac output, cardiac index (CI): myocardial mass, myocardial mass index, end-diastolic volume, end-diastolic volume index, or end-systolic volume index)~~ to BSA and/or body mass index ~~(BMI)~~ is often helpful clinically to account from differences in patient habitus and size.

Increased pulmonary arterial pressure causes an increased workload of the RV, leading to RV hypertrophy with subsequent dilatation and right heart failure. MR and CT have been increasingly used for imaging the RV, as well as for the LV, but protocol should be carefully adjusted to accurately visualize the more complex shape of the RV [59]. **In the case of acute pulmonary embolism (PE), the chest CT measures the RV/LV diameter ratio and uses greater than 0.9 to predict 30-day mortality and major complications** [60-**62**]. **A ratio of main pulmonary artery diameter to the ascending aorta diameter of greater than 1 can be reliably used to detect pulmonary**

hypertension in adult patients with cardiopulmonary diseases if the ascending thoracic aorta is of normal size [60-**62**]**. In pediatric patients, a ratio of the main pulmonary artery diameter to the ascending aorta diameter of greater than 1.3 may suggest pulmonary hypertension** [63]**. In addition to morphological assessment, MR imaging can easily measure EF of both ventricles and LV end-diastolic volume, which are significantly decreased in patients with PAH** [61,64].

Acute PE increases the pulmonary arterial pressure, which may progress to right heart failure and circulatory collapse. Right ventricular dysfunction is a marker for adverse outcome in patients with acute PE [60,65]. The ratio of the RV to LV diameters is an accurate sign for RV dysfunction [65]. Other signs have been described, including bowing of the interventricular septum and reflux of contrast medium into the inferior vena cava. The sizes of the azygous vein, superior vena cava, and pulmonary artery are also indirect measures of right heart dysfunction and pulmonary hypertension. Mean pulmonary artery (PA) pressure correlates linearly with main PA diameter [66]**, and a PA diameter greater than 30 mm indicates a PA pressure greater than 20 mm Hg** [67].

ii. Wall motion:

Although there are a variety of methods for quantitative assessment of wall motion, the visual assessment of cine images remains the standard ~~for wall motion assessment~~. Wall motion can be visually assessed during systole as normal, hypokinetic (decreased wall motion), **hyperkinetic (increased wall motion),** akinetic (no wall motion), or dyskinetic (paradoxical motion or reversal of wall motion) ~~eg. aneurysm). In some circumstances it may be helpful to further subdivide hypokinesis into mild, moderate, and severe hypokinesis~~ **ie, aneurysm). Atrioventricular dyssynchrony occurs when the timing between atrial and ventricular contractions does not favor forward flow. Interventricular desynchrony occurs with a timing difference between the ventricles, and intraventricular desynchrony occurs when the sequence of activation and relaxation of segments within the LC or RV are abnormal**.

Assessment of myocardial wall motion can be performed during rest. For the assessment of patients with suspected coronary artery disease, however, wall motion assessment during pharmacologic stress using ~~an inotropic medication (eg,~~ dobutamine is often helpful as significant coronary disease may not be demonstrated in the resting state. For stress wall motion assessments, regional wall motion during stress is compared with resting wall motion, typically on a segment-by-segment basis **[68,69].** ~~Recent meta-analyses and large reviews have shown favorable performance of MRI to detect significant CAD compared to cardiac stress scintigraphy.~~

f. Myocardial perfusion:

Among cross-sectional imaging modalities, myocardial perfusion imaging is most commonly performed with MRI, but ~~more~~ recently, CT **is increasingly used because of the advancements of the last generation CT scanners that decrease radiation exposure and scan time** [70]. ~~has shown promise as well, particularly with dual-energy technique. Myocardial perfusion imaging~~ is ~~most typically~~

Stress perfusion cardiac MR is performed during administration of a pharmacologic vasodilator stress agent (eg, adenosine, dipyridamole, ~~or, more recently,~~ regadenoson) and **concurrent imaging** ~~enhancement~~ of myocardium **enhancement** using **short axis** rapid T1-weighted images. **These stress first pass perfusion images are then compared with perfusion images** acquired **at rest (second pass perfusion), enabling a** visual assessment of regional differences in the myocardial **enhancement at** stress **and at rest. Focal areas with inducible** myocardial **ischemia after pharmacologic stress agent show decreased or lack of** perfusion ~~MRI~~ **at stress (darker) compared** with **at rest (enhanced), whereas areas of chronic myocardial infarct show decreased or lack of perfusion at stress and at rest** [68,69,71,72]. ~~is evaluated over time. This assessment is typically performed using a series of rapidly short axis T1-weighted images that enables enhancement. Enhancement of each region reflects perfusion of specific coronary arterial vascular territories. Similar to wall motion evaluation, a meta-analysis has shown stress. have a high sensitivity (90%) and specificity (81%) for detecting significant coronary artery disease (≥50% arterial~~

~~diameter stenosis).~~

~~g. Myocardial delayed enhancement imaging Myocardial delayed enhancement (MDE) also called late~~

g. LGE~~, delayed~~:

LGE is used to **depict myocardium focal necrosis, fibrosis/scarring, or infiltration.**

~~, or delayed contrast enhancement imaging is a useful tool for assessing myocardial tissue. Imaging is typically performed using MRI 10 20 minutes following the intravenous injection of a gadolinium-chelate contrast agent (eg, 0.2 mmol/kg cumulative dose) in short axis views and often in supplemental long axis and/or 4-chamber views. On delayed imaging,~~

Abnormal regions of myocardium appear brighter than adjacent normal myocardium **in LGE** and are therefore ~~often~~ **also** termed "hyperenhancement." The underlying mechanisms for ~~hyper-enhancement are varied and not fully understood but reflect~~ **LGE reflect** the relative faster washout of contrast in normal myocardium ~~and~~ **compared with** prolonged retention of contrast in the abnormal tissue **due to enlargement of the extracellular space** [73,74]. **Imaging is typically performed approximately 10 minutes following gadolinium-chelate contrast agent injection in short axis, 2-, 3-, and 4-chamber views.**

~~Hyperenhancement on MDE imaging was initially reported in the setting of myocardial infarction in which infarcted or nonviable myocardium is hyperenhanced. Hyperenhancement typically~~

LGE is seen in both acute and chronic MI [75]. **In MI, the LGE** begins in the subendocardial region, as this represents the end-vessel or "at risk" territory of the myocardium as coronary arteries originate**s** from the epicardial surface of the heart and **branches** dive deep into the subepicardium, mesocardium, and ultimately into **capillaries at** the subendocardium.

~~Hyperenhancement of myocardial infarction is seen in both acute and chronic myocardial infarction.~~

The segmental transmurality of the hyperenhancement has been shown to correlate with the likelihood for functional improvement following a coronary revascularization procedure. Transmurality of ~~hyperenhancement~~ **LGE** is best characterized in quartiles, as less than 0% to 25%, 26% to 50%, 51% to 75%, ~~or~~ **and** 76% to 100% **of the myocardial thickness [76]**. The likelihood of benefit from a revascularization procedure is high if there is little or no hyperenhancement (ie, entirely viable myocardium) and very low if there is transmural enhancement (100%) **[77,78].**

~~Generally, myocardial segments with less than 50% hyperenhancement on MDE will benefit from a coronary revascularization procedure since they retain sufficient viable myocardium to respond favorably to revascularization efforts~~

More recently, the use of CT for myocardial delayed enhancement imaging has shown promise for myocardial characterization, notably for identification of myocardial scar, a known potential substrate for ventricular arrhythmia, the most concerning being ventricular tachycardia, which is ~~associated with increased risk for sudden cardiac death~~ **an independent predictor of mortality** [79]. **A volume greater than 2.8 cm^3 is associated with inducibility of ventricular tachycardia [78,80]. Software quantification for delayed enhancement volume is possible using manual and automated thresholding techniques. Although there is no consensus regarding the technique of quantification of LGE, and the quantification depends greatly upon the method used, results using 6 SDs above the threshold and full width half maximum methods had no difference between visual assessments. All other thresholding techniques resulted in significant differences of LGE volumes for patients with hypertrophic cardiomyopathy** [81].

T1-mapping and extracellular volume fraction (ECV) mapping ~~MRI~~ **cardiac MR** ACR-NASCI-SPR Practice Parameter for the Performance and Interpretation of Cardiac Magnetic Resonance Imaging (MRI) **[82]:**

Native T1 relaxation time (ie, ~~T1~~ **native** mapping) and ECV differences, in normal and **focal or diffuse** fibrotic myocardium, may be used to detect and quantify myocardial disease, **which may not be as evident using other MR sequences.** ~~such as myocardial infarction and nonischemic cardiomyopathies.~~ These techniques may be particularly helpful for identifying diffuse myocardial processes such as diffuse myocardial fibrosis in **hypertrophic cardiomyopathy, muscular dystrophy, and cardiac** amyloidosis [83]. ~~such as diffuse myocardial fibrosis, which may not be evident using other MR methods. Initial experience with these novel T1 mapping techniques suggest the potential for these techniques to reliably image diffuse myocardial disease and may allow earlier detection and perhaps treatment of myocardial disease, enabling earlier treatment. Evaluation of the cellular and extracellular interstitial compartments of the myocardium may be prognostically important.~~

The ECV can be calculated using the values from myocardium and blood, before and after injection of contrast, and the patient's hematocrit [84]. T1 mapping can also be helpful in determining intrinsic myocardial disease in patients who can otherwise not receive IV contrast. There is a large amount of variability between vendors and MRI scanner models for normal T1 values based upon sequence options, and field strengths; thus, it is incumbent upon each site to determine their normal range of T1 values locall, by performing quality control using a standardized phantom [85,86].

~~In 2002, the American Heart Association suggested delayed enhancement. Calcium~~

h. T2-weighted and T2 mapping sequences cardiac MR:

Water in the myocardium causes longer T2 relaxation times and increased signal intensity. High signal intensity on T2-weighted and abnormal values on T2 mapping sequences are the result of myocardial inflammation or edema frequently seen with myocarditis, MI, and cardiomyopathies such as amyloidosis. In STIR, the extent of high T2-signal intensity in ischemia-associated myocardial edema reflects the area of risk that may include regions of reversible injury as well [87]. **T2 mapping normal values varies with the strength of the magnetic field and has been described at 1.5 T as 52.18 ± 3.4 ms and at 3T as 45.1 ms** [88,89].

i. Coronary artery calcium scoring:

Calcium-scoring images are acquired with noncontrast ECG-gated CT to optimally visualize and quantify calcified plaque. High "calcium scores" are associated with an increased risk of MI, and a calcium score of 0 has a very low but nonzero risk of a major adverse cardiac event [90,91].

Coronary calcium scores were first reported more than 20 years ago by Agatston et al [92,93] using electron-beam CT whereby coronary calcium lesions with **3 adjacent pixels of** >130 HU were assessed using an ROI. The area of each calcified coronary lesion was then multiplied by a weighting factor based on the peak HU measured within the lesion (weighting factor = 1: 130 to 199 HU; weighting factor = 2: 200 to 299; weighting factor = 3: HU; 300 to 399 HU; weighting factor = 4: ≥400 HU). The Agatston score is achieved by adding all the calcium scores **in the coronary system.** ~~for each region.~~

Two other methods for measuring coronary calcium are the volume score and the mass score. The volume score reflects the volume of calcium above the threshold; the mass score uses a phantom to calibrate the mass (milligram) of coronary calcium above the threshold. In a large cohort study of 11,490 individuals, the Agatston, volume, and mass scores were found to be equally accurate for calcium scoring, and no single method was deemed superior in terms of reproducibility of results from consecutive scans in a patient.

~~A. Applications of Quantitative Imaging to Specific Disease Entities~~

a. Aneurysm (primarily aorta): CTA and MRA

i. Initial diagnosis and description

Location, involved anatomy, size, morphology/configuration, volume, and attenuation (ROI) of mural thrombus

The location and involvement of the ascending thoracic aorta, transverse arch, descending thoracic aorta, and juxtarenal and infrarenal abdominal aorta will determine potential repair, and their respective diameters should be reported. The largest diameter is the most important one to be reported. The aneurysm diameter can only be estimated from axial images. When there is angulation in the vessel, measurements from MPRs orthogonal to the arterial axis are the most accurate. CPR with centerline tracing as denoted for coronary artery assessment can similarly be performed for aortic measurements. If workstations for MPRs are not available, then measurements of the vessel perpendicular to the axis of the vessel (ie, shortest in plane diameter) can be made from the axial images but are not preferred. It may also be useful to describe or report aneurysm length. If the length of the aneurysm is reported, it should be clearly identified as the length to avoid confusion with the diameter of the aneurysm. The aneurysm morphology (fusiform, saccular, "onion" or "tulip" bulb from effaced sinotubular junction) as well as mural thrombus volume should be evaluated and described. A fissure or dissection within the intraluminal thrombus may predict a higher risk of rupture. Hyperdense (CT) or hyperintense (MR) thrombus within the intraluminal thrombus may suggest acute hemorrhage within the thrombus and may suggest impending rupture.

ii. Surveillance

1. Role of noncontrast CT and MRI for surveillance of aneurysmal disease

In the surveillance of an aortic aneurysm, the diameter and rate of growth of the diameter should be reported. They can be evaluated on noncontrast or contrast enhanced imaging. MR or CT can be used; however, the spatial resolution of CT and the standardization between different CT scanners have generally led to CT becoming the standard surveillance test, particularly in older patients. In younger patients or patients with small aneurysms, an ultrasound examination may be used with the understanding that if there is growth of the aneurysm, a CT or MRI scan can be obtained in order to best assess the precise size and characteristics of the aneurysm prior to treatment. There is no consensus algorithm for the surveillance of patients with aortic aneurysms.

a. Aortic annulus

b. Ascending Descending Infrarenal artery diameters

iii. Presurgical planning

1. Endostent and open repair

An aortic aneurysm may be repaired either in an open surgical fashion where a graft replaces the aneurysm or in an endovascular fashion where an endostent is deployed to exclude the aneurysm lumen. A number of cases may require a hybrid technique where both techniques are used.

2. Location, size, volume, angles, areas, access via femoral/iliac arteries, etc

The evaluation for and endovascular treatment of aortic aneurysms requires several important measurements and observations. The lengths of the nondilated aorta proximal and distal to the aneurysm are termed the proximal neck and distal neck of the aneurysm, respectively. The diameter and length of the proximal and distal neck determine the possibility and long term success of an endovascular repair. The angulation, quality of the aneurysm neck (calcification, thrombus), and relationship to nearby branches from the aorta are also factors involved in an endovascular repair.

For a descending thoracic aortic aneurysm, the distance between the left subclavian artery or left common carotid artery to the beginning of the aneurysm determines the proximal neck length. The distance between the distal aspect of the descending thoracic aortic aneurysm and the visceral vessels defines the distal neck. In an abdominal aortic aneurysm (AAA), the extent of the aneurysm into the iliac vessels determines the length and distal diameter of the bifurcated grafts used in endovascular abdominal aneurysm repair (EVAR). The length from the proximal neck to the aortic bifurcation is also important for stent placement planning. These lengths can be estimated on axial imaging using table position, but a centerline measurement is preferred and considered the most accurate method. The centerline measurement is based on the true

perpendicular vessel center acquired from the double oblique MPR technique. Endovascular repair may require the delivery of large devices from the femoral approach into the aorta. The diameter, tortuosity, and degree of calcification of the iliac and femoral vessels will usually predict the successful delivery of the graft devices

iv. Postsurgical monitoring guidelines

In contrast to patients who undergo surgical repair of an aortic aneurysm and may receive a single follow-up scan, patients who have undergone endovascular aneurysm repair with endografts require lifelong monitoring. There are no established guidelines for surveillance imaging post endovascular repair. Most patients receive a CT examination with intravenous contrast media to assess the aorta and graft and the possibility for endoleaks within the first 3 months after the repair. Endoleaks represent arterial flow into the aneurysm sac. If there is enlargement of the endosac (excluded aortic lumen) from an endoleak, the aneurysm remains at risk of rupture. Therefore, aneurysm diameter measurements and possible increase in sac diameter must be reported. Changes in endosac volume, however, may be a more sensitive measure of sac enlargement. Sac volumes as well as sac diameters may be reported on noncontrast imaging and may be helpful to identify an enlarging sac or shrinking sac before there are changes in sac diameter.

v. Other sites of aneurysmal disease

1. Popliteal

Popliteal artery aneurysms as well as a number of peripheral aneurysms may not only be a risk for rupture but may also serve as a source of thrombi and subsequent distal embolization. The description of popliteal artery aneurysm should include not only the diameter and length of the aneurysm but also the presence and amount of thrombus within the aneurysm, as well as the patency of the distal (ie, tibial) vessels at risk of embolization.

2. Renal, splenic, mesenteric, great vessels, upper extremities

b. The size and location of an aneurysm, number of inflow and outflow vessels, and the amount of tissue perfused by the vessel are important in the determination as to when and how the aneurysm should be repaired or excluded. Pseudoaneurysms are associated with a higher risk of rupture., intramural hematomas, penetrating ulcer (primarily aorta): CTA and MRA

Penetrating atherosclerotic ulcers, intramural hematomas, and aortic dissections are closely related diagnoses discussed with the term "acute aortic syndromes". CTA is more commonly used in the acute setting because of its availability and faster image acquisition, although MRA examinations are common particularly in surveillance and follow up of these patients. The use of noncontrast CT prior to a contrast enhanced study is essential for the diagnosis of intramural hematoma.

i. Initial diagnosis and description

Location, involved anatomy, size, volume ROI in IMH (CT)) should be reported. are important to recognize and report. Additionally, the location and number of fenestrations as well as the relative size and density of the false and true lumen may be helpful in determining the possible need for treatment. The extent of a penetrating ulcer and possible involvement into nearby branches should be reported. Aortic size and size of true and false lumen should be reported.

The noncontrast acquisition allows depiction of the hyperdensity of the acute hemorrhage within the wall of the vessel. T1-weighted MRI sequences can also be used to depict methemoglobin in the acute and subacute intramural hematoma. With intramural hematoma and dissection the extent of hematoma (both length and width) and possible branch vessel involvement should be noted. Imaging will document the existence of vessel rupture. In aortic dissection, the diameter and flow within the true and false lumen should be reported.

1. Involvement of end organs (eg, renal and mesenteric arteries)

The patients should be evaluated for possible end-organ malperfusion, as this finding may necessitate urgent therapy.

ii. Surveillance

Surveillance of patients with known high risk conditions associated with thoracic aortic dilatation and dissection require meticulous evaluation with MRA and CTA. These patients require centerline diameter measurements at the aortic annulus, sinus of Valsalva, sinotubular ridge, ascending aorta, and other involved areas.

iii. Presurgical planning

Vessel diameters and treatment length must be quantitated. These will help determine if an endovascular repair can be performed and the diameter of the grafts needed. The amount of angulation of the arch, length from the arch vessels (left subclavian and left carotid artery) and from the visceral vessels, and the status of the vertebral arteries should be reported. Possible sites of endovascular access, including subclavian arteries and common femoral and iliac arteries, should be assessed.

iv. Postsurgical monitoring

Early after endovascular repair, CTA is most commonly used to determine the presence of endoleak as well as possible complications such as stent migration or fracture. Generally, lifelong annual CTA scans are needed to assess changes in the aortic diameter after repair. MRA is less commonly used because of its limited direct visualization of stent grafts, but it is an excellent alternative in patients with contraindications to CTA.

c. Atherosclerotic stenotic disease: CTA and MRA

Location, extent (length), severity (stenosis grading) is a progressive systemic disease characterized by accumulation of lipid, fibrous tissue, and occasionally hemorrhages in the large arteries. Clinical manifestations are primarily due to ischemia related to stenotic disease or from rupture of aneurysms or emboli from associated in situ thrombus. CT and MR accurately depict the location, severity, and length of arterial stenoses or aneurysms. Quantitative evaluation of the stenoses is heavily dependent on the spatial resolution of the CT or MR technique used. Spatial resolution determines the level of detail that can be evaluated and the accuracy of quantitative measurements atherosclerotic plaque is present, its precise anatomic location should be described and the severity and length of stenosis reported. However, in smaller vessels, limitations in spatial resolution may preclude accurate use of percentage reduction, and qualitative analysis is used (mild, moderate, or severe). In smaller vessels, such as the infrapopliteal arteries of the leg, calcified atherosclerotic plaque may also cause artifactual narrowing of the apparent residual lumen because of blooming and beam hardening on CT; this should be taken into account during stenosis determination in order to avoid overestimating the degree of diameter reduction. MRA may be the preferred imaging modality in such patients. The length from the beginning to the distal most aspect of a stenosis should be described; this will influence the choice of potential intervention.

i. Typical sites of disease

1. Renal, mesenteric, aorto-iliac-femoral, runoff

Renal artery atherosclerosis leads to renal failure and renovascular hypertension. Aortic or proximal renal artery plaques are the usual culprit when atherosclerosis causes renal failure, whereas stenosis of the proximal or more distal main renal artery or its branches leads to hypertension. Both CTA and MRA have high sensitivity and specificity for depicting atherosclerotic narrowing of the entire renal artery and often the segmental branches.

Mesenteric occlusive disease is frequently due to atherosclerosis of the celiac axis, superior mesenteric artery, and inferior mesenteric artery. Accurate detection of proximal mesenteric arterial stenosis is possible with both CTA and MRA, and precise description of the site, length, and diameter reduction should be reported.

The abdominal aorta is a common site of atherosclerosis. The infrarenal aorta is generally considered aneurysmal if it is 3 cm or greater in diameter, "ectatic" if it is between 2 and 3 cm in diameter and considered stenotic if the lumen is less than 1 cm. Imaging studies are important in determining the aneurysm size, detecting the involvement of branch vessels, and depicting any associated significant stenoses involving the abdominal visceral or extremities. Preoperative imaging for potential endovascular repair (EVAR) of AAA is based on aneurysm morphology and access vessel size and patency. After stent placement, imaging is used to monitor aneurysm diameter and volume, detect and classify endoleaks, and evaluate morphologic details of the stent graft.

In the iliac and lower extremity arteries, atherosclerosis may lead to claudication or limb threatening ischemia. Depiction of the anatomic location, length, and severity of stenosis is critical in determining if medical management, intervention, or surgery is best.

ii. Other sites: great vessels, subclavian, carotids

The thoracic aorta may become aneurysmal secondary to extensive atherosclerosis, connective tissue disease, aortitis, dissection, or poststenotic changes. Accurate short-axis measurement of the

aortic diameter is determined using multiplanar techniques as diameters determined on axial images may be inaccurate. The presence of aortic atheromata, ulceration, intramural hematoma, and dissection can all be accurately depicted and described using current cross-sectional techniques. Atherosclerosis of the proximal internal carotid artery leads to cerebrovascular ischemia and stroke. Ultrasound, CTA, and contrast-enhanced MRA (CE-MRA) are all highly sensitive for detecting internal carotid artery stenosis. Depiction of a stenosis with a diameter reduction of 70% to 99% is most commonly used for intervention.

iii. Role of phase contrast MRI

1. Visualization of flow reversal, waveforms (tardus-parvus), etc

Most current CT and MR PC imaging can depict a tardus-parvus phenomenon distal to a high-grade stenosis, often adding specificity to other MR angiographic methods.

2. Hemodynamic significant stenosis (eg, renal artery MRA with signal dropout)

The hemodynamic significance of a stenosis can be assessed using a phase contrast MR flow profile, which may depict a delay or loss of the early systolic peak or a signal void. A signal dropout on PC MRA is seen when a stenosis is hemodynamically significant because of the presence of turbulent flow and intravoxel dephasing resulting from a broad spectrum of intravoxel velocities. Cine phase-contrast MRI flow quantification techniques in combination with contrast-enhanced MRA can accurately detect and determine the degree of renal artery stenosis.

Estimation of pressure gradients Embolic disease: CTA and MRA embolus (acute)

iv. Pulmonary embolus (chronic) – see the ACR-NASCI-SPR Practice Parameter for the Performance and Interpretation of Cardiac Magnetic Resonance Imaging (MRI).

d. Vasculitides (infectious and inflammatory): MRA and CTA

MRA and CTA are excellent methods to evaluate the presence, severity, and extent of vasculitides such as, but not limited to:

Takayasu arteritis

Giant cell arteritis

Infectious arteritis

Kawasaki disease

Autoimmune vasculitis (eg, Lupus, Behçet syndrome) Phakomatoses (eg, neurofibromatosis)

MRA and CTA are cross-sectional methods that have the unique advantage of not only evaluating for luminal narrowing but also allowing direct visualization of the vessel wall. In general, direct visualization of vasculitis with CTA and MRA is limited to processes involving large vessels such as the aorta and its branches. Vasculitis of medium and small vessels may be more challenging related to the spatial resolution of these imaging methods, and evaluation of these entities may be indirect, related to tissue damage caused by the vasculitis.

Location, extent, and severity of luminal narrowing and/or aneurysmal dilation

1. grading (stenotic disease)

Luminal narrowing/stenosis is an important sequela of large vessel vasculitis and is responsible for a large percentage of morbidity related to vasculitis. Quantification of stenosis in vasculitis is identical to that performed for atherosclerotic disease, and details are described above. As with all stenotic disease, the location, severity, and length of the stenosis are important to report.

2. Diameter and/or cross-sectional area (aneurysmal disease)

Aneurysmal dilatation is another major complication of vasculitis, leading to potential rupture (eg, luetic vasculitis of the ascending aorta in syphilis) or formation of thrombus with subsequent embolization (eg, Kawasaki disease). Quantitative evaluation of aneurysmal dilatation associated with vasculitis is identical to that for aneurysmal disease, providing a description of the location, length, cross-sectional diameter, or area measured from orthogonal multiplanar reconstruction (MPR). In addition, it may be helpful in some situations to measure the volume of the aneurysm using 3-D segmentation software for longitudinal observation.

3. Wall thickness

In addition to quantifying the luminal dimensions, CTA and MRA are uniquely positioned to visualize the vessel wall and therefore quantify the thickness. An abnormally thickened artery may indicate the presence of vasculitis. In general, the aorta should be no thicker than

approximately 2 mm, although it can vary up to 4 mm. Longitudinal tracking of wall thickening may be a useful marker of disease activity, although the definitions of abnormal wall thickness are not precise. When measuring the wall thickness, it is important to use orthogonal MPR measurements to obtain a slice perpendicular to the vessel wall to ensure accurate measurements by minimizing partial volume effects that may cause wall thickness to be overestimated. Both MRI and CT are excellent methods to visualize vessel walls.

ii. Role of phase contrast MRI for flow reversal (eg, subclavian steal in great vessel disease)

In stenotic disease, particularly Takayasu arteritis and giant cell arteritis, severe narrowing or occlusion of the great vessels produces altered flow patterns that can result in symptomatic conditions such as subclavian steal. Cardiac gated phase contrast MRI performed in the axial plane is a useful means to visualize flow direction and also quantifies flow reversal in the vertebral arteries. In some cases, it may be helpful to perform maneuvers such as arm exercises of the affected side to elicit steal phenomenon.

e. Fibromuscular dysplasia

Fibromuscular dysplasia (FMD) is a relatively common nonatherosclerotic vascular disease that affects the intima or media of large and medium arteries, including, but not limited to:

Renal arteries

Internal carotid arteries Iliac arteries

Vertebral arteries Mesenteric arteries

i. Morphology

The morphology of FMD is highly varied, ranging from focal stenoses to long tubular stenoses to the classic "string of beads" appearance. FMD is associated with the development of aneurysms and dissections of the affected vessels. Quantification of stenosis can be performed just as with other forms of stenotic disease. In addition, the presence of webs, particularly in the string of beads configuration, may make identification and grading of hemodynamically significant stenoses challenging. For these reasons, CTA may be the preferable modality if FMD is suspected, as it has higher spatial resolution than MRA, although both methods provide an excellent noninvasive means for evaluating renal artery stenosis. However, few direct comparisons in the setting of FMD have been made.

Phase contrast for turbulence / hemodynamically significant stenosis

3-D phase contrast (PC) MRA is commonly used to evaluate stenoses for hemodynamic significance. As discussed above, Grist et al demonstrated that signal dropout on PC MRA images at the site of a hemodynamically significant stenosis may be a useful method to distinguish mild to moderate narrowing from more severe disease because of the dephasing of signal within a voxel that occurs in the presence of turbulent flow. Further, Prince et al first demonstrated the ability of 3-D PC MRA to predict functional recovery after revascularization.

ii. Phase contrast for pressure gradients

2-D phase contrast, like ultrasound Doppler, can be used to measure the peak velocity across a focal stenosis. Using the Bernoulli approximation (also known as the modified Bernoulli equation), the pressure gradient across a focal stenosis can be approximated as: ΔP (mmHg) $\approx 4V^2$, where V=maximum velocity (m/s). This approximation is not valid over long segment stenoses.

f. Vascular malformations: MRA and CTA

Vascular malformations are complex entities with a spectrum of abnormalities, including parenchymal arteriovenous malformations (AVMs), venous angiomas, cavernous angiomas, and capillary telangiectasias. In addition to characterizing the qualitative features of vascular malformations (eg, presence of nidus, draining, veins), MRA and CTA can be used for quantitative assessment of these entities.

i. Location, extent, size

The location with respect to adjacent anatomy and the extent and size of a vascular malformation should be reported.

ii. Other quantitative aspects of morphology, size of feeding/draining vessels

In AVMs large draining veins are often identified. Their diameter (measured with MPR) and potential length may be helpful information for the treating physician.

iii. Use of time resolved imaging, bolus passage time

Time resolved contrast enhanced MR imaging methods (eg, TRICKS, TWIST, CENTRA) may offer relative estimates of transit times of small boluses of injected gadolinium based contrast agents (GBCAs) to help characterize vascular malformations. Higher temporal resolution techniques are

under development. The precise utility of transit time is not well defined at this time.

g. Venous disease: MRA and CTA

CTA and MRA in the delayed phase (for contrast enhanced imaging) or non-contrast enhanced MRA using time of flight methods are excellent methods to evaluate for the presence of deep venous thrombosis in the lower extremities and pelvis.

May-Thurner syndrome

May-Thurner syndrome typically occurs in young women presenting with left lower extremity deep vein thrombosis (DVT) and is caused by compression of the left common iliac vein as it passes between the lumbar spine posteriorly and (typically) the right common iliac artery anteriorly.

1. Morphology of venous stenosis

In addition to the presence of clot, patients with left lower extremity DVT should undergo evaluation of the left common iliac vein with high resolution CTA or MRA acquired in the delayed phase. Orthogonal MPRs visualizing the iliac vein at the narrowest point should be performed. The area of narrowing is typically ribbon-like, and measurements of the major and minor axis of the vessel cross-section should be provided. In some cases the vein may be occluded.

2. Time resolved MRA for venous collaterals, flow reversal, etc.

Time resolved contrast enhanced MRA (TRICKS, TWIST, CENTRA) may be helpful for identifying venous collaterals and the presence of flow reversal. The use of phase contrast MRA for quantitative assessment of venous narrowing for measuring pressure gradients in May-Thurner syndrome is not well established, although it holds promise.

h. Acquired cardiac disease: MRI/MRA, CTA

i. Ischemic disease

Function and morphology (primarily LV, but also RV)Regional ventricular dysfunction (thinning of wall, decreased systolic wall thickening, abnormal wall motion, or the presence of LV thrombus) is also a good indicator of acute/chronic ischemia. Based on these data, quantitative measures of ventricular function should be performed by short axes direct planimetry when ECG gating is used for image acquisition. For cardiac CT, imaging is often performed with prospective ECG gating to limit patient radiation exposure. When this acquisition strategy is used, quantitative measures will not be available.

Myocardial perfusion imaging is another important method using myocardial blood flow (MBF) or coronary flow reserve (CFR), detecting multivessel disease that is sometimes not obvious in qualitative imaging. Although quantification has been studied, at present image interpretation is primarily subjective. The main target is LV in most IHD patients, but RV evaluation is also important, especially in inferior wall ischemia/infarction. Later generation multidetector CT scanners with faster scan time and thinner slices are now used for research purposes in this field, with encouraging preliminary data.

1. Presence and extent of scar/infarct, T2 signal in acute MI

Myocardial delayed contrast enhancement (MDE) imaging using either gadolinium (MR) or iodine (CT) indicates irreversible injury. At present, these metrics are used on a quartile basis with specific cutoffs of 50% delayed enhancement. In more extensive myocardial infarctions, microvascular obstruction (a region of "no re-flow") may be seen as a dark subendocardially-based inner core of the myocardial infarction surrounded by hyperenhancement or the larger myocardial infarct territory. Ischemia-associated myocardial edema shows high signal on T2-weighted imaging. The extent of high T2-signal reflects the area of risk that may include regions of reversible injury as well. Myocardium with potentially reversible injury (myocardial salvage area) is represented by the difference between the entire high T2- signal area and the MDE area determined from MR images. This is routinely performed subjectively. T1- and T2-mapping MRI are emerging techniques that are showing promise for further myocardial characterization and may be of particular value for not only myocardial infarction but diffuse myocardial involvement as can be seen in many cardiomyopathies.

Complications, eg, valvular related abnormalities

Several complications are associated with acute myocardial infarction (MI), including papillary muscle injury, ventricular septal defect (VSD), contained rupture, and pericarditis or Dressler's

~~syndrome, which can be detected by CT or MR imaging. Papillary muscle involvement is known to cause mitral valve regurgitation. Quantification of valve regurgitant volume/fraction by MR and evaluation of pericardium are discussed below.~~

~~ii. Coronary artery calcium scoring (CT) for risk assessment Nonischemic cardiomyopathy and infiltrative disease~~

~~1. Function and morphology~~

~~There are several nonischemic cardiomyopathies: hypertrophic cardiomyopathy (HCM), dilated cardiomyopathy (DCM), and restrictive cardiomyopathy. Restrictive cardiomyopathy usually occurs secondary to infiltration of the myocardium, amyloidosis, myocardial fibrosis (after open heart surgery), radiation, sarcoidosis, or endomyocardial eosinophilia. Nonischemic cardiomyopathy usually has an alteration in the ventricular function, leading to heart failure. In addition to EF, the LV myocardial mass (myocardial volume × myocardial density) is a useful parameter to assess nonischemic cardiomyopathy; LV mass and myocardial wall thickening correlate independently with prognosis. Generalized or regional wall motion abnormalities also occur in DCM and HCM. The metrics for function and morphology follow those described in section IV.A. Native T1 mapping and extracellular volume fraction (ECV) mapping using MRI are promising techniques for identification of diffuse myocardial disease that may not be readily apparently on standard perfusion or MDE MR imaging.~~

~~2. Extent of delayed enhancement for staging/prognosis~~

~~Although MDE imaging is used more often in detecting MI, scar quantification on MDE images may also play an important role in determining prognosis and risk assessment for nonischemic cardiomyopathy patients. Hyper-enhancement is often detected in the myocardium of HCM patients in a characteristically patchy midwall distribution in hypertrophied areas, although DCM patients often show linear midwall striae. A higher percentage of MDE on MR in HCM patients is known to be associated with ventricular tachycardia and fatal arrhythmias. Subjective assessment is routine.~~

~~3. Complications (valvular disease, subaortic stenosis)~~

~~HCM is known to cause subaortic stenosis outflow obstruction because of the septum hypertrophy and systolic anterior motion (SAM) of the anterior leaflet of the mitral valve. MR imaging can potentially quantify pressure gradients or valve area using a phase contrast acquisition, which is discussed in the valvular disease section c.~~

~~iii. Valvular disease~~

~~1. Cross sectional area (CT and MRI)~~

~~Valve area measurements in patients with aortic stenosis greatly affect treatment strategies and predict prognosis. On MR images, the valve area is usually calculated indirectly by measuring the time-velocity integrals at the valve and at an adjacent site with an easily measurable diameter (for example, the aortic outflow tract) and then assuming conservation of flow. Several studies have also tested the direct measurement of valve areas by MR cine or phase-contrast sequences through the valve plane. However, when measuring valve planimetry directly, CT with cardiac ECG gating allows excellent visualization of valve structure and thus is frequently used in clinical settings. When using either MR or CT for measuring valve planimetry, at least 30 cardiac phases should be imaged or reconstructed in order to most accurately identify end systole, or the time at which the aortic valve orifice is most open.~~

~~2. Detection of insufficiency and stenosis~~

~~MR enables quantitative analysis of valvular disease, consisting of calculation of regurgitant volume and fraction in patients with regurgitant valves and measurement of peak or time average velocities and pressure gradients in patients with stenotic valves. CT usually detects valve stenosis itself or poststenotic dilatation with direct planimetry but does not greatly contribute to the diagnosis of valve insufficiency.~~

~~3. Phase-contrast MR: pressure gradients, regurgitant fractions~~

~~4. Effect on heart (chamber enlargement) or great vessels (poststenotic dilatation)~~

~~The pathophysiology of aortic stenosis involves obstruction of LV outflow, which leads to elevated LV pressures and LV hypertrophy. Arterial stenosis also causes poststenotic dilatation, a dilation of the vessel 1 to 3 cm distal to the area of stenosis. In contrast, aortic insufficiency~~

~~involves volume overload of the left ventricle, resulting in LV dilatation. CT or MR imaging can directly demonstrate and measure LV hypertrophy, LV dilatation, and poststenotic dilatation of the ascending aorta.~~

~~5. Presurgical Planning~~

~~In high surgical risk patients with severe aortic stenosis (AS), transcatheter aortic valve replacement (TAVR) has demonstrated long-term results comparable to open surgical repair. In a meta-analysis of 344 studies and 872 participants who had undergone previous CABG, TAVR patients had shorter hospital stays and performed similarly to surgical valve replacement patients in mid-term all-cause cardiovascular mortality. Pre-procedural imaging evaluation should include cardiac-gated evaluation and measurement of the following intracardiac and aortic structures: LV cavity for thrombus, alignment of the LVOT, dimensions of the aortic valve annulus, distance of the coronary ostia to the aortic valve plane, length of the aortic cusp, width of the aortic sinus, sinotubular junction and ascending aorta. Additionally, the width of the descending thoracic aorta, abdominal aorta, and iliofemoral arteries should be measured and evaluated for extensive atherosclerotic disease or tortuosity. Most studies have utilized contrast-enhanced cardiac CT, although CMR may have a role, given the high prevalence of renal dysfunction in TAVR patients.~~

~~iv. Diastolic dysfunction/heart failure~~

~~1. Function/morphology~~

~~Heart failure is characterized by any structural or functional cardiac disorder that impairs the ability of ventricles to fill with or eject blood. Therefore, for a final diagnosis of heart failure, the evaluation of systolic and/or diastolic dysfunction is required. As described above, MR imaging can quantify LV volume and ejection fraction (EF), or assess wall motion and be used for both diagnosis and monitoring. Myocardial perfusion imaging determines whether coronary artery disease contributes to the development of heart failure. Delayed enhancement (DE) imaging can also be used for heart failure assessment; the extent of DE predicts the response to beta-blocker therapy.~~

~~2. Role of phase contrast (E/A reversal)~~

~~The E/A ratio is the ratio of early to late ("atrial") diastolic filling velocity of the ventricle and can rapidly detect abnormal diastolic function. Although the normal E/A ratio is greater than 1, impaired relaxation of the ventricle decreases early diastolic filling and results in a reduced or reversed E/A ratio, eg, E/A ratio less than 1. E/A ratio is usually measured by echocardiography but can also be acquired with phase-contrast MRI by calculating transmitral (or transtricuspid) velocity.~~

j. Pericardial disease**:**

~~Morphology and function~~

Many disease processes can affect the pericardium, including inflammation, infection, neoplasm, trauma, primary myocardial disease, and congenital disease. Imaging can provide morphologic evaluation of the pericardium, such as thickened, enhanced, **or calcified** pericardium, presence of pericardial fluid, and chamber sizes (eg, atrial and ventricular size). Imaging usually targets the direct visualization of thickened/enhanced pericardium or the analysis of ventricular function.

~~For example, in patients with constrictive pericarditis, a leftward bounce (or flattening) of the interventricular septum can often be identified on early-diastolic images, best noted on short-axis cine views. This occurs secondary to pericardial constriction of diastolic ventricular filling and an increase in ventricular pressure. In constrictive pericarditis, the elevation in right ventricular pressure results in the paradoxical leftward motion (ie, bounce) of the interventricular septum during early diastole. On occasion, the septal bounce can also be seen during inspiratory phases of a free breathing cine acquisition secondary to the augmentation of systemic venous return that occurs during inspiration.~~

~~Pericardial thickness and enhancement~~

~~CT and MRI provide excellent visualization of the pericardium and can lend support to the diagnosis of~~

~~pericardial disease. Regarding constrictive pericarditis, the~~

CT and MR images can be used to ~~directly~~ measure **the** pericardial **thickness in which normal is 1.2** mm **± 0.5 mm, and abnormal thickness is defined as a thickness ≥3 mm** ~~thickening greater than 4~~ **[94-97]**. This metric can be used with a subjective assessment of narrow, tubular deformation of the ventricles with a straightened or sigmoid-shaped interventricular septum to support the diagnosis **of pericardial constriction**. Contrast enhancement is an additional qualitative finding associated with abnormal pericardium.

~~ROI analysis for hemopericardium, calcium (CT)~~
~~ROI CT attenuation measurements characterize pericardial fluid about 40 to 60 HU.~~

A fluid collection with attenuation close to that of water **(approximately 20 HU)** is likely to be a simple effusion, but attenuation **measurements** greater than that **may** ~~of water~~ suggest~~s~~ malignancy, hemopericardium **(HU ≥35),** purulent exudate, or effusion associated with hypothyroidism [98]. MR can also characterize pericardial fluid, although qualitatively, with the use of multiple pulse sequences; hemorrhagic effusion is characterized by high signal on **intrinsic** T1-weighted SE images and low intensity on gradient echo (GRE) cine images. Another important feature of CT is its ability to detect pericardial calcifications, a finding **that may be** indicative of constrictive pericarditis. ~~Assessment of constrictive physiology with MRI or CT requires ECG gating.~~ **MRI is also helpful for the evaluation of pericardial adhesion and constriction with tagging sequence and cine techniques to detect ventricular coupling.**

~~Pulmonary veins preablation, postablation~~

k. Transcatheter Aortic Valve Replacement (TAVR):

In high surgical risk patients with severe aortic stenosis, TAVR has demonstrated long-term results comparable to open surgical repair [99,100]**. Preprocedural imaging evaluation should include noncontrast and contrast cardiac-gated evaluation and measurement of the following intracardiac and aortic structures [101].**

- **Aortic valve calcium score**
- **Presence and severity of calcifications in the annulus and sub-annular region**
- **Left cardiac chambers and left atrial appendage (LAA) for thrombus**
- **Alignment of the LV outlet tract (LVOT)**
- **Dimensions (perimeter, maximum and minimum diameters, and area) of the aortic annulus at the maximum aortic valve opening, typically during systole.**
- **Width of the aortic sinus (cusp to commissure distance), number of cusps (tricuspid or bicuspid)**
- **Coronary ostia height from the annulus**
- **Width and height of sinotubular junction**
- **Width and tortuosity of ascending and descending thoracic aorta, and abdominal aorta**
- **Vascular access (subclavian arteries, common and external iliac arteries, and common femoral arteries): minimal luminal diameter, tortuosity, and extend and distribution of atherosclerotic disease**
- **Incidental noncardiovascular findings**

l. Transmitral Valve Replacement (TMVR):

Preprocedural evaluation of the left ventricular outflow track for TMVR is increasingly used for predicting post procedural neo-LVOT stenosis with balloon expandable valves. Postprocessing allows simulation of the percutaneous valve in position using CAD. When the predicted neo-LVOT surface area is ≤1.9 cm^2, the result is 100% sensitivity and 96.8% specificity for predicting TMVR-induced LVOT obstruction of >10 mm Hg [102].

m. Pre- and postimplantation LAA closure device imaging:

LAA occlusion is a reasonable alternative to long-term anticoagulation therapy for patients with AF ~~and pulmonary vein stenosis~~ **to prevent stroke [103,104].**

Preprocedure imaging is performed to assess LAA measurements (length, width, and orifice size/area) for size optimization of the closure device; LAA shape, size, and relationship with adjacent structures; presence of LAA thrombus, which is a contraindication for device occlusion; LA volume; and interatrial septal abnormalities (patent foramen ovale and septal defects [105], lipomatous hypertrophy, and aneurysm). When there is an LAA filling defect in the arterial phase, it is important to differentiate between slow flow (or mixed contrast-blood flow) and thrombus. The thrombus tends to be well defined and hypodense (<100 HU) and persistent in the delayed phase (acquired 60 sec after the arterial phase); on the contrary, slow flow is more ill-defined with heterogeneous attenuation and disappears in the delayed phase. Postprocedure imaging is performed for device surveillance to assess atrial-side device thrombus, residual leak, device embolization and position, and pericardial effusion [106,107].

~~3. Preprocedure measurements (cross sectional diameters, length, number of veins, anatomy [especially variants])~~

~~4. In atrial fibrillation (AF) patients, atrial myocardium tissue is more often present in the pulmonary veins (PVs) and the atrial myocardium in the PVs has more severe discontinuity, hypertrophy, and fibrosis [142]. Catheter ablation has been widely used to treat AF and usually ablates the atrial myocardium inside the PVs to disconnect an abnormal interaction with left atrium. Postprocedure stenoses. A well-known complication of catheter ablation is PV stenosis. CT has been the most commonly used modality to detect post-procedure stenoses, but MRI can be used as well. Because the PV size varies throughout the cardiac cycle and the difference between maximum and minimum diameter is 15% ± 8%, ECG-gated CTA acquisitions are preferred.~~

~~v. Pulmonary arterial hypertension~~

~~1. Primary or secondary~~

~~Pulmonary arterial hypertension (PAH) is a condition characterized by increased pulmonary arterial pressure. In the conventional classification, it is divided into 2 main categories: 1) primary PAH (not caused by any other disease or condition); and 2) secondary PAH (caused by another underlying condition), including lung diseases (eg, COPD, interstitial lung diseases), heart diseases (eg, congestive heart failure, congenital heart disease, mitral stenosis), chronic thromboembolic diseases (eg, pulmonary embolism), HIV infection, or medications. Secondary PAH is much more common than primary PAH.~~

~~Right ventricle function. In case of acute pulmonary embolism (PE), the chest CT measures the RV/LV diameter ratio and uses greater than 0.9 to predict 30-day mortality and major complications. A ratio of main pulmonary artery diameter to the ascending aorta diameter of greater than 1 can be reliably used to detect pulmonary hypertension in adult patients with cardiopulmonary diseases if the ascending aorta is of normal size. In pediatric patients, a ratio of the main pulmonary artery diameter to the ascending aorta diameter of greater than 1.3 may suggest pulmonary hypertension. In addition to morphological assessment, MR imaging can easily measure EF of both ventricles and LV end- diastolic volume, which are significantly decreased in patients with PAH.~~

~~Pulmonary artery morphology (diameters, cross sectional areas)~~

~~However, several studies failed to demonstrate that main PA diameter predicts increased mortality or indicates severity of acute PE.~~

~~2. Assessment of clot burden with chronic thromboembolic disease~~

~~The presence, location, and degree of obstruction of arterial clots can be scored according to several different scoring systems. Qanadli and Mastora use CT pulmonary angiography to quantify acute PE severity. However, PA clot load scores usually do not take into account clots located in small peripheral PAs and the current literature shows some discrepancies regarding the association between the clot burden and immediate outcome. For example, although reports~~

~~of the score proposed by Qanadli suggest that it is a significant predictor of death, others reported the clot scores to be a poor predictor of mortality. In general, clot burden in CTPA is not reported.~~

~~3. Assessment of valve function in PAH (morphology, flow, pressure gradients)~~

~~Mitral valve stenosis can cause PAH. On the other hand, PAH can cause dilatation of the pulmonic valve ring and then results in pulmonic valve regurgitation. Assessment of mitral valve stenosis or pulmonic valve regurgitation can be performed on phase-contrast sequences for quantitative velocity and flow measurement using the methods previously described.~~

~~i. Congenital cardiac disease (vascular and cardiac): MRI, CT~~

~~i. Cardiac function~~

~~Cardiac-gated CT and MRI are useful for the evaluation of patients with suspected or known congenital heart disease (CHD). As with other conditions, both cardiac-gated CT and MRI can provide quantitative measurements of the various chamber sizes and function, notably chamber volumes, myocardial mass, and ejection fractions for the left and right ventricles using standard quantitative tools outlined previously in section IV.A.4. Valvular function can also be assessed as detailed previously in section IV.B.9.c. For example, CT and MRI are useful for the postoperative assessment of repaired tetralogy of Fallot, although MRI is the preferred modality unless there is a contraindication to MRI . In this case, CT and MRI can provide functional assessment of ventricular volumes and ejection fractions. Pulmonic insufficiency and pulmonic stenosis can also be assessed using cine phase contrast MRI performed perpendicular to the main pulmonary artery. These data provide essential functional information, especially of the RV, for determining proper timing for pulmonic valve replacement in patients with corrected or uncorrected tetralogy of Fallot.~~

~~ii. Vessel assessment~~

~~Arterial (eg, thoracic aorta) and venous structures (eg, pulmonary veins) are also well evaluated using CT angiography or MR angiography. For example, both CT and MRI have been shown to provide comparable diagnostic evaluation of aortic narrowing in children with coarctation of the aorta. MRI has the added benefit of allowing blood flow analysis using velocity-encoded cine phase contrast MRI that can measure peak velocity across a juxtaductal aortic narrowing to estimate the pressure gradient across the aortic coarctation using the modified Bernoulli equation. Time-resolved MR angiography can be particularly helpful when evaluating the presence of anomalous and/or postsurgical vascular connections in patients with CHD.~~

~~CT angiography of the cardiopulmonary structures is often a very informative method of examination. Elimination of retrospective ECG-gating allows one to decrease the radiation dose to the patient. Prospective ECG triggered studies can allow for anatomic imaging with reduced cardiac motion artifacts and with radiation dose equivalent to non-gated studies. Pulmonary-to-systemic shunt (Qp/Qs ratio).~~

~~A unique evaluation in patients with suspected or known CHD is the assessment for a left-to-right shunt using the pulmonary (Qp) to systemic (Qs) blood flow ratio (Qp/Qs ratio). This measures the volume of blood flow between the pulmonary (ie, right heart) and systemic (ie, In patients with an underlying left-to-right shunt lesion (eg, ie, Qp/Qs>1.5) or large (eg, Qp/Qs >2.2).~~

~~In younger patients, MRI may be the preferred modality, particularly when functional assessment with CT would require retrospective ECG gating and relatively high radiation doses. Further, the use of time-resolved MRA and phase contrast MRI methods offer significant advantages whose relative importance will depend on the specific application.~~

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings **[108].**

VI. EQUIPMENT SPECIFICATIONS

The MRI equipment specifications and performance must meet all state and federal requirements. The requirements

include, but are not limited to, specifications of maximum static magnetic strength, maximum rate of change of the magnetic field strength (dB/dt), maximum radiofrequency power deposition (specific absorption rate), and maximum acoustic noise levels.

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Computed Tomography (CT) Equipment [109] or ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging (MRI) Equipment [110], as appropriate.

VII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on Quality Control & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

Development Chronology for this Practice Parameter
2012 (Resolution 14)
Amended 2014 (Resolution 39)
Revised 2017 (Resolution 21)

REFERENCE COMMITTEE IV

Amanda J. Ferrell, MD, FACR, *Chair*
Haley Letter, MD
Join Y. Luh, MD, FACR
Loralie Dawn Ma, MD, PhD, FACR
Tariq A. Mian, PhD, FACR
Faezeh Sodagari, MD

COMMISSIONS, COMMITTEES & TASK FORCES:

Commission on Breast Imaging
Commission on Leadership & Practice Development; RLI
Commission on Membership and Communications
Commission on Medical Physics
Commission on Nuclear Medicine & Molecular Imaging
Awards and Honors Committee
Board Self-Evaluation Committee
Intersociety Committee
American Roentgen Ray Society

No.	RESOLUTION	TYPE	REFERENCE COMMITTEE RECOMMENDATIONS
38.	Bylaws Amendment – Article X Rules of Order	BYLAWS	RECOMMEND ADOPTION
39.	Bylaws Amendment – Article II, Section I Membership	BYLAWS	RECOMMEND ADOPTION
40.	Neiman Health Policy Institute Named Fellowship	NEW POLICY	RECOMMEND ADOPTION AS AMENDED
41.	Ten Year Extension of Policies:	POLICY	
	(a) Radiological Practice and Ethics 3. Position Statements a. Benefits and Limitations of Mammography	RENEWALS	RECOMMEND ADOPTION
	(b) Radiological Practice and Ethics 3. Position Statements c. Colorectal Cancer Screening		RECOMMEND ADOPTION
	(c) Radiological Practice and Ethics 3. Position Statements f. Mammography: Diagnostic Mammography Arising from Screening Mammography		RECOMMEND ADOPTION
	(d) Radiological Practice and Ethics 3. Position Statements h. Multidisciplinary Management of Early-Stage Breast Cancer		RECOMMEND ADOPTION
	(e) Radiological Practice and Ethics 3. Position Statements m. Sonographic Evaluations		RECOMMEND ADOPTION
	(f) Radiological Practice and Ethics 5. Miscellaneous Radiological Practice and Ethics Policies z. Physics		RECOMMEND ADOPTION
	(g) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies j. Proprietary Clinical Pathways Policy		RECOMMEND ADOPTION
	(h) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies k. Radiologist Admitting Privileges		RECOMMEND ADOPTION
42.	ACR Practice Parameter for the Performance of Molecular Breast Imaging (MBI) Using a Dedicated Gamma Camera	REVISED PP	RECOMMEND ADOPTION

REFERENCE COMMITTEE IV

43.	ACR–ACNM–SNMMI Practice Parameter for the Performance of Dopamine Transporter (DaT) Single Photon Emission Computed Tomography (SPECT) Imaging for Movement Disorders	REVISED PP	RECOMMEND ADOPTION
44.	ACR–ACNM–SPR Practice Parameter for the Performance of Renal Scintigraphy	REVISED PP	RECOMMEND ADOPTION
45.	ACR–AAPM–ACNM–SNMMI–SPR Technical Standard for Therapeutic Procedures Using Radiopharmaceuticals	REVISED PP	RECOMMEND ADOPTION AS AMENDED
46.	ACR–AAPM–SIIM Practice Parameter for Determinants of Image Quality in ~~Digital~~ Mammography	REVISED PP	RECOMMEND ADOPTION AS AMENDED
47.	ACR–AAPM–SIIM–SPR Practice Parameter for Digital Radiography	REVISED PP	RECOMMEND ADOPTION
48.	ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging	REVISED PP	RECOMMEND ADOPTION
49	Sunset the ACR–SPR Practice Parameter for General Radiography	SUNSET PP	RECOMMEND ADOPTION
50.	Extension of Review Cycle for Two Practice Parameters	EXTEND PP	RECOMMEND ADOPTION
51.	Extension of Review Cycle for One Practice Parameters	EXTEND PP	RECOMMEND ADOPTION

ACR STAFF:

Director *Jan Cox*
Assistant *Manjusha Pandit*
Moderator *Jennifer Walter*
Attorney *Tom Hoffman*
Recorder *Dee Salem*
Coordinator: Troy Williams

REFERENCE COMMITTEE IV

Reference Committee IV met on Monday, April 25, 2022. The members of this committee were Amanda J. Ferrell, MD, FACR, *Chair*, Haley Letter, MD, Join Y. Luh, MD, FACR, Loralie Dawn Ma, MD, PhD, FACR, Tariq A. Mian, PhD, FACR, and Faezeh Sodagari, MD.

The session was attended by approximately 800 members, guests, and staff in person and virtual.

The Reference Committee recognizes the following reports as informational and I recommend that they be filed.

COMMISSIONS, COMMITTEES & TASK FORCES:

Commission on Breast Imaging
Commission on Leadership & Practice Development; DLI
Commission Membership and Communications
Commission on Medical Physics
Commission on Nuclear Medicine & Molecular Imaging
Awards and Honors Committee
Board Self-Evaluation Committee
Intersociety Committee
American Roentgen Ray Society

The Committee was assigned the following resolutions for consideration:

	Resolution	**Sponsor**
38.	Bylaws Amendment – Article X Rules of Order	BOC CSC
39.	Bylaws Amendment – Article II, Section I Membership	BOC CSC
40.	Neiman Health Policy Institute Named Fellowship	Tennessee Radiological Society Pennsylvania Radiological Society Wisconsin Radiological Society
41.	Ten Year Extension of Policies: (a) Radiological Practice and Ethics 3. Position Statements a. Benefits and Limitations of Mammography (b) Radiological Practice and Ethics 3. Position Statements c. Colorectal Cancer Screening (c) Radiological Practice and Ethics 3. Position Statements f. Mammography: Diagnostic Mammography Arising from Screening Mammography (d) Radiological Practice and Ethics 3. Position Statements h. Multidisciplinary Management of Early-Stage Breast Cancer (e) Radiological Practice and Ethics 3. Position Statements m. Sonographic Evaluations (f) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies	CSC

z. Physics
(g) Radiological Practice and Ethics
5. Miscellaneous Radiologic Practice and Ethics Policies
j. Proprietary Clinical Pathways Policy
(h) Radiological Practice and Ethics
5. Miscellaneous Radiologic Practice and Ethics Policies
k. Radiologist Admitting Privileges

42.	ACR Practice Parameter for the Performance of Molecular Breast Imaging (MBI) Using a Dedicated Gamma Camera	CSC
43.	ACR–ACNM–SNMMI Practice Parameter for the Performance of Dopamine Transporter (DaT) Single Photon Emission Computed Tomography (SPECT) Imaging for Movement Disorders	CSC
44.	ACR–ACNM–SPR Practice Parameter for the Performance of Renal Scintigraphy	CSC
45.	ACR–AAPM–ACNM–SNMMI–SPR Technical Standard for Therapeutic Procedures Using Radiopharmaceuticals	CSC
46.	ACR–AAPM–SIIM Practice Parameter for Determinants of Image Quality in ~~Digital~~ Mammography	CSC
47.	ACR–AAPM–SIIM–SPR Practice Parameter for Digital Radiography	CSC
48.	ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging	CSC
49.	Sunset the ACR–SPR Practice Parameter for General Radiography	CSC
50.	Extension of Review Cycle for Two Practice Parameters	CSC
51.	Extension of Review Cycle for One Practice Parameter	CSC

THE REFERENCE COMMITTEE RECOMMENDS THE FOLLOWING CONSENT CALENDAR FOR ACCEPTANCE:

RECOMMENDED FOR ADOPTION:

Resolution No. 38 **Article X – Rules of Order**

~~**In the absence of any provision in these bylaws**~~, all meetings of the College shall be governed by the parliamentary rules and usages contained in the **most** current edition of ~~**Sturgis'**~~ **the American Institute of Parliamentarians** "*Standard Code of Parliamentary Procedure*."

Resolution No. 39 **Article II, Section I - Membership**

Section 1
Classes of Membership

3. Fellows - *A member in good standing of the College who has evidenced significant*

accomplishments in service, research, or teaching may be elected a fellow by the BOC.

Recipients of the award must attend the convocation at the annual meeting of the ACR following notice of the honor. Individuals who are unable to attend the first convocation following approval for the award remain eligible by attendance at ~~a convocation at~~ an ACR ~~annual~~ meeting in either of the two succeeding years.

The College recognizes that a serious health condition or similar extraordinary life event may prevent an otherwise qualified member from meeting a requirement for fellowship. Therefore, the Committee on Fellowship Credentials may recommend a waiver of one or more of the requirements for fellowship based on the member's serious health condition or other extraordinary circumstances, and ~~**the BOC may grant fellowship based on such recommendation**~~ **refer to the Executive Committee for approval**. **In such circumstances, fellowship may be bestowed on an individual outside of a convocation, including posthumously for members who are recommended by the Committee and approved by the BOC.**

Resolution No. 41 **Ten Year Extension of Policy**

BE IT RESOLVED,

that the following policies of the American College of Radiology be extended for an additional ten year period:

(a) **A. RADIOLOGICAL PRACTICE AND ETHICS**

3. POSITION STATEMENTS

a. Benefits and Limitations of Mammography

The American College of Radiology reaffirms its position, consistent with its current ACR Practice Guideline for the Performance of Screening and Diagnostic Mammography, that all women 40 years of age or older should have an annual screening mammogram. The American College of Radiology will continue its educational programs with the ACR membership and the American public that discuss and review the indications, efficacy, benefits, and limitations of mammography; 2002, amended 2012 (Res. 23-c).

(b) **B. RADIOLOGICAL PRACTICE AND ETHICS**

3. POSITION STATEMENTS

c. Colorectal Cancer Screening

The American College of Radiology supports the practice of screening for colorectal cancer (CRC) as outlined in the article**s: Lin JS, Perdue LA, Henrikson NB, Bean SI, Blasi PR. Screening for colorectal cancer: updated evidence report and systematic review for the US Preventive Services Task Force. (JAMA 2021; JAMA. 2021;325(19):1978-1998); Knudsen AB, Rutter CM, Peterse EFP, et al. Colorectal cancer screening: a collaborative modeling study for the US Preventive Services Task Force. (JAMA 2021;325(19):1965-1977);** Levin B, Lieberman DA, McFarland B, et.al. Screening and Surveillance for the Early Detection of Colorectal Cancer and

Adenomatous Polyp 2008: A joint guideline from the American Cancer Society, the U.S. Multi-Society Task Force on Colorectal Cancer, and the American College of Radiology (CA Cancer J Clin 2008; 58:130-160); 1992, 2002, amended 2012 (Res. 23-f).

(c) I. RADIOLOGICAL PRACTICE AND ETHICS

3. POSITION STATEMENTS

f. Mammography: Diagnostic Mammography Arising from Screening Mammography

The American College of Radiology will continue to work diligently with CMS, the Congress, and other payers to modify their policies so that screening and diagnostic mammography can be provided in a way that permits appropriate and efficient medical care without jeopardizing quality patient care; adopted 1992, amended 2002, 2012 (Res. 23-d).

(d) I. RADIOLOGICAL PRACTICE AND ETHICS

3. POSITION STATEMENTS

h. Multidisciplinary Management of Early-Stage Breast Cancer

If a diagnosis of breast cancer is made women should be offered a multidisciplinary consultation regarding treatment options. This should include referral to a radiation oncologist to discuss the role of radiation as an option in conservative breast management; adopted 2002, 2012 (Res. 33-c).

(e) I. RADIOLOGICAL PRACTICE AND ETHICS

3. POSITION STATEMENTS

m. Sonographic Evaluations

The American College of Radiology supports the following:

• that ultrasound studies shall be supervised and sonographic interpretations must be rendered by a physician with appropriate training and experience in the specific area of sonography, and

• that registered sonographers are trained to assist and obtain information for supervising physicians, and

• that the rendering of a diagnosis from ultrasound studies represents the practice of medicine and is outside the responsibility of sonographers, and

• that the interpretations of the supervising physician must be recorded and results communicated in a timely manner to the referring physician; 1992, amended 2002, 2012 (Res. 23-e).

(f) I. RADIOLOGICAL PRACTICE AND ETHICS

5. MISCELLANEOUS RADIOLOGIC PRACTICE AND ETHICS POLICIES

z. Physics

Definition of a Qualified Medical Physicist (QMP)
The American College of Radiology adopts the following Definition of a Qualified Medical Physicist as revised:

A Qualified Medical Physicist is an individual who is competent to practice independently in one or more of the subfields in medical physics. The American College of Radiology considers certification, continuing education and experience in the appropriate subfield(s) to demonstrate that an individual is competent to practice one or more of the subfields in medical physics, and to be a Qualified Medical Physicist. The ACR strongly recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR), the Canadian College of Physics in Medicine, **the American Board of Science in Nuclear Medicine (ABSNM),** or the American Board of Medical Physics (ABMP).

A qualified medical physicist should meet the ACR Practice Guideline for Continuing Medical Education (CME).

The subfields of medical physics are:

- Therapeutic Medical Physics

This pertains to (1) the therapeutic applications of x-rays, of gamma rays, of electrons and charged particle beams, of neutrons, of radiations from sealed and unsealed radionuclide sources, (2) the equipment associated with their production, use, measurement and evaluation, (3) the quality of information and images resulting from their production and use, and (4) associated patient and personnel radiation safety issues.

- Diagnostic Medical Physics

This pertains to (1) the diagnostic applications of x-rays, or gamma rays from sealed and unsealed sources, of ultrasound, of radiofrequency radiation, of magnetic fields, (2) the equipment associated with their production, use, measurement and evaluation, (3) the quality of information and images resulting from their production and use, and (4) associated patient and personnel radiation safety issues.

- Nuclear Medical Physics

This pertains to (1) the therapeutic and diagnostic applications of radionuclides (except those used in sealed sources for therapeutic purposes), (2) the equipment associated with their production, use, measurement and evaluation, (3) the quality of information and images resulting from their production and use, and (4) associated patient and personnel radiation safety issues.

The ACR shall review all appropriate guidelines and technical standards to ensure that each contain this definition of Qualified Medical Physicists where indicated; 1996, 2006, 2008, amended 2012 (Res. 42).

Previous medical physics certification categories including radiological physics, therapeutic radiological physics, medical nuclear physics, diagnostic radiological physics and diagnostic imaging physics are also acceptable.

(g) I. RADIOLOGICAL PRACTICE AND ETHICS

5. MISCELLANEOUS RADIOLOGIC PRACTICE AND ETHICS POLICIES

j. Proprietary Clinical Pathways Policy

The ACR recognizes that properly constructed clinical pathways are educational and research tools that may assist physicians in clinical decision-making. However, the ACR opposes proprietary clinical pathways, or any utilization 'product,' that has not been the subject of independent external review by relevant physician organizations and by actively practicing physicians with specialty expertise relevant to the product and that may be used by third party payers to recommend, suggest or compel, directly, indirectly or implied, the use of such pathways. Use of clinical pathways in the hospital setting should be in compliance with policies and procedures set by the organized medical staff. ~~To the extent allowed by law, the ACR will actively assist state and local societies in opposing clinical pathways that are in conflict with current ACR Practice Parameters and Technical Standards, policies, and ACR Appropriateness Criteria~~; 2002, amended 2012 (Res. 12-f).

(h) I. RADIOLOGICAL PRACTICE AND ETHICS

5. MISCELLANEOUS RADIOLOGIC PRACTICE AND ETHICS POLICIES

k. Radiologist Admitting Privileges

Radiologists should have access to admitting privileges in hospitals where they practice; adopted 2002, 2012 (Res.1-f).

Resolution No. 42 **ACR Practice Parameter for the Performance of Molecular Breast Imaging (MBI) Using a Dedicated Gamma Camera**

Resolution No. 43 **ACR–ACNM–<u>SNMMI</u> Practice Parameter for the Performance of Dopamine Transporter (DaT) Single Photon Emission Computed Tomography (SPECT) Imaging for Movement Disorders**

Resolution No. 44 **ACR–<u>ACNM</u>–SPR Practice Parameter for the Performance of Renal Scintigraphy**

Resolution No. 47 **ACR–AAPM–SIIM–SPR Practice Parameter for Digital Radiography**

Resolution No. 48 **ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging**

Resolution No. 49 **Sunset the ACR–SPR Practice Parameter for General Radiography**

BE IT RESOLVED,

that the ACR–SPR Practice Parameter for General Radiography is to be sunset.

BE IT FURTHER RESOLVED,

that in the event that the ACR–AAPM–SIIM–SPR Practice Parameter for Digital Radiography is not adopted or referred at the 2022 ACR Annual Meeting, ACR–SPR Practice Parameter for General Radiography will be extended for one year.

Resolution No. 50 **Extension of Review Cycle for Two Practice Parameters**

BE IT RESOLVED,

that the review cycle for the practice parameters listed below is hereby extended by one additional year and that these practice parameters are to be presented for consideration at the 2024 ACR Annual Meeting:

(a) ACR–ACNM Practice Parameter for the Performance of Fluorine-18 Fluciclovine-PET/CT for Recurrent Prostate Cancer
(b) ACR–SPR–SSR Practice Parameter for the Performance of Dual-Energy X-Ray Absorptiometry (DXA)

Resolution No. 51 **Extension of Review Cycle for One Practice Parameter**

BE IT RESOLVED,

that the 5-year review cycle for the ACR–ACNM–SNMMI–SPR–STR Practice Parameter for the Performance of Cardiac Positron Emission Tomography Computed Tomography (PET/CT) Imaging is extended for one additional year and that this practice parameter will be scheduled for consideration at the 2023 ACR Annual Meeting.

RECOMMENDED FOR ADOPTION AS AMENDED:

Resolution No. 40 **Neiman Health Policy Institute Named Fellowship**

BE IT RESOLVED,

that on the ten-year anniversary of the founding of the Neiman Health Policy Institute, the ACR membership acknowledges and states its appreciation for the NHPI's founding CEO, Richard Duszak Jr, MD, and his outstanding accomplishments and benefits provided to ACR members during the NHPI's first decade; and

BE IT FURTHER RESOLVED,

~~that the Neiman Institute Fellowship in Clinical Effectiveness and Health Policy Research be designated as the "Richard Duszak Jr., MD Fellowship in Health Policy Research.~~ that the ACR seek to establish a Neiman Health Policy fellowship named in honor of Richard Duszak Jr., MD.

Resolution No. 45 **ACR–AAPM–ACNM–SNMMI–SPR Technical Standard for Therapeutic Procedures Using Radiopharmaceuticals *(Lines 115-118)***

AAPM, ACNM, SNMMI and SPR representatives affirm that in their best judgement the proposed changes would be acceptable to AAPM, ACNM, SNMMI and SPR; subject to ratification by AAPM, ACNM, SNMMI and SPR.

Resolution No. 46 **AAPM–SIIM Practice Parameter for Determinants of Image Quality in Digital Mammography** ***(Lines 89-96)***

AAPM and SIIM representatives affirm that in their best judgement the proposed changes would be acceptable to AAPM and SIIM; subject to ratification by AAPM and SIIM.

Reference Committee IV wishes to thank the Councilors and visitors for their valuable input in these deliberations.

Respectfully Submitted:

_____

Amanda J. Ferrell, MD, FACR, *Chair*
Haley Letter, MD
Join Y. Luh, MD, FACR
Loralie Dawn Ma, MD, PhD, FACR
Tariq A. Mian, PhD, FACR
Faezeh Sodagari, MD

NOT FOR PUBLICATION, QUOTATION, OR CITATION

RESOLUTION NO. 45

BE IT RESOLVED,

that the American College of Radiology adopt the ACR–AAPM–ACNM–SNMMI–SPR Technical Standard for Therapeutic Procedures Using Radiopharmaceuticals

Sponsored By: **ACR Council Steering Committee**

Adopted 2017 (Resolution 39)*

ACR–AAPM–ACNM–SNMMI–SPR TECHNICAL STANDARD FOR THERAPEUTIC PROCEDURES USING RADIOPHARMACEUTICALS

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1] For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

I. INTRODUCTION

This technical standard has been developed collaboratively by the American College of Radiology (ACR), the American Association of Physicists in Medicine (AAPM), **the American College of Nuclear Medicine (ACNM), the Society of Nuclear Medicine and Molecular Imaging (SNMMI),** and the Society for Pediatric Radiology (SPR).

The goal of therapy with ~~unsealed radiopharmaceutical sources~~ **radiopharmaceuticals and other radionuclide sources** is to provide ~~either~~ cure or ~~effective~~ palliation of disease while minimizing ~~untoward~~ side effects and complications. This technical standard was developed to cover key aspects pertinent to the performance of therapeutic procedures using radiopharmaceuticals.

This technical standard is intended to set practice parameters and technical standards covering the use of radiopharmaceuticals for therapy.

Radiopharmaceuticals are ~~drugs~~ **agents** that are intended for use in the diagnosis, therapy, or monitoring of a disease or a manifestation of a disease in humans and that exhibit spontaneous disintegration of unstable nuclei with the emission of nuclear particles or photons. ~~or~~ **Radiopharmaceuticals also include** any nonradioactive reagent kit or radionuclide generator that is intended to be used in the preparation of such **agents** ~~articles~~ (see FDA definition of radiopharmaceutical: 21CFR315.2, 1997 FDAMA section 122[b].) [1].

Facility management and their responsible staff using radioactive materials should consult with their Radiation Safety Officer to ensure that there are policies and procedures specific to unsealed diagnostic and therapeutic radiopharmaceuticals that address all duties and equipment from ordering, receipt, use, administration, storage, and disposal in compliance with all applicable laws and regulations ACR–AAPM Radiation Safety Officer Resources [2].

The term "dosage" is used by the Nuclear Regulatory Commission (NRC) and Agreement States in their regulatory language for what is the administered activity. Both terms are used in this document.

~~Facilities and their responsible staff should consult with their radiation safety officer to ensure that there are policies and procedures specific to each unsealed radiopharmaceutical source that address 1) required instrumentation, calibration, and calibration frequency and 2) ordering and receiving, recordkeeping, safe use, and waste disposal of therapeutic radiopharmaceuticals in compliance with the applicable laws and regulations as described in ACR–AAPM Radiation Safety Officer Resources [1].~~
~~This technical standard is intended to be antecedent to all practice parameters and technical standards covering the use of radiopharmaceuticals for therapy.~~

II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

Qualifications and responsibilities of personnel should adhere to Nuclear Regulatory Commission (NRC) requirements for training as specified in 10 CFR 35, as appropriate.

A. Physician **(Authorized User [AU])**

The qualifications and responsibilities of physicians performing these therapeutic procedures should be in accordance with the ACR–ACNM–ASTRO–SNMMI Practice Parameter for the Performance of Therapy with Unsealed Radiopharmaceutical Sources. In addition, training and experience must be in compliance with the applicable laws and regulations as pertain to AUs or equivalent.

The physician authorized to use the therapeutic radiopharmaceutical to be administered is ultimately responsible for supervision of the entire procedure and all aspects related to of its use. The qualifications of the physician performing therapy procedures must meet the appropriate training and experience requirements of 10 CFR Part 35, Subpart E (or its Agreement State equivalent) and be specified on the license. This physician is called the AU.

The AU may delegate tasks to qualified personnel, subject to applicable federal, state, or local regulations. The AU remains responsible for supervising those persons to whom tasks are delegated [3].

An AU must be immediately available in the facility during the administration of the radiopharmaceutical therapy. This may require being in the room if so constrained by license condition or licensee protocol.

~~The qualifications and responsibilities of physicians performing these therapeutic procedures should be in accordance with the [3]. Application of this parameter should be in accordance with the ACR–ACNM–SNMMI–SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [4], as that standard relates to the handling of radiopharmaceuticals, radiation safety, and radiation protection of patients, personnel, and the public. In addition, training and experience must be in compliance with the applicable laws and regulations as pertain to Authorized Users (AU) or equivalent.~~

B. Nuclear Medicine Technologist

The technologist performing nuclear medicine services should meet all of the **following** criteria**:** ~~as defined in the ACR–ACNM–SNMMI–SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [4].~~

1. **Successful completion of an accredited program in nuclear medicine technology. This program must include education in the basic and medical sciences as they apply to nuclear medicine technology and practical experience in performing nuclear medicine procedures. The technologist must satisfy all state and federal regulations that pertain to the in vivo and in vitro use of radiopharmaceuticals and performance of imaging examinations.**

or

2. **Hold current registration in Nuclear Medicine Technology with the American Registry of Radiologic Technologists (ARRT) or equivalent body as recognized by the American College of Radiology or certification in Nuclear Medicine Technology by the Nuclear Medicine Technology Certification Board (NMTCB).**

and

3. **Licensure, if required by state regulations.**
4. **In addition to the general certification requirements, nuclear medicine technologists also must complete continuing education hours to maintain certification. Documented regular participation in continuing education to maintain competence in the workplace.**
5. **Have knowledge of radiation safety, administration of radiopharmaceuticals, operation of equipment, handling of medical and radioactive waste, patient release instructions, and applicable regulations.**

C. Nuclear Pharmacist

The Nuclear Pharmacist must meet applicable NRC requirements for training as specified in 10 CFR 35, or equivalent **Agreement S**tate regulations.

D. Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently in one or more of the subfields in medical physics. The American College of Radiology (ACR) considers certification, continuing education, and experience in the appropriate subfield(s) to demonstrate that an individual is competent to practice one or more of the subfields in medical physics and to be a Qualified Medical Physicist. The ACR strongly recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR), the Canadian College of Physics in Medicine, or by the American Board of Medical Physics (ABMP).

A Qualified Medical Physicist should meet the ACR Practice Parameter for Continuing Medical Education (CME) **[4]**.

The appropriate subfield of medical physics for this technical standard is Nuclear Medical Physics (including medical physics certification categories of Radiological Physics, Medical Nuclear Physics and Nuclear Medicine Physics).

Certification by the American Board of Science in Nuclear Medicine in Nuclear Medicine Physics and Instrumentation is also acceptable. (ACR Resolution 17, 1996 – revised in 2012, Resolution 42)

Individuals who are ABR certified in either the Therapeutic Medical Physics or Diagnostic Medical Physics subfield may be qualified with ~~additional~~ appropriate training in radiopharmaceutical therapy consistent with AAPM Report 249 and procedure-specific training in the radiopharmaceutical therapies being performed at their institutions [5].

In addition, the Qualified Medical Physicist must meet any qualifications imposed by **licensure of an Agreement State, if applicable.** ~~the state and/or local radiation control agency.~~

E. Radiation Safety Officer (RSO)

Each licensee must designate the Radiation Safety Officer (RSO) ~~must~~ **who** meet**s** applicable NRC requirements for training as specified in 10 CFR 35, **Subpart B,** or equivalent **Agreement S**tate regulations [6]. ~~[2]~~

III. RADIOPHARMACY

A. Responsibility

The physician authorized to use the therapeutic radiopharmaceutical to be administered is ultimately responsible for the safety and appropriate preparation and/or administration under his or her direction.

Handling, aseptic preparation, and administration may be delegated to qualified personnel, subject to applicable federal, state, or local regulations. The AU remains responsible for supervising those persons to whom tasks are delegated.

The delegated qualified individual performing radiopharmaceutical tasks shares responsibility for the safety and quality of all radiopharmaceuticals with which he or she is involved, under the supervision of the authorized physician.

B. Radiopharmaceuticals (prescription, assay)

1. **Written Directive: This is the prescription of the quantity of radioactivity to be administered. A written directive is required prior to administration that includes the patient's name, radiopharmaceutical (not just radionuclide), route of administration, specified activity or range of activity to be administered, and signature of an authorized user. In an emergency situation, an oral directive is acceptable. The information contained in the oral directive must be documented as soon as possible in writing in the patient's record. A written directive must be completed within 48 hours of the emergency oral directive [7]. If the quantity of activity to be administered is based on dosimetry, then information regarding the dosimetric quantity upon which the activity prescription is based should be included (eg, absorbed dose, BED, EQD2, etc). The term "dosage" is used by the Nuclear Regulatory Commission (NRC) and Agreement States in their regulatory language for what is administered activity. Both terms are used in this document.**
2. **Assay: The quantity of administered activity must be assayed by the AU or by a person whom the AU has delegated the task prior to administration even if the unit dose was assayed by a commercial radiopharmacy. Dual verification of the assay should be performed. If there are any discrepancies, they must be resolved, per licensee protocol.**

3. **Administration and Documentation: Administered activity must fall within the tolerance of the prescribed activity according to applicable state and federal regulations. The identity of the patient using at a minimum of 2 identifiers, per a written procedure (patient's name, date of birth, picture identification, etc), the radiopharmaceutical, the route of administration, and pregnancy and breastfeeding status in patients of childbearing age, must be verified prior to administration and documented in the patient's record.**
4. **Informed consent must be obtained and documented. Refer to the ACR Practice Parameter on Informed Consent – Radiation Oncology [8].**
5. **Preferably within 24 hours prior to administration, a human chorionic gonadotropin (hCG) blood test must be performed to verify the patient's pregnancy status. If the patient is found to be pregnant, then the AU (with consultation with involved parties) will decide whether to proceed with the administration.**
6. **If applicable, breastfeeding precautions must be made prior to administration. The patient's acknowledgement must be documented.**
7. **For the radiopharmaceuticals that are potentially marrow radiotoxic, a complete blood count with differential and platelet count should be part of the pretreatment assessment within 1 week of the therapy procedure. Other laboratory tests may be indicated, as stated in the product description or per protocol.**
8. **Assay radiopharmaceutical dosage container after administration to assess the amount of the residual activity and verify the appropriate amount of activity has been given.**

For specific information related to ~~the~~ **other records maintained for** radiopharmacy **operations**, refer to the ACR–ACNM–SNMMI–SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures **[9]**.

IV. INSTRUMENTATION AND EQUIPMENT

A. Dose calibrator

The dose calibrator **(also known as activity meter)** is **a pressurized ion chamber** used ~~for~~ **to assay** radiopharmaceutical **activity in a syringe or vial. The assay of the intended administered activity is displayed in units of Curies or Becquerels. The assay requires a specific dose calibrator setting for each radionuclide. Sources for the radionuclide setting of a specific dose calibrator are 1) the dose calibrator preprogrammed isotope library; 2) based on guidelines/instructions for the calibration of a dose calibrator dial setting as provided by the centralized radiopharmacy supplier; or 3) the dose-calibrator manufacturer's user manual or website.** ~~assay and requires a specific internal setting for each radionuclide.~~

Requirements and methods for ~~calibration~~ **acceptance testing** and **routine** quality control (QC) of dose calibrators can be found in the ACR–AAPM Radiation Safety Officer Resources, section V, part M **[2,10]**. **Tests should evaluate constancy or precision, linearity of response with activity, accuracy of radionuclide assays, and effects of source (volume) geometry. Depending on the test, the frequency will vary from daily, quarterly, annually, at acceptance, or after repair.**

~~For suggested guidance on Preparing the Dose Calibrator for Specific Radiopharmaceutical Assay, see appendix A.~~

B. Survey meters

Survey meters are used to monitor radiation levels from radioactivity contamination or **assess** radiation exposure **rates** from **patients receiving radionuclide therapies. The survey instruments must be sufficiently sensitive to detect the type and energy of radiation used [11].** ~~all therapies covered in this technical standard.~~

~~Requirements and methods for calibration and QC of survey meters can be found in the ACR–AAPM Radiation Safety Officer Resources, section V, part I [2], as well as NRC 10 CFR 35.61[8] and NUREG-1556, Volume 9, Revision 2 [9].~~

To survey for personnel and equipment contamination, a Geiger-Müller (GM) detector with or without detachable

probes (pancake or cylinder style) or a handheld scintillation counter also with or without detachable probes as appropriate depending on radionuclide and emissions should be used. Common display ~~or readout~~ units of such devices are counts per minute (cpm) and/or microroentgens per hour (μR/hr) or microsieverts per hour (μSv/hr).

To survey patient **and received radiopharmaceutical package** exposure rates, **a survey meter using either an energy-compensated** GM ~~dose rate survey meters,~~ **probe, a** solid-state detector~~s~~, **or an** ionization chamber~~s, or handheld scintillation counters that are~~ **may be used. The meter must be** calibrated to accurately measure exposure rate or dose rate across the entire spectrum of emitted photons **from the therapeutic radionuclide being used.** ~~should be used. Common display or readout units are milli- or micro- roentgens per hour (mR/hr; μR/hr) or milli- or microsievert per hour (mSv/hr; μSv/hr). Limitations of radiation exposure survey instruments are that they are generally not as sensitive as contamination survey instruments and may not efficiently detect some types of contamination.~~

Common display or readout units are milli- or microroentgens per hour (mR/hr; μR/hr) or milli- or microsieverts per hour (mSv/hr; μSv/hr). ~~Limitations of radiation~~ **Instruments designed to measure** exposure ~~survey instruments are that they are generally not as sensitive as contamination survey instruments and~~ may not ~~efficiently~~ **be sufficiently sensitive to** detect some ~~types of~~ contamination.

Survey meters must be calibrated to a NIST traceable source annually and after repair unless a regulatory license condition specifies differently. Calibrations must be performed by a licensee specifically authorized to perform such calibration service. Each instrument should be checked for proper operation with a dedicated check source (if present) before the first use on each day of use.

C. Uptake probes ~~and intraoperative probes~~

~~Intraoperative probes and~~ **O**rgan uptake probes such as thyroid probes are radiation detection **and** counting instruments that are used to measure the ~~presence~~ **quantitative** or **relative** amount of radioactivity in specific **anatomical** location~~s~~. **Most commonly uptake probes are in the form of a solid NaI(Tl) scintillation detector or a solid-state detector interfaced to a multichannel analyzer for energy discrimination.**

QC testing of uptake probes **must be done if used to assess internal activity and should include radionuclide efficiency, background correction, χ^2, energy calibration, and energy resolution. The frequency of the tests can vary from daily, monthly, or quarterly. Acceptable QC programs** ~~and their frequency~~ can be found in the ACR–AAPM Radiation Safety Officer Resources section V**, part O [2] or** Zanzonico [12]. ~~, part O [2], as well as in the article by~~ ~~These tests include efficiency, chi square, energy calibration, energy resolution, and activity calibration.~~

D. Well counters

~~All radiopharmaceutical therapies require a well counter to measure radioactive contamination on surfaces.~~ **The use of unsealed radiopharmaceuticals requires radiation detection and counting instruments to measure and quantitate removable radioactive contamination from work surfaces, radionuclide packaging, or leakage from radioactive sources. The well counter is the recommended instrument for this use and may also be used for in vitro radioactive samples.** The measured ~~results are~~ **output is** expressed in units of counts per minute, which must be transformed to activity by ~~including~~ **applying** an efficiency factor **(dpm/cpm or microcurie/cpm or Becquerel/cpm)** for different radionuclides**. The efficiency factor may be built into the system or may need to be empirically determined for the system by the user. Most commonly, the well counter is a well-shaped, solid NaI(Tl) scintillation detector interfaced to a multichannel analyzer for energy discrimination.** ~~that are built into the system.~~

QC testing of well counters must be done to demonstrate that counting results used to demonstrate regulatory and license compliance are valid and accurate. The tests and their frequency should be the same as that for scintillation uptake probes indicated above.

~~Requirements and methods for calibration and QC of well counters can be found in the ACR–AAPM Radiation Safety~~

~~Officer Resources~~ ~~section V, part N. [2].~~

E. Infusion

~~Various~~ **P**arenteral therapies require the infusion of the radiopharmaceutical through slow hand infusion or via infusion pump. **Infusion should not be done via a "straight stick" directly into the blood vessel, and infusions should employ a 3-way stopcock system using an intracatheter, the shielded syringe, vial, or infusion pump containing the radiopharmaceutical dosage, and a saline flush. Patency of the infusion setup must be confirmed, immediately prior to administration of the radiopharmaceutical to prevent infiltration or extravasation.**

Infusion pumps are mainly ~~2 types:~~ large or small volume. Large-volume infusion pumps are based on peristaltic **movement to pulse medication through additional** infusion **tubing**, whereas small volume infusion pumps use **a piston or plunger for** direct infusion **from a syringe**. Infusion pumps are equipped with safety features that activate in the event of a problem such as the presence of air, blockage in the tubing, or pressure buildup beyond a preset value. When used to deliver radiopharmaceuticals, it is advisable that the infusion pump **or the radioactive dosage syringe or vial** be shielded**. S**ome infusion pumps can accommodate syringe shields or are equipped with shielding enclosures**, otherwise portable L-blocks or other shielding should be used** to reduce personnel radiation exposure.

During the use of these devices, prevention of skin contamination is critical requiring precautionary measures and close visual monitoring until the end of administration [13].

F. Shielding ~~(syringe shields, L-Blocks, pigs/shielded containers, staff protection)~~

Together with (shorter) time and (greater) distance, passive shielding is a simple yet effective technique to decrease the radiation exposure ~~of workers~~ from nuclear medicine therapeutic procedures. **Shielding should be of the material thickness that is appropriate for the radiopharmaceutical emission energies and activity.** ~~Passive~~ **S**hields **of the appropriate material thickness** such as L-Blocks **for dosage handling and assay stations, shielded cabinets, syringe/vial transport carriers,** ~~syringe shields,~~ and shielded waste containers are commercially available and are recommended for use with all nuclear medicine therapeutic procedures in order to keep occupational exposure as low as reasonably achievable (ALARA).

For inpatient and outpatient therapies, shielded walls, floors, ceilings and doors, or rolling shields that are properly positioned and of the appropriate material thickness can minimize exposure and assure radiation levels in adjacent public areas are below actionable levels. These are highly effective for energies up to that of I-131. Adjacent room(s) may need to be kept empty, when room shielding cannot provide radiation levels below the actionable general public limit.

Administration of the radiopharmaceutical therapy from a syringe or vial must be done using an appropriate syringe or vial shield. Administration of the radiopharmaceutical therapy from an infusion pump must be done using appropriate shielding.

~~In high-volume facilities the use of structural shielding should be considered.~~
~~For further information, refer to the US NRC NUREG-1556 Volume 11, Rev 2 Consolidated Guidance About Materials Licenses: Program-Specific Guidance About Medical Use Licenses and the ACR-AAPM Radiation Safety Officer Resources [2].~~

G. Fume hood

Nuclear medicine therapeutic procedures involving ~~aerosols or gaseous products that might produce~~ **volatile liquid forms of radiopharmaceuticals (eg, radioiodine) have the potential for** airborne contamination **and** may require the use of a fume hood. ~~These~~ **Fume hood** systems **for such forms must be under negative pressure and vent either directly outside or through a proper filter. These systems** should ~~have a method of verification~~ **be checked annually for proper operation and** to ensure that effluents are ~~ALARA, are~~ within the dose limits of 10 CFR 20.1301, and are within the ALARA constraints for air emissions established under 10 CFR 20.1101(d~~). For further information,~~

~~refer to the US NRC NUREG- 1556 Volume 11, Rev 2 Consolidated Guidance About Materials Licenses- Program Specific Guidance About Medical Use Licenses and the ACR- AAPM Radiation Safety Officer Resources [2].~~

H. Personnel dosimeters

Staff handling and administering unsealed radiopharmaceuticals must be issued personnel dosimeters **to measure their whole body and hand dose equivalents (ie, reported in units of millirem). These dosimeters are typically either** ~~such as~~ thermoluminescent dosimeters **(TLD)** ~~and~~ **or** optically stimulated luminescent **dosimeters (OSLD). The** dosimeters **measure the dose received by the wearer to evaluate whether or not occupational dose limits have been exceeded and that the licensee is maintaining doses ALARA. These dosimeters are also used by workers and caregivers, who may be providing inpatient assistance (eg, pediatric therapy). For some situations, calibrated electronic dosimeters may be employed for special-case, one-time potentially high exposures.** ~~capture the radiation exposure received by the radiation workers.~~

The dosimeters and their records must be processed and evaluated by a dosimetry processor that complies with NRC regulations 10 CFR 20.1501, or equivalent Agreement State regulations. The licensee must maintain occupational dose monitoring records in an available format for the duration of the license or as required by the NRC regulations 10 CFR 20.2106, or equivalent Agreement State regulations.

~~The American National Standards Institute and the Health Physics Society have established a standard procedure and criteria for the testing and performance of personnel dosimetry in ANSI/HPS N13.11-2009 [11].~~

V. PATIENT AND PERSONNEL SAFETY

A. ~~Shipping, delivery, and~~ **R**eceipt of radioactive materials

Packages containing diagnostic or therapy radioactive material must be received by personnel with appropriate training**. Opening** and ~~surveyed~~ **surveying of packages** for contamination **must be done within 3 hours of receipt.** Requirements for shipping and receiving radioactive materials are described in the ACR–AAPM Radiation Safety Officer Resources section V, part D **[2]**.

B. Patient release ~~criteria~~

Patient release criteria following a radionuclide therapy procedure are codified ~~in the federal~~ **in NRC** ~~guidelines~~ **regulation** 10 CFR 35.75 [14] and ~~key~~ sections of **the NRC regulatory guidance document** NUREG 1556 **[11]**. These criteria ~~are independent of the~~ **apply to any** radiopharmaceutical ~~therapy~~ administered. The patient may be released if the total effective dose equivalent to any other individual (including any caregiver or family member) who is exposed to the patient is not likely to exceed 5 mSv (0.5 rem). **This limit is per event and not an annual total if additional treatments or other radionuclides are administered within the year of the radionuclide therapy procedures. Calculations following an acceptable methodology must document that the patient dose to other individuals will not exceed this limit before the patient is released from the licensee's control/facility [2,15].**

Instructions, including written instructions, must be provided to the patient **or the patient's guardian** on ~~actions~~ **precautions or restrictions** to minimize doses **and radioactive contamination** to others by following ALARA principle if the total effective dose equivalent to any individual is likely to exceed 1 mSv (0.1 rem). **It is important that the patient understands any precautions that are provided and documented acknowledgement by patient should be done. Patient ability to understand instructions because of age or language barriers need to be considered and resolved before administration.** Agreement States may have specific rules and regulations regarding release of patients with significant residual activity. ~~[9,14,15]~~ **The precautions and their durations will depend on the specific radiopharmaceutical therapy and patient circumstances [16].**

After the patient has been released, wipe survey (for removable contamination) and radiation level survey must be done of the room where the therapy dosage was handled and administered, even if the treatment was outpatient.

~~For further information on patient release including instructions, refer to the ACR–AAPM Radiation Safety Officer Resources [2] and refer to your facility's radiation safety officer.~~

C. Emergency procedures ~~(radioactive spill or contamination)~~

The 2 most likely, although uncommon, emergency situations to arise with unsealed radiopharmaceuticals are radioactive spill or patient death. The RSO must be notified and consulted in any case as soon as possible.

A radioactive spill may occur ~~when treating a patient with~~ **from handling or administering unsealed radiopharmaceuticals.** ~~solutions, colloidal suspensions, or microspheres. There is a possibility of~~ **A**ccidental contamination of staff **or surfaces can occur from patient's bodily fluids. Staff must be trained in management of and cleaning up a spill. A kit with spill clean-up materials should be immediately available. A model spill procedure [2] would be to:**

- **Notify persons in the area that a spill has occurred. Have all persons not involved in the spill or possibly contaminated vacate the room.**
- **Prevent the spread of contamination by covering the spill with absorbent paper.**
- **Wear gloves and protective clothing such as a lab coat and booties and clean up the spill using absorbent paper, working from the perimeter toward the center. Carefully fold the absorbent paper with the clean side out and place in a bag labeled "caution radioactive material" for transfer to a radioactive waste container. Also, put contaminated gloves and any other contaminated disposable material in the bag.**
- **Survey the area with a low-range radiation detection survey instrument sufficiently sensitive to detect the radionuclide's emissions. Check for removable contamination to ensure contamination levels are below trigger levels. Check the area around the spill. Also check hands, clothing, and shoes for contamination.**
- **Document radiation survey levels at beginning of clean up, at end of clean up, and background.**
- **Report the incident to the RSO.**

In the case of patient death before radiation restrictions have expired, immediately notify the AU, RSO, and referring physician for any needed precautions to be given to the funeral director.

~~by contact with patients or their excreta or vomitus. The following table provides resource guides for these emergency situations.~~
~~Refer to your facility's radiation safety officer for further information, see Appendix B.~~

D. Radioactive waste disposal~~/decay-in-storage~~

Radioactive waste can be disposed by decay-in-storage, return to supplier, or transfer to a licensed disposal facility. Records of disposal of radioactive material must be maintained by the licensee. Radioactive material may be held for decay-in-storage if the half-life is less than or equal to 120 days. At the time of disposal, typically 10 half-lives, the material must be indistinguishable from background radiation levels when measured with **no shielding and** an appropriate survey meter.

Disposal by return to supplier (commercial radiopharmacy or manufacturer) involves shipping of radioactive material and must be done in compliance with Department of Transportation (DOT) regulations. Staff who package and document shipments must have documented training in the relevant DOT shipping requirements. Containers being returned to supplier must be assessed for residual activity for shipping document even if used dosage container is deemed "empty."

If **radioactive** material is ineligible for **disposal by** decay-in-storage ~~and disposal through standard waste streams,~~ **or**

return to supplier, a licensed and authorized disposal company must be used to properly dispose of **the waste** material. **Some therapy radiopharmaceuticals may contain detectable quantities of long-lived contaminants that may require this disposal method [17,18].** ~~Records of disposal must be maintained.~~

For further information, refer to the ACR–AAPM Radiation Safety Officer Resources, section V, part J **[2]**.

E. Inpatient therapy

~~The following documents serve as~~ **R**adiation protection guidance **and documentation** for ~~personnel~~ caring ~~for~~ **of** inpatients **receiving a therapeutic amount of a radionuclide must address the following:** ~~who have received a therapeutic dosage of a radionuclide~~.

- **Room radiation signage to restrict room access**
- **Rooms should be far from nursing stations or heavily trafficked hallways (when possible) to reduce staff and public radiation exposure**
- **Use and positioning of portable bedside shielding, if needed**
- **Radiation safety training and personnel dosimetry monitoring for caregivers or staff**
- **Preparing and covering surfaces to prevent contamination**
- **Stocking room/nursing station with supplies for staff to control contamination**
- **Ordering disposable table service during treatment**
- **Provide a written copy of restrictions for nursing and other hospital staff**
- **Establishing restrictions for visitors, if visiting is permitted**
- **Containers for handling room radioactive waste**
- **After patient release, room decontamination and survey for release to routine use**

For further information, refer to your facility radiation safety officer, the ACR–ACNM–ASTRO–SNMMI Practice Parameter for the Performance of Therapy with Unsealed Radiopharmaceutical Sources **[16]**, and the ACR–AAPM Radiation Safety Officer Resources section **V, part** F **[2]**.

~~F. Written request for therapy~~

~~The written or electronic request for a radiopharmaceutical procedure should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance.~~

~~Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the procedure or diagnosis would be helpful and may at times be needed to allow for the proper performance of the procedure.~~

~~The request for the procedure must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state's scope of practice requirements. (ACR Resolution 35, adopted in 2006, revised 2016 resolution 12b).~~

~~Informed consent must be obtained and documented. Refer to the ACR Practice Parameter on Informed Consent – Radiation Oncology [16]. Pregnancy should be excluded and breastfeeding precautions must be considered prior to therapeutic radiopharmaceutical administration. For the radiopharmaceuticals that are potentially marrow toxic, a complete blood count with differential and platelet count should be part of the pretreatment assessment.~~

~~The procedure should include duplicative procedures for identifying patients. The final report should include the radiopharmaceutical used, dosage, and route of administration. For additional information, refer to the ACR–ACNM–SNMMI–SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [4].~~

~~VI. PROCEDURE MANUAL~~

~~Refer to the ACR–ACNM–SNMMI–SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [9].~~

VI. RECORDKEEPING

It is required that documentation be kept to verify compliance with regulations and licensee's procedures. This recordkeeping includes, but may not be limited to:

1. **Written directive signed by the AU prior to administration.**
2. **Assay of administered activity by the user prior to administration.**
3. **Assay of activity container (vial/syringe) after administration.**
4. **Two methods used to identify the patient.**
5. **For patients of childbearing age, hCG pregnancy assessment <48 hours before administration.**
6. **For patients of childbearing age, breastfeeding status and precautions, if appropriate.**
7. **Test results to assess blood or other organ toxicity risk.**
8. **Dose calibrator QC, day of therapy use.**
9. **Survey meter annual calibration.**
10. **Contamination wipe and radiation level survey of therapy package.**
11. **Contamination wipes and radiation levels survey of administration room after patient release.**
12. **Day of use QC for well counter(s) used for contamination surveys.**
13. **Day of QC for uptake probe, if used for patient therapy measurements.**
14. **For inpatient therapy, copy of posted room precautions and visitor restrictions.**
15. **For inpatient therapy, radiation levels in adjacent rooms/areas.**
16. **Patient release calculations, noting any patient specific conditions.**
17. **Copy of patient release instructions signed by the patient or caregiver.**
18. **Hand and body personnel dosimeter reports of staff.**
19. **Records of patient's therapy radioactive waste storage/disposal.**

The final report should include the radiopharmaceutical ~~used, dosage,~~ **administered activity,** and route of administration. For additional information, refer to the ACR–ACNM–SNMMI–SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures **[9]**.

~~Refer to the ACR–ACNM–SNMMI–SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [8].~~

VII. RADIATION SAFETY IN IMAGING

~~Radiologists, medical physicists, registered radiologist assistants, nuclear medicine technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff and to society as a whole ALARA and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure necessary to achieve the clinical objective. All personnel that work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection, and application of dose limits) and the principles of proper management of radiation dose to patients (justification and optimization): http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf.~~

Facilities and their responsible staff should consult with the radiation safety officer to ensure that there are **current** policies and procedures for the safe handling and administration of radiopharmaceuticals and that they are adhered to in accordance with ALARA. These policies and procedures must comply with all applicable radiation safety regulations and ~~conditions of licensure imposed by~~ **license conditions of** the NRC**, Agreement** ~~and by~~ **S**tate**,** and/or other regulatory agencies. ~~Quantities of radiopharmaceuticals should be tailored to the individual patient by prescription or protocol.~~ Policies and procedures for the safe handling and administration of radiopharmaceuticals should also comply with the radiation safety recommendations of the National Council on Radiation Protection and Measurements as provided in NCRP 155 [7].

VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on Quality Control & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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Appendix A

Guidance on Preparing the Dose Calibrator for Specific Radiopharmaceutical Assay:

Radiopharmaceuticals	Guidance
Iodine-131	
Iodine-131 (meta-iodobenzylguanidine [MIBG I-131])	1) Included in the dose calibrator preprogrammed isotope library
Lutetium-177 DOTA	
Yttrium-90 DOTA	1) May be included in the dose calibrator preprogrammed isotope library 2) Guidelines for the calibration of Lutetium-177 DOTA, dose calibrator dial setting instructions as provided by the radiopharmacy 3) Guidelines for the calibration of Yttrium-90 DOTA, dose calibrator dial setting instructions as provided by the radiopharmacy
Phosphorus-32 (sodium phosophate)	
Phosphorus-32 (colloidal chromic phosphate)	1) Refer to guidance document provided by your radiopharmacy
Radium-223 (radium dichloride)	1) May be included in the dose calibrator preprogrammed isotope library 2) Guidelines for the calibration of Radium-223 (radium dichloride), dose calibrator dial setting instructions as provided by the radiopharmacy
Samarium-153 (lexidronam ethylene-diamine-tetra-methylene phosphonic acid [EDTMPA])	1) May be included in the dose calibrator preprogrammed isotope library 2) Guidelines for the calibration of Samarium-153, dose calibrator dial setting instructions as provided by the radiopharmacy
Strontium-89 (strontium chloride)	1) Refer to guidance document provided by your radiopharmacy: "Guidelines for the Calibration (Strontium-89 chloride injection)"
Yttrium-90 (ibritumomab tiuxetan)	1) Refer to guidance document provided by your radiopharmacy

Appendix B

Radiation Safety Officer Information:

Radiopharmaceuticals	Guidance

~~Iodine-131 (sodium iodide)~~ ~~Iodine-131 (meta-iodobenzylguandine-MIBG iodine-131)~~ ~~Lutetium-177 DOTA~~ ~~Yttrium-90 DOTA~~ ~~Phosphorus-32 (sodium phosphate)~~ ~~Phosphorus-32 (colloidal chromic-phosphate)~~ ~~Radium-223 (radium dichloride)~~ ~~Samarium-153 (lexidronam ethylene-diamine tetra-methylene phosphonic acid [EDTMPA])~~ ~~Strontium-89 (strontium chloride)~~ ~~Yttrium-90 (ibritumomab tiuxetan)~~	~~1) ACR-AAPM Radiation Safety Officer Resources Section V.A. [2]~~ ~~2) NUREG-1556, Vol. 9, Rev 2, page 8-59, and Appendix~~ ~~3) Manufacturer website~~ ~~4) Package insert~~

*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

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RESOLUTION NO. 46

BE IT RESOLVED,

that the American College of Radiology adopt the ACR–AAPM–SIIM Practice Parameter for Determinants of Image Quality in ~~Digital~~ Mammography

Sponsored By: **ACR Council Steering Committee**

Revised 2017 (Resolution 42)*

ACR–AAPM–SIIM PRACTICE PARAMETER FOR DETERMINANTS OF IMAGE QUALITY IN ~~DIGITAL~~ MAMMOGRAPHY

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

I. INTRODUCTION

This practice parameter was developed collaboratively by individuals with recognized expertise in breast imaging, medical physics, and imaging informatics, representing the American College of Radiology (ACR), the American Association of Physicists in Medicine (AAPM), and the Society for Imaging Informatics in Medicine (SIIM), primarily for technical guidance. It is based on a review of the clinical and physics literature on digital mammography and the experience of experts and publications from the Image Quality Collaborative Workgroup [1-3]. Additionally, this practice parameter includes input from industry, radiologists, and other interested parties in an attempt to represent the consensus of the broader community. It received further input from another working group of the Integrating the Healthcare Enterprise (IHE) Initiative [4].

For the purposes of this practice parameter, ~~digital~~ mammography is defined as the radiographic **and tomographic** examination of the breast by using dedicated electronic detectors to record the image ~~(rather than screen-film)~~ and having the capability for image display on computer monitors. This practice parameter in ~~digital~~ mammography **image quality** does not pertain to computed tomography (CT) mammography. **Image quality for stereotactic/tomosynthesis-guided breast biopsy is not explicitly addressed in this document, although much of what is discussed in this document applies to biopsy units as well. For further information on breast biopsy, see the ACR Practice Parameter for the Performance of Stereotactic/Tomosynthesis-Guided Breast Interventional Procedures [5].**

~~In many parts of this practice parameter, the level of technical detail regarding the determinants of image quality for digital mammography is advanced and is intended to provide radiologists, Qualified Medical Physicists, mammography technologists, regulators, and other support personnel directly involved in clinical implementation and oversight an expanded knowledge of the issues pertinent to assessing and maintaining digital mammography image quality from the acquisition, display, and data storage aspects of the process.~~ **In many parts of this practice parameter, the level of technical detail regarding the determinants of image quality for mammography is advanced. It is intended to provide an expanded knowledge of the issues pertinent to assessing and maintaining mammography image quality from acquisition, to display, and then to the data storage aspects of the process. Personnel directly involved in clinical implementation and oversight, such as Radiologists, Qualified Medical Physicists, mammography technologists, and regulators, will benefit from this guidance.** Where basic technical requirements for ~~digital~~ mammography overlap with those for digital radiography in general, users are directed to consult the referenced ACR **articles** ~~practice parameters~~ [6,7]. All interested individuals are encouraged to review the ACR–AAPM–SIIM–SPR Practice Parameter for Digital Radiography **[8]**. Furthermore, the ACR Subcommittee on Quality Assurance in Mammography has developed a Digital Mammography Quality Control (QC) Manual **[9]**.

Analysis of image quality has meaning primarily in the context of a particular imaging task [10]. This practice parameter has been developed with reference to specific imaging tasks required by mammography, using the information available in the peer-reviewed medical literature regarding ~~digital~~ mammography acquisition, image processing and display, storage, transmission, and retrieval. Specifically, the imaging tasks unique to mammography that determine the essential characteristics of a high-quality mammogram are its ability to visualize the following features of breast **disease** ~~cancer~~:

1. The characteristic morphology of a mass
2. The shape and spatial configuration of calcifications
3. Distortion of the normal architecture of the breast tissue
4. Asymmetry between images of the left and right breast
5. The development of anatomically definable changes when compared with prior studies

The primary goal of mammography is to detect breast cancer by accurately visualizing these features. At the same time, it is important that these signs of breast cancer not be falsely identified if breast cancer is not present. Two aspects of digital image quality can be distinguished: technical and clinical. It is possible to make technical measurements describing the above attributes, and it may be possible to infer a connection between these technical measures and clinical image quality. The extent to which these features are rendered optimally with a ~~digital~~ mammography system using current technology depends on several factors and is the major focus of this practice parameter.

II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

Interpreting physicians, Qualified Medical Physicists, and ~~radiological~~ **radiologic** technologists who work in mammography must meet the requirements of the Mammography Quality Standards Act (MQSA) final rule as published by the Food and Drug Administration (FDA) [11]. Under MQSA, personnel need to receive 8 hours of initial training prior to independently using any new mammographic modality, defined as a modality in which the person has not previously been trained. See the ACR Practice Parameter for the Performance of Screening and Diagnostic Mammography **[12]**. This includes **full-field** digital mammography **(FFDM)** and digital breast tomosynthesis (DBT). For further information see the FDA's Frequently Asked Questions about DBT and MQSA Training Requirements **[13]**.

~~Although the FDA's Division of Mammography Quality Standards (DMQS) considers each manufacturer's DBT system to be a new modality, they recognize that there are many features which are common to different DBT systems, while some features are unique to each specific system [13]. Consequently, the FDA specifies that training must include both the common features of DBT and the unique features of the particular manufacturer's DBT system. These two aspects of the training may be obtained either in a single training program or in separate settings. Also, once personnel have received training in the common features of DBT, they do not need to repeat this portion of the training when receiving training in the unique features of another DBT system.~~

III. ~~DIGITAL~~ MAMMOGRAPHY IMAGE ACQUISITION

In **FFDM** ~~digital mammography~~ and DBT, the processes of image acquisition, display, **transmission,** and storage are performed by separate systems, each of which can be optimized. The digital detector is designed to efficiently absorb X-rays, produce an electronic signal, digitize the signal, and store the results in computer memory. The output image is saved as a 2-D matrix, in which each picture element (pixel) represents the X-ray transmission corresponding to a particular path through the breast. This image can be digitally processed such that when it is displayed in softcopy form on a high-resolution display device or printed on laser film, the key features required for mammographic interpretation can be visualized.

Technical descriptions of digital radiography image acquisition devices and specifications are available in Williams et al [7], and individual device specifications are available on request from the specific equipment manufacturers. Once a system has been purchased, calibrated, and acceptance tested, regularly scheduled quality control (QC) procedures performed by the technologist and annual testing (or as needed) by the Qualified Medical Physicist are required to maintain compliance with the FDA regulations. ~~of the FDA~~ ~~Currently,~~These regulations allow mammography quality assurance programs the ~~responsibility for~~option to follow the ~~development and provision of~~ system specific QC testing procedures for ~~the image acquisition system is the specific manufacturer of~~FFDM and DBT systems required to be prescribed by the image acquisition device ~~. Manufacturers of mammography equipment are responsible for developing system-specific QC test procedures.~~ ~~However~~manufacturer, or those found in the recently-approved ACR Digital Mammography Quality Control Manual **[9]** ~~has recently been approved by the FDA as an alternative standard to the manufacturer's recommended quality assurance program for full-field digital mammography (FFDM)~~ ~~**and DBT**~~ ~~systems~~.

For digital acquisition systems, accurate representation of anatomical detail and pathology requires adequate anatomic coverage and image quality. Image quality can be described in terms of spatial resolution, image contrast, ~~latitude or dynamic range,~~ noise, and artifacts. **Any technique adjustments should be performed in consultation with and verified by the radiologist in charge of the mammography program and the Qualified Medical Physicist.**

A. ~~Tissue~~ **Anatomic** coverage depends on the chosen view (projection) and positioning of the breast. The goal is to project as much of the breast tissue as possible onto the image detector to maximize breast disease detection. The following factors affect tissue coverage:

1. The geometrical relationship of the X-ray source, collimation, compression device, patient, grid, and image detector requires the X-ray beam and image receptor to come as close to the chest wall edge of the breast support as possible. ~~for digital mammography, DBT, and stereoscopic digital mammography, just as for screen-film mammography~~.

2. The image receptor should be large enough to image the entire breast of most women. Along the edge of the detector nearest the chest wall, inactive regions of the image receptor will result in missed breast tissue. Consequently, the gap between the chest wall edge of the image receptor and the breast support should be minimized and in no case should exceed 7 mm. Typical digital units have a gap of 4 to 7 mm [3,14]. On all other sides of the detector, there should be complete coverage of the breast tissue.

3. **Large breasts may require imaging of the breast in sections, particularly for smaller field of view (FOV) detectors. The resulting multiple images in the same projection must be viewed together to form the complete mammogram. An increase in radiation dose occurs to regions of the breast that are exposed to X-rays in more than 1 image in the same projection. Standard tiling methods that minimize double exposure should be used. A larger FOV detector lowers the need for multiple-section imaging.**

4. Clinical assessment of positioning in ~~digital~~ **FFDM** ~~mammography matches that required for screen-film and~~ evaluates the ~~retromammary~~ **retroglandular** aspects of the breast between the craniocaudal (CC) and mediolateral oblique (MLO) views. On the CC view, the posterior nipple line of the breast (the distance between the nipple and the posterior edge of the image) should be ~~no more than~~ **within** 1 cm ~~less~~ (approximately) ~~than~~ **of** that on the MLO view (the distance between the nipple and the anterior edge of pectoralis muscle). The anterior edge of the pectoralis muscle on the MLO view should be convex, and it is desirable for the muscle to extend to the level of the nipple. The posterior nipple line should be drawn at an angle perpendicular to the muscle, usually at approximately 45 degrees on the MLO image.

B. Spatial resolution [7] of an imaging system refers to its ability to depict 2 adjacent structures as being separate, or the distinctness of an edge in the image (ie, sharpness). Measurement is performed by qualitative or quantitative methods [7]. ~~Spatial resolution losses occur because of blurring caused by geometric factors such as the size of the x-ray tube focal spot and the magnification of a given structure of interest. Other factors include unsharpness due to detector material, detector element effective aperture and pitch, and relative motion of the x-ray source, the breast, or the image detector during the exposure.~~ The effects of spatial resolution on clinical image quality are most easily observed when imaging fine detail in the breast such as spiculations radiating from a mass or microcalcifications. Shape and margins help differentiate a benign from a malignant process. However, one may not isolate spatial resolution effects on clinical image quality from effects due to quantum mottle and electronic noise under typical digital image acquisition conditions.

Spatial resolution losses occur because of blurring caused by geometric factors such as the size of the X-ray tube focal spot and the amount of applied compression. Magnification is used to improve spatial resolution, but it will introduce magnification-dependent focal spot blur; therefore, a smaller focal spot size is required. Other factors that affect spatial resolution include detection methods used (direct or indirect detection); detector material; detector element effective aperture and pitch; and relative motion of the X-ray source, breast, or image detector during the exposure. For DBT systems, tube motion, the number of projections acquired, the angular range, and the angle of incidence will affect the in-plane and z-axis spatial resolution. Geometric optimization techniques are vendor-specific, resulting in variability in image quality of DBT systems [15].

Motion blurring can have a particularly strong impact on limiting spatial resolution and image sharpness. In ~~digital~~ **FFDM,** ~~mammography,~~ motion blurring is caused by movement of the breast during exposure and is minimized by using a short exposure time and appropriate breast compression. **Magnification techniques with small focal**

spots and lower tube current (mA) require longer exposure times and are therefore more susceptible to motion blur.

1. Applied kilovoltage (kV) may be increased for thick, dense breasts to allow reduction of exposure time. Image processing may compensate for contrast losses to the extent allowed by the background noise and the image signal-to-noise ratio (SNR).

C. Contrast resolution (radiographic contrast) refers to the magnitude of the signal difference between the structure of interest and its surroundings in the displayed image and is influenced by subject contrast and display (image) contrast [7]. High radiographic contrast is needed to visualize the subtle differences in soft-tissue densities of normal and pathologic structures, including structural characteristics of the margins of masses and the detection and characterization of minute microcalcifications.

1. Subject contrast is the relative difference between the X-ray transmissions at the entrance plane of the image receptor through different parts of the breast. Attenuation, and therefore subject contrast, depend**s** strongly on the X-ray energy spectrum, which is determined by the target material, ~~kV~~ **tube potential**, and filtration (either inherent in the tube or added). **In mammography, low tube potentials (~24-35 kV) are employed. Target and filtration materials are vendor-specific, but generally include molybdenum, rhodium, and tungsten targets and molybdenum, rhodium, silver, and aluminum filters. In general, a molybdenum target/filter with a low tube potential will only be used for imaging smaller breasts (thickness of 2 to 5 cm). For thicker and/or denser breasts, a higher-energy X-ray beam is needed to achieve adequate tissue penetration. The properties of digital detectors and adjustment of display contrast through image processing allow the use of higher energy X-rays as a means of dose reduction without compromising image SNR. The subject contrast may be increased by the use of a contrast agent. Contrast-enhanced mammography (CEM) is a technique that uses iodinated contrast and dual-energy digital mammography to enhance visualization of tumor neovascularity [16].**

2. Grids [7] designed for mammography reduce scattered radiation and improve ~~subject~~ **radiographic** contrast ~~at~~ **with** the ~~cost~~ **trade-off** of higher breast dose [17,18]. **Linear and cellular g**rids are used for contact (nonmagnification) imaging to reduce noise contributed by scatter. With geometric magnification views, the increased air gap between the breast and detector eliminates the need for a grid. Mammography systems may use image processing instead of a grid to reduce the effects of scattered radiation on **image** contrast. Some DBT systems do not use a grid because of the low exposure available per projection and the moving x-ray source position during acquisition.

3. Breast compression ~~is as important for digital mammography as it is for screen-film mammography. It contributes to digital image quality by immobilizing the breast and shortening exposure times, reducing the likelihood of motion unsharpness. In addition, compression~~ produces thinner, more uniform tissue, which results in less scattered radiation, more even penetration of x-rays, less magnification or geometric blurring, less anatomical ~~super-position~~ **superimposition**, and lower breast radiation dose.

D. ~~In digital mammography, it is important to discuss noise as well as contrast [7].~~ Radiographic image noise is the unwanted random (uncorrelated), nonrandom (correlated), or static (eg, detector defect) variation in signal in an image acquired from a uniform x-ray exposure [19-21]. Using fewer x-rays (quanta) increases random noise or quantum mottle (for a fixed signal), decreases SNR, and reduces the ability to discern subtle differences in **image** contrast. Fine calcifications or subtle masses that can be the first signs of cancer may not be visible in a noisy (underexposed) image. The exposure required to achieve a desired SNR is inversely related to the detective quantum efficiency (DQE). Consequently, as DQE increases, so does the dose efficiency. "Appropriate" x-ray exposure depends on the system's DQE, and requisite SNR can be achieved with a calibrated automatic exposure control system.

Anatomical noise is another common source of noise in mammography. Mammographic breast density is the amount of radiopaque tissue relative to the amount of radiolucent tissue present in the breast. Dense breasts, with high amounts of glandular and fibrous tissues, can produce abundant anatomic noise in the

image, leading to challenges in interpretation by masking underlying pathology [22]. DBT, CEM, breast CT, breast MRI, molecular breast imaging, and breast ultrasound are also useful as supplemental tools to aid in breast cancer detection for women with dense breasts.

E. Artifacts in FFDM images can lead to errors in interpretation by either mimicking or obscuring abnormalities in the breast. There are a number of sources of these artifacts related to the patient, machine, detector, image processing, and data storage [23].

There are specific artifacts associated with DBT imaging that can enhance or impede object visibility. High-contrast objects can cause out-of-plane ghosting or result in shadowing that appears as dark, "embossed" regions in the direction of the tube movement. Both are due to incomplete sampling that results from the limited angular range and the reduced number of acquisition angles [24,25]. These artifacts can be minimized via image post processing, either by reconstructing thicker slices or by viewing multiple slabs or stacked thin slices. Each vendor has reconstruction algorithms for artifact reduction and enhancement. Training is imperative for understanding individual vendor reconstruction characteristics.

~~It should be noted that although image processing has a number of beneficial aspects, the user must also be aware of the potential deleterious consequences of using certain image processing tools with digital mammography. For example, un-sharp masking can enhance the sharpness of mass lesion borders, but it can make indistinct masses appear more circumscribed. Histogram-based intensity windowing can improve the conspicuity of edges, but at the potential cost of losing detail outside of the denser parts of the image. Contrast-limited adaptive histogram equalization also brings out edge information of lesions but, at the same time, enhances the visibility of distracting nonlesion features, potentially leading to false positive reports. Peripheral equalization brings out lesion detail while preserving peripheral information in the surrounding breast, but the downside is possible flattening of image contrast in nonperipheral areas.~~

1. ~~Magnification techniques with small focal spots and lower tube current (mA) require longer exposure times. The amount of blurring depends on object motion speed, exposure duration, and degree of magnification.~~
2. ~~For scanned slot systems, motion causes misregistration artifacts between the anatomy imaged both before and after motion occurs.~~
3. ~~Spatial resolution may be diminished when using DBT because of x-ray tube motion during acquisition and the increased angle of incident x-rays in wider projections. Geometric optimization techniques are vendor-specific, resulting in variability in image quality of DBT systems [15].~~

~~It should be noted that although image processing has a number of beneficial aspects, the user must also be aware of the potential deleterious consequences of using certain image processing tools with digital mammography. For example, unsharp masking can enhance the sharpness of mass lesion borders, but it can make indistinct masses appear more circumscribed. Histogram-based intensity windowing can improve the conspicuity of edges but at the potential cost of losing detail outside the denser parts of the breast. Contrast-limited adaptive histogram equalization also brings out edge information of lesions but at the same time enhances the visibility of distracting nonlesion features, potentially leading to false positive reports. Peripheral equalization brings out lesion detail while preserving peripheral information in the surrounding breast, but the downside is possible flattening of image contrast in nonperipheral areas.~~

- ~~a. Molybdenum (Mo) target x-ray units generate characteristic radiation at 17.4 and 19.5 keV. A Mo filter 0.025 to 0.03 mm thick strongly suppresses photon energies less than 15 keV and those greater than 20 keV, yielding high subject contrast and avoiding excess radiation dose for 2- to 5-cm breasts imaged at typical voltages of 25 to 28 kV.~~
- ~~b. For thicker and/or denser breasts, a higher-energy x-ray beam is needed to achieve adequate tissue penetration. To image thicker breasts (5 cm to 7 cm), a mammography system with a Mo target material uses a Mo filter (0.030 mm thickness) or a rhodium (Rh) filter (0.025 mm thickness) and a tube voltage higher than 28 kV. For denser breasts, a Rh filter is used, preferentially transmitting photon energies between 15 to 23 keV.~~
- ~~c. For very dense or difficult-to-penetrate breasts, a tube voltage of 28 kV is used with a Rh target and Rh filter (0.025 mm), producing characteristic x-rays at 20.2 and 22.7 keV. This preserves subject contrast without a substantial increase in dose.~~
- ~~d. Anode targets made with tungsten (W) produce a beam with higher effective energy and, in some cases,~~

~~lower patient dose compared with Mo or Rh systems. W targets can withstand a higher tube heat load, allowing for longer exposure times. Since the characteristic x-rays produced by W are above the energies used in mammography, the energy spectrum by using Mo, Rh, and silver (Ag) filters with a typical thickness of at least 0.05 mm. Greater filter thickness is necessary to attenuate higher energy L-shell characteristic x-rays. Careful choice of kV and filter material can yield excellent image contrast with a radiation dose similar to that of a system with a Mo or Rh target.~~

~~2. There are specific artifacts associated with DBT imaging that can enhance or impede object visibility. Adjacent high-contrast objects can cause out-of-plane ghosting or result in shadowing that appears as dark, "embossed" regions in the direction of the tube movement. Both are due to incomplete sampling that results from the limited angular range and the reduced number of acquisition angles [16,17]. These artifacts can be minimized via image post processing, either by reconstructing thicker slices or by viewing multiple slabs or stacked thin slices. Each vendor has reconstruction algorithms for artifact reduction and enhancement. Training is imperative for understanding individual vendor reconstruction characteristics.~~

~~3. The properties of digital detectors and adjustment of display contrast through image processing allow the use of higher energy x-rays (25 to 35 kV and above) for digital systems compared to screen-film systems (where 22 to 32 kV is more typical). Dose is reduced while maintaining image SNR by using higher energy x-rays, especially for large or dense breasts.~~

~~6. Any technique adjustments should be performed in consultation with and verified by the radiologist in charge of the digital mammography program and the Qualified Medical Physicist.~~

~~4. Large breasts may require imaging of the breast in sections, particularly for smaller field-of-view (FOV) detectors. The resulting multiple images in the same projection must be viewed together to form the complete mammogram. An increase in radiation dose occurs to regions of the breast that are exposed to x-rays in more than 1 image in the same projection. Standard tiling methods that minimize double exposure should be used. A larger FOV detector lowers the need for multiple-section imaging.~~

IV. MAMMOGRAPHY IMAGE PROCESSING

Image processing has great potential to improve image quality **and** ~~and secondarily~~ diagnostic accuracy and even to reduce the radiation dose necessary to achieve an image of acceptable quality [26-28]. **Digital mammograms typically have a wide dynamic range and the ability to process the image data provides an opportunity to display the data more effectively. Storage of "for processing" image data provides greater flexibility for subsequent postprocessing using different algorithms. Systematic variations in intensity can be equalized, local contrast can be enhanced, and the sharpness of calcifications can be restored. Enhanced visualization of subtle structures is suggested as a possible contributor to the improved performance of digital mammography in patients with dense breast tissue** [29].

1. **Segmentation of the breast from the region of the direct beam is the first step for defining the areas to be processed, using edge detection algorithms and grayscale adjustment to equalize apparent tissue thickness. Artifacts near the skin line can occur in the equalized image, and the potential for this improper segmentation requires the ability to turn off the algorithm.**

2. **Spatial frequency restoration and deblurring are used to render microcalcifications with greater detail and higher conspicuity.**

3. **Selective (adaptive) noise reduction attempts to reduce noise only in regions where tissue contrast does not have noticeable fine detail. Difficulty arises in reducing noise and preserving high spatial resolution with the same process. In some cases, noise reduction might not improve detection performance if the reduced noise texture is similar to that of target objects.**

4. **Unsharp masking sharpens images by using Fourier filters or spatial convolution kernels of large spatial extent to create a low frequency blurred image that is then subtracted from the nonblurred image.**

5. **Global latitude reduction increases the relative signal in underpenetrated areas and reduces the signal**

in highly transmissive regions.

6. **Adaptive local contrast enhancement and multiscale processing are other methods that have been used. When applying global latitude equalization or adaptive contrast enhancement, there is always some risk that subtle tissue characteristics of potential diagnostic significance may be diminished in relation to the detail that is enhanced.**

7. **Differently processed versions of the same mammogram may be preferred depending on the task and lesion type, suggesting that workstations might implement multiple processing options for use during interpretation [29].**

8. **Desired processing parameters may vary with radiographic factors such as tube target, kV, and tube filter type and thickness. One must be careful to ensure that the processing being used is appropriately matched to the techniques used to obtain the mammogram.**

9. **A synthetic 2-D mammogram can be reconstructed from DBT projections and has the potential to replace 2-D FFDM. Use of synthetic mammography allows for a reduction in radiation dose and a shorter total examination time and may result in better conspicuity of high-contrast calcifications and architectural distortions relative to 2-D FFDM. Synthetic mammography images have been shown to underperform in terms of spatial resolution, the potential for false-positive calcifications, and synthetic-mammography-specific artifacts [30].**

10. **Comparison of images from prior mammography examinations is essential in the interpretation of a new study. However, variations in the processing of prior and current images may make such comparisons difficult. See the discussion below under section VI. C. "Archive" for further information on this subject.**

11. **Application of image processing at the reading station (or by a processing box located separately from the primary interpretation workstation) requires image processing software that is applicable to the images from any mammography system. This requires an understanding of the characteristics of the image data from the mammography system or other input devices (eg, film digitizers) as well as storage of image data in the DICOM format intended "for processing."**

It should be noted that although image processing has a number of beneficial aspects, the user must also be aware of the potential deleterious consequences of using certain image processing tools with digital mammography. For example, unsharp masking can enhance the sharpness of mass lesion borders, but it can make indistinct masses appear more circumscribed. Histogram-based intensity windowing can improve the conspicuity of edges but at the potential cost of losing detail outside the denser parts of the breast. Contrast-enhanced adaptive histogram equalization brings out edge information of lesions but also enhances the visibility of distracting nonlesion features, potentially leading to false-positive reports. Peripheral equalization brings out lesion detail while preserving peripheral information in the surrounding breast, but the downside is possible flattening of image contrast in nonperipheral areas.

V. ~~DIGITAL~~ MAMMOGRAPHIC IMAGE DISPLAY

Although it is possible to display digital images in a hardcopy format, the advantages of **FFDM** ~~digital mammography~~ may not be fully realized without softcopy display [31]. The quality of the display used to view mammographic images has a direct effect on radiologic interpretation. A faulty, inadequately calibrated, or improperly set-up display device can compromise the overall quality of the mammography examination [31,32]. Since DBT provides the radiologist with a series of images through the breast that are scrolled through, rather than viewed as single images as with FFDM, ~~digital mammography~~ there are added display requirements (eg, temporal resolution or frame rate). Many display manufacturers have DBT specific displays to counteract motion blur during scrolling.

Many aspects of display technologies and uniform practice have been addressed by standards-setting groups [33-38].

The Medical Imaging and Technology Alliance (MITA) has published 2 standards that include templates and describe a minimum set of QC tests that should be included as part of the quality assurance plan for displays and workstations [39] as well as hardcopy printing devices [40] for FFDM. As new display technologies emerge (eg, workstations for viewing DBT images), it is important to ~~ensure~~ verify that the technical specifications of the device are reviewed and compared to the ~~image~~ specifications **required to provide adequate image quality for efficient and accurate diagnosis.** ~~to ensure adequate presentation of image details on the display for display provides adequate image quality to ensure efficient and accurate diagnoses.~~ For example, hand-held displays are currently available with software applications approved for viewing certain types of radiographic images under certain explicit conditions (eg, ambient light requirements). At this time, these devices do not have the spatial resolution required for viewing mammograms. ~~and thus should not be used.~~

A. Hardcopy Printing

Despite the adoption of **FFDM**, ~~digital mammography~~ some ~~images are still printed to~~ **facilities may print images for** hardcopy ~~for~~ display and interpretation. MQSA gives the decision of maintaining a printer and/or the ability to print hardcopy images to each individual facility. MQSA states, "If a facility chooses to maintain a printer, it must follow all the QC requirements that are prescribed by the manufacturer of the printer and mammographic unit. The manufacturer's quality control program benefits the facility that wants to provide the best possible quality in any hardcopy mammography images it prints. Although the FDA's MQSA inspection program has removed printer QC questions from its inspection procedures, if a facility decides to maintain a printer, medical physicists must continue to include that printer QC in the mammography equipment evaluation upon installation, after a major repair, and annually, if required by the printer's or image receptor's manufacture quality control program" [41].

Lightbox considerations

1. Luminance: A minimum of 3,000 candelas per square meter (cd/m2) is the standard for screen-film mammography [42]. The ~~same guidelines should be~~ **luminance** used for display of digital images printed on film **should be sufficiently bright to view the darkest image**. A "hot light" (focal or lightbox) will be of limited value for digital mammograms printed to film.
2. Uniformity: No specific standards address spatial uniformity of lightbox luminance or of intralightbox luminance uniformity. Luminance variations should be minimized.
3. Shutters and masking: The FDA requires that masking materials be available for interpreting physicians [11,43]. Viewscopes are allowed as long as the illuminated area can be limited to a region equal to or smaller than the exposed portion of the film. The average ambient light conditions should be adjusted relative to the average luminance of the displayed images (properly masked). Care should be taken to avoid any direct reflections on image surfaces. Darker images require a darker environment to interpret properly.

~~MQSA requires facilities to have the ability to print images. Thus, hardcopy mammographic image quality remains an important issue and must be included in any effort to address digital image quality in mammography.~~ Although the FDA recommends that only printers specifically cleared for FFDM use by the FDA be used, the use of other printers is also legal under MQSA [41]. The ACR also strongly recommends that only FDA-cleared printers be used for **FFDM**. ~~digital mammography~~ Quality assurance issues for hardcopy display have been set forth in a number of publications [40,42,44]. ~~While there are no recommendations regarding the use of hardcopy versus softcopy display for interpretation, the FDA requires the ability to print FFDM images of final interpretation quality to film if so requested by patients or their health care providers [36].~~ When FFDM images are printed to film, the manufacturer's guidelines should be followed.

B. Softcopy Display Devices

Many factors contribute to image quality in softcopy radiographic and mammographic display [45-48]. Although the FDA recommends that monitors used for interpretation be specifically cleared for FFDM/DBT use by the FDA, the use of other monitors is permitted under MQSA [49]. Softcopy displays for mammography should meet minimum quality specifications for acquisition, interpretation, and review workstations [6]. Displays for DBT should incorporate technology to compensate for image blur during scrolling via optimized frame rates. The AAPM Task Group 18 documentation on assessment of display performance for medical imaging systems provides test images [45], an

executive summary of tests [50], and a complete overview [51], which are very useful for specifying and verifying adequate performance for displays used in medical images. Descriptions of most of the display performance metrics can be found in Krupinski et al [6]. **The AAPM Task Group 270 report provides more specific recommendations for flat-panel displays, including both liquid crystal displays and organic light-emitting diode displays that are used for acquisition and diagnostic review [49].**

Individual device specifications and expected performance criteria can be requested from display manufacturers. Once a display has been purchased and calibrated, it should be tested regularly by a Qualified Medical Physicist, a biomedical engineer, or a qualified technologist to ensure compliance. MQSA requires that a Qualified Medical Physicist test the **diagnostic** review workstation prior to its clinical use. Facilities should refer to their FFDM **or DBT** system QC manuals or the ACR Digital Mammography Quality Control Manual [9] for details and requirements pertaining to ongoing and annual testing for their image displays [52].

1. Luminance response
   The brightness and contrast of grayscale medical images result from the luminance in relation to the image gray level values [50]. **The reader is referred to the ACR-AAPM-SIIM Technical Standard for Electronic Practice of Medical Imaging [53] for current guidance regarding ambient luminance, minimum and maximum luminance, and display contrast response for displays.**

2. Contrast
   Within the applicable luminance range of the mammographic display, the device should render the image details with a consistent grayscale that should be measured and maintained over time. The contrast (luminance) response of mammographic displays should comply with the AAPM Task Group 18 **and Task Group 270** recommendations**. Guidance is also provided in the ACR-AAPM-SIIM Technical Standard for Electronic Practice of Medical Imaging [53].** ~~and be within 10% of the Digital Imaging and Communication in Medicine (DICOM) grayscale display function (GSDF) over the full luminance response [42,43].~~

3. Bit depth
   For further information on bit depth, please see the ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging [53].
   ~~a. A display device must accurately represent mammography image information with a sufficient number of grayscale values to prevent the loss of image contrast and eliminate contour artifacts.~~
   ~~b. Several manufacturers provide FDA FFDM approved monitors with 5 megapixel displays and bit depths of 10 to 12 bits (1024 grayscale capabilities). Their use is recommended particularly for DBT image viewing.~~

4. Digital image matrix size and display size
   For further information on digital image matrix size and display size, please see the ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging [53].
   ~~a. A 5 megapixel monitor (2,048 × 2,560 requires less zoom/pan for image interpretation when the mammography radiologist desires to view the full resolution image dataset compared to a lower resolution display [54]. Display device specifications should match the acquisition matrix size as closely as possible. A number of manufacturers have developed 8 and 10 megapixel widescreen displays for mammography (and other applications) and these are generally suitable for FFDM and DBT viewing as they make it feasible to display 2 images (eg, right and left CC or MLO) on the same display.~~
   ~~For a standard viewing distance of approximately 67 cm, the diagonal dimension of a standard display should be 21 inches (53 cm), with a total viewing field approximately 32 × 42 cm. Widescreen displays typically require a slightly farther viewing distance.~~
   ~~b. Mammographic displays should render images with a pixel density sufficient to enable viewing of a full or partial (50% or greater area of the breast image) mammogram with sufficient spatial detail at a normal viewing distance of approximately 67 cm. Panning through a reduced subset of the entire image at full spatial resolution without excessive magnification should be easily available to the reader.~~

~~Zoom/pan functions should be used rather than moving closer to the display or using a magnifying glass to view details. A magnifying glass is generally inappropriate, as it simply magnifies the pixels rather than increasing the magnification of the image details.~~

~~c. During image interpretation, all images should be viewed at 1:1 or 100% size. Routine viewing at 2:1 (or 200% size increase) with zoom/pan function to examine the entire image is feasible [54]. When using a "fit to view" feature, images are often displayed at a size that is less than 100%, although the amount of size reduction will vary. For example, some displays scale the fit to viewport to maximize the scale of the mammogram. Hanging protocols and viewing modes for evaluation and comparison of longitudinal studies are important to maintain consistent viewing conditions, particularly for mammograms from different acquisition devices. The IHE Mammography Image profile [48] should be consulted for recommendations and implementation of digital mammography image display for interpretation.~~

5. Other softcopy display characteristics
   a. Image displays must be able to display mammography computer-aided detection (CAD) marks (when CAD is implemented) and to apply marks on the displayed image corresponding to all findings encoded in the DICOM mammography CAD structured reporting (SR) objects.
   b. Image displays must be able to display images at the same size as the imaged object [48]. This is critical because the sizes of objects in the image are generally judged visually and limitations in the size of the displayed image could distort the appearance of anatomy and negatively affect the interpretation of mammograms.
   c. Displays must be able to show images at the "same" physical size on the display (eg, 18 × 24 cm) even though they might be from different acquisition stations with different pixel sizes and detector dimensions.
   d. Displays must be capable of showing image information, including patient identification, image information, and acquisition technique [43].
   e. Image displays must be capable of displaying a set of current and prior ~~conventional~~ 4-view ~~screening~~ mammograms (left and right CC and MLO views) simultaneously.
   f. Image displays should be able to display a ruler on the screen as a visual clue to indicate physical size.
   g. Image displays should ensure that the luminance of the image background (outside the breast) is maintained at L_{min} as window width and level are adjusted during interpretation.
   h. Additional guidelines for viewing images can be found in the ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging **[53]**.

C. ~~Digital~~ Image Presentation Issues

The IHE initiative has defined a presentation of image integration profile that provides a standard method for storing grayscale images and information about their presentation state, including user annotations, shutters, flip/rotate, display area, and zoom [48].

1. It should not take more than 3 seconds to retrieve an image from online local storage and display it on a workstation. Times for image retrieval from storage archives and from remote sites will vary significantly depending on prefetching rules, management of image routing, and network speeds, among other issues.

2. Mammographic displays should allow fast and easy navigation between old and new studies. This is especially critical when there is a mix of FFDM and DBT images.

3. Hanging protocols should be specific to mammography, have proper labeling and orientation of the images, and be flexible and tailored to user preferences.

4. Workstation software tools must include window/level and zoom/pan. Use of image display tools can aid in image interpretation but increases reading time. There are no specific recommendations regarding which tools should be used with softcopy mammography displays and how they can be used effectively. Further

research on the ergonomics of using image display tools is encouraged.

5. Multimodality datasets and interoperability:
   a. To ensure that a workstation is capable of displaying digital mammograms correctly, it should conform to the IHE MAMMO profile. If it does not, then it is possible that the workstation will fail to show all digital mammograms as they are intended to be displayed by the acquisition system manufacturer.
   b. Mammography workstations should accommodate and display images from several modalities.
   c. Vendor-specific workstations form part of the "vertical industrial stack," making image sharing among different workstations difficult. For those who seek best-of-breed solutions tailored to imaging needs, current capabilities are limited.
   d. New workstations should also be capable of displaying DBT examinations correctly (eg, proper frame rates) and should conform to the IHE DBT profile as well as the IHE MAMMO profile. If it does not, then it is possible that the workstation will fail to show all DBT examinations as they are intended to be displayed by the acquisition system manufacturer.

D. Computer-aided detection (CAD)

1. The purpose of CAD is to help radiologists **detect malignancies**. ~~find cancers they may have overlooked otherwise~~ Studies of mammography CAD alone (without a human observer) suggest that mammography CAD detects some types of lesions well (especially calcifications, although possibly less well with amorphous forms). Mammography CAD is used to supplement routine image evaluation, and a human reader would not be expected to recall all or even most of mammography CAD marked lesions for further workup.

2. CAD may potentially play a role with DBT [54]. The increased number of images along with the subsequent time needed for review can have a significant impact on workflow. Because DBT is still fairly new, more research needs to be done before recommendations can be made for the particular properties associated with the various CAD programs designed for DBT. The current research suggests that DBT CAD software is comparable in sensitivity and false-positive rates when compared with other commercial CAD systems used with ~~standard digital mammography~~ **FFDM** [54].

E. Reading Environment

Factors as diverse as ambient light, temperature, noise, posture fatigue, and poor ergonomics may have significant effects not only on radiologist comfort but also on the quality, accuracy, and consistency of image interpretation [6,55-58]. **A more detailed discussion of factors affecting the reading room environment can be found in the AAPM Task Group 270 report and the ACR–AAPM–SIIM Technical Standard for the Electronic Practice of Medical Imaging [49,53].**

~~F. Image Processing Considerations~~

~~Image processing has great potential to improve image quality, and secondarily diagnostic accuracy and even to reduce the radiation dose necessary to achieve an image of acceptable quality [26-28]. Digital mammograms typically have a wide dynamic range, and the ability to process the image data provides an opportunity to display the data more effectively. Storage of "for processing" image data provides greater flexibility for subsequent postprocessing using different algorithms. Systematic variations in intensity can be equalized, local contrast can be enhanced, and the sharpness of calcifications can be restored. Enhanced visualization of subtle structures is suggested as a possible contributor to the improved performance of digital mammography in patients with dense breast tissue [29].~~

~~1. Segmentation of the breast from the region of the direct beam is the first step for defining the areas to be processed, using edge detection algorithms and grayscale adjustment to equalize apparent tissue thickness. Artifacts near the skin line can occur in the equalized image, and the potential for this improper segmentation requires the ability to turn off the algorithm.~~

~~2. Image processing steps (spatial frequency restoration and deblurring) are then carried out to render microcalcifications with greater detail and higher conspicuity.~~

3. ~~Selective (adaptive) noise reduction attempts to reduce noise only in regions where tissue contrast does not have noticeable fine detail. Difficulty arises in reducing noise and preserving high spatial resolution with the same process. In some cases, noise reduction might not improve detection performance if the reduced noise texture is similar to that of target objects.~~
4. ~~Unsharp masking and global latitude reduction increase the relative signal in underpenetrated areas and reduce the signal in highly transmissive regions. Fourier filters or spatial convolution kernels of large spatial extent create a low frequency blurred image that is then subtracted from the nonblurred image.~~
5. ~~Adaptive local contrast enhancement and multiscale processing are other methods that have been used. When applying global latitude equalization or adaptive contrast enhancement, there is always some risk that subtle tissue characteristics of potential diagnostic significance may be diminished in relation to the detail that is enhanced.~~
6. ~~Differently processed versions of the same digital mammogram are preferred depending on the task and lesion type, suggesting that workstations might implement multiple processing options for use during interpretation [29].~~
7. ~~Desired processing parameters may vary with radiographic factors such as tube target, kV, and tube filter type and thickness. One must be careful to ensure that the processing being used is appropriately matched to the techniques used to obtain the mammogram.~~
8. ~~Comparison of images from prior mammography examinations is essential in the interpretation of a new study. However, variations in the processing of prior and current images may make such comparisons difficult. See the discussion below under section V. C. "Archive" for further information on this subject.~~
9. ~~Application of image processing at the reading station (or by a processing box located separately from the primary interpretation workstation) requires image processing software that is applicable to the images from any digital mammography system. This requires an understanding of the characteristics of the image data from the digital mammography system or other input devices (eg, film digitizers) as well as storage of image data in the DICOM format intended "for processing."~~

~~Some of the more critical considerations include the following:~~

10. ~~Impact of ambient light~~
    a. ~~Ambient light should be low and consistent, particularly in a hybrid viewing environment where stray light from bright lightboxes can be detrimental when displaying softcopy images. The amount of ambient light (illuminance) should be approximately equal to the level of the average luminance of a clinical image being displayed [56], generally in the 20 to **50** 45 lux range; total darkness is not recommended.~~
    b. ~~Distracting glare and reflections occur from the display surface, even when antiglare coatings are applied. Thus overhead or direct lighting is not recommended; rather, indirect lighting is preferred.~~
    c. ~~Variations in the adaptation of the human eye to ambient light levels affect the contrast sensitivity and hence the ability to detect low contrast targets. Thus it is recommended that radiologists take at least 5 minutes to "dark adapt" to reading room light levels before viewing images when transitioning from daylight or other higher ambient light conditions.~~
    d. ~~Fatigue levels and eyestrain increase and interpretation accuracy decreases with higher levels of ambient light [57].~~
11. ~~Other environment factors [57]~~
    a. ~~Adequate air flow, optimal temperature, and humidity control should be maintained in reading areas.~~
    b. ~~Viewing conditions should be optimized to minimize eye fatigue by controlling the reading room ambient lighting. The ambient lighting should be set to minimize specular and diffuse reflection on the workstation display, which can be accomplished by setting the ambient illuminance to 25 to 50 lux [58,59]. Modern displays with improved reflection characteristics may allow the use of brighter ambient lighting conditions, although conformance with current recommendations from the AAPM and ACR should always be considered.~~
    c. ~~Noise from computer equipment and other devices should be minimized.~~
    d. ~~Proper chairs with lumbar support and adjustable height controls (including armrests) are recommended to avoid injuries and excessive fatigue.~~
    e. ~~The workstation table should be height adjustable, and the keyboard, mouse, and monitors should be designed to maximize comfort and efficiency. The display devices should be placed to maintain the~~

viewers at an arm's length from the display (ie, about 2/3 meter or 60 cm).

f. Dictation tools, internet access, and other reference tools should be readily accessible and easy to use during image interpretation.

g. Guidelines on the maximum number of acceptable pixel defects are specified by ISO 9241 as a function of display class [60]. Documentation of allowed pixel defects should be provided by the display manufacturer. Displays should be evaluated for significant pixel defects initially and periodically (at least annually is recommended). Pixel defects should be evaluated for clinical relevance by the interpreting physician in consultation with a Qualified Medical Physicist.

12. An interpreting physician's or "primary interpretation" workstation is one that is used to render an "official" or "final" interpretation of a study.

13. A "technologist's workstation" is one used by the technologist during the acquisition and QC process of an examination. It should also comply with and be calibrated to the DICOM GSDF standard [37]. Since technologists will perform QC on mammographic images at the acquisition or QC workstation to ensure that the radiologist has images of adequate quality, these displays must be of high quality.

a. When checking for positioning, contrast, and patient motion, the technologist should use a monitor having the same maximum luminance (eg, 400 cd/m^2) as the one used by the interpreting physician.

b. A high-resolution monitor similar to the one at the primary interpretation workstation is desirable.

14. An "acquisition workstation" is one used to review images as an adjunct to the official interpretation by a radiologist and may not require the high-resolution displays necessary for final interpretation.

15. Monitors used to display images acquired in the process of needle localization must provide sufficient spatial resolution compared to final image interpretation monitors, so there should be the means to provide zoom and pan features allowing the user to view images at full spatial resolution in the acquisition room.

a. Monochrome versus color

i. No clinical application requires color rather than monochrome displays for mammography.

ii. With technological advances, newer LCD or OLED monitors may meet the performance criteria for the display of mammographic images and may be appropriate for mammography applications.

16. Minimum and maximum luminance

a. Monitor luminance, L, is characterized by minimum (Lmin) and maximum (Lmax) values. Ideally, the maximum luminance of monitors used for primary interpretation should be at least 400 cd/m^2, whereas greater than 450 cd/m^2 is recommended for optimized contrast.

a. ambient luminance (Lamb): When the power to the display device is off, the display surface will still show some brightness due to diffusely reflected room lighting. This is called the ambient luminance and should be less than one-fourth of the luminance of the darkest gray level.

b. Minimum luminance (Lmin): Since the contrast response of the adapted human visual system is poor in very dark regions, the luminance of the lowest gray value, Lmin, should not be extremely low. The minimum luminance including a component from ambient lighting, L'min = Lmin + Lamb, should be at least 1.2 cd/m^2 for interpretation of mammograms.

c. Maximum luminance (Lmax): The perceived contrast characteristics of an image on a display depend on the ratio of L'max (the luminance for the maximum gray value) to L'min. This is the luminance ratio (LR), which is not the same as the contrast ratio often reported by monitor manufacturers. Ideally, all display devices in a facility should have the same LR so that the presentation is consistent for all viewers of a study. To achieve a suitable LR, for a system with an L'min of 1.2 cd/m^2, Lmax should be at least 420 cd/m^2 for displays used to interpret mammograms.

d. The bit depth of mammographic images should be at least 8, corresponding to 256 grayscale values. At the time of publication, relatively few studies have been reported in the literature that address possible advantages of higher bit-depth display devices. However, 9-bit or higher is recommended if the "for processing" image data are greater than 8 bits.

VI. TRANSMISSION, STORAGE, AND RETRIEVAL

The development of tools for image storage and retrieval has emphasized the isolated silo concept, with each manufacturer optimizing its own system, at the expense of the PACS interoperability common for other imaging technologies, such as CT and MRI. The goal of DICOM is to provide a standard for storage and transmission, whereas the IHE mammography profile [48] provides a recommendation for best practice implementation and work

flow. Relevant standards **of DICOM Information Object Definitions (IOD)** are ~~the DICOM DX Image Information Object,~~ the ~~DICOM~~ Digital Mammography X-Ray Image ~~Information Object~~ (MG), ~~the DICOM~~ Mammography CAD SR, ~~the DICOM Accumulated Mammography~~ X-Ray Radiation Dose SR, ~~and the DICOM~~ Breast Tomosynthesis Image**, and Breast Projection X-Ray Image** ~~Storage SOP Class~~. Any of these information objects can be stored for later retrieval.

A. ~~Digital~~ Mammography Image and Data Types

1. The MG information object descriptor includes a specification for 2 types of image information. "For processing" represents image data that are corrected for detector acquisition but not processed for interpretation. "For presentation" image information has been processed by vendor-specific algorithms and is ready to be displayed on a workstation.

    a. "For processing" image data require mammography-specific algorithms to produce a high quality image for interpretation. Mammography CAD devices most commonly use "for processing" image data.
    b. "For presentation" image data are processed for display on any DICOM-compliant and calibrated monitor acceptable for mammography viewing. DICOM presentation state information enables the reproduction of the appearance of the image on different display devices or media.

2. **For DBT, the following 2 or 3 types of image data are created:**
    a. A sequence of low-dose 2-D projection images, conceptually similar to 2-D mammograms but acquired at different X-ray tube angles and using a lower dose per image. These projections may be stored for future reference in a DICOM standard format but are generally only used at the time of acquisition to form reconstructed DBT images.
    b. DBT images or "slices" are a stack of 2-D mammogram-like images that make up the DBT volume. In general, the DBT images are oriented parallel to the detector surface. DBT images are stored as a DICOM breast tomosynthesis object (BTO), or sometimes as a proprietary DICOM secondary capture object (SCO).
    c. A synthetic mammogram (optional), which is generated from the DBT projection and/or volume data by use of a proprietary algorithm. The synthetic mammogram should be stored as a DICOM MG "for presentation" image or DICOM BTO.

3. Mammography CAD devices produce a DICOM mammography structured report and presentation state that may be used by other mammography workstations to display the results of the mammography CAD process.

4. ~~Digital~~ **M**ammography acquisition devices may transmit all types of image data to other storage devices, display devices, or postprocessing devices such as mammography CAD systems (see Figure 1).

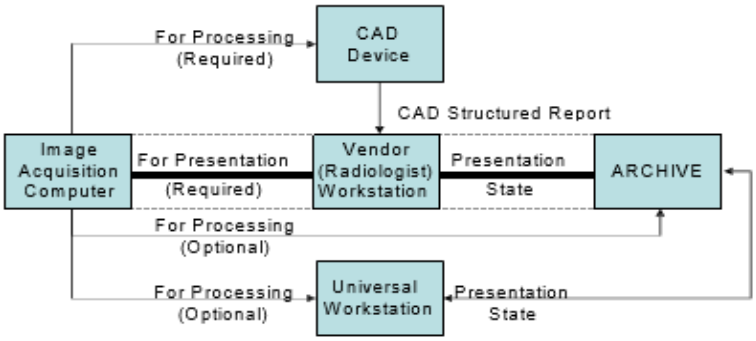
5. Since many mammography CAD systems require "for processing" images, vendors of ~~digital~~ mammography acquisition devices should ensure that the devices support DICOM transmission of both "for presentation" and "for processing" MG images.

6. Telemammography demands high speed networks and/or compression (see below). Reasonable transmission speeds may make the difference between an efficient~~, successful~~ service and **an unsuccessful one** ~~failure~~.

7. Other considerations regarding image datasets

    a. File sizes of stereotactic biopsy unit images are typically 0.5 to 2 MB per image.
    b. Breast MRI, breast ultrasound, breast CT, and DBT are modalities that typically produce a large number of images and, for breast CT and DBT, very large data sets.

Figure 1. Flowchart of image data distribution



B. Workstation

1. The mammography display workstation must support receipt of DICOM-compatible MG images, DBT data sets, and mammography CAD structured reports "for presentation."

2. Display of new data "for processing" should be optional and configurable for ~~digital~~ mammography workstations.

3. The display system should support DICOM query and retrieve ~~digital~~ mammograms from a DICOM archive.

4. Support for DICOM presentation states for displaying images with the ability to save and retrieve various presentation states as specified by the user is required.

5. Mammography workstations should support the IHE Consistent Presentation of Images Integration Profile and the IHE Mammography Image Profile (see the IHE Radiology Technical Framework, Supplement 2006-2007 [48]).

6. A universal workstation should:
   a. Properly display "for processing" and "for presentation" MG data, with mammography-specific hanging protocols and support for the IHE Mammography Image Profile.
   b. Provide user-defined processing algorithms for ~~digital~~ mammograms as well as display acquisition-defined "for presentation" algorithms and Lookup Tables.
   c. Allow multimodality image viewing of associated breast imaging studies (eg, ultrasound, MRI, CT, PET/CT, biopsy specimens, stereotactic images, surgical specimens, and other pertinent studies).

C. Archive

1. The archive device for ~~digital~~ mammography should support DICOM receipt of MG images and DBT data sets.

2. Storage of "for presentation" images is required to ensure the ability of radiologists to reproduce the original images used for interpretation. The "for presentation" image set must be archived to PACS and be viewable with comparable quality on different but suitable workstations.

3. Storage of images "for processing" is encouraged but is not required. The "for processing" image data storage is optional, with the possible exception of mammography CAD, which might require storage of the "for-processing" data. Each facility should carefully consider the ramifications of archive space necessary for additional storage of the "for processing" images as well as the potential downstream benefit and legal implications of reprocessing these data to create new "for-presentation" image sets for future comparisons.

Storage of these data sets should not be required for technical reasons but may be required for local medical-legal ones.

4. Storage of mammography CAD SRs is recommended but should be optional. However, those who choose to discard the mammography CAD information on which they based their interpretations should understand that the only way to reproduce the original mammography CAD data is to retain the original report. Reprocessing may yield different results. If CAD SR is not stored, the CAD version used at the time of the original interpretation ~~should~~ **may** be documented.

5. The archive device should be able to query and retrieve ~~digital mammograms~~ **FFDM images** and DBT data sets.

6. Prior examinations
   a. If possible, comparison of current studies to prior examinations ~~is strongly recommended~~ **should be performed** (see the ACR Practice Parameter for the Performance of Screening and Diagnostic Mammography **[12]**). Storage requirement estimates should therefore take into account the need to store and access current and prior images.
   b. Prior examinations may be imported from portable media. Prior examinations may have been obtained using a screen-film system, and these can be digitized for softcopy display. Currently, a digital practice of approximately 150,000 examinations per year would produce 25 GB of data per day, assuming nonstorage of the "for processing" images. If the "for processing" images are stored, the data storage requirements will be considerably higher.
   c. Although the FDA does allow the digitization of prior film examinations for comparison purposes, its current guidelines [43] do not allow digitized film images to be the sole source for archival purposes. The original film images must be maintained.

D. Image and Data Compression

Digital ~~mammogram~~ image compression can provide more efficient transmission and storage. The digital image is an exact representation of an inexact noisy signal, with finite limits to the amount of compression that can be applied. **Compression may be defined as mathematically reversible (lossless) or irreversible (lossy).** Mammography images are suitable for compression (lossless or not) because of large black areas outside the breast that do not contain diagnostically relevant information. **Reversible compression may always be used, since by definition there is no impact on the image. Irreversible compression may be used to reduce transmission time or storage space only if the quality of the result is sufficient to reliably perform the clinical task. The FDA does not allow irreversible compression of digital mammograms for retention, transmission, or final interpretation, although irreversibly compressed images may be used as priors for comparison [59]. The reader is referred to the ACR-AAPM-SIIM Technical Standard for Electronic Practice of Medical Imaging [53] for current guidance regarding image compression in mammography.**

~~The type of image, modality, and the objective of the study will determine the amount of compression that can be tolerated. The term "diagnostically acceptable irreversible compression" (DAIC) is mathematically irreversible compression that does not affect a particular diagnostic task [62]. DAIC may be used under the direction of a qualified physician or practitioner with no reduction in clinical diagnostic performance by either the primary image interpreter or the decision makers reviewing the images.~~

~~The ACR and this practice parameter make no general statement on the type or amount of compression that is appropriate to any particular modality, disease, or clinical application to achieve the diagnostically acceptable goal. The scientific literature and other national guidelines may serve to assist the responsible physician in choosing appropriate types and amounts of compression, weighing the risk of degraded performance against the benefits of reduced storage space or transmission time. The type and amount of compression applied to different imaging studies transmitted and stored by the system should be initially selected and periodically reviewed by the responsible physician to ensure appropriate clinical image quality, always considering that it may be difficult to evaluate the impact on observer performance objectively and reliably [63]. Lossy compression is not justified solely by the small cost savings to be realized. The benefits and costs of using lossy compression need to be carefully considered, and~~

~~compression schemes that preserve the high frequency content of microcalcifications should be used.~~
~~If reversible or irreversible compression is used, only algorithms defined by the DICOM standard, such as JPEG, JPEG LS, JPEG 2000, or MPEG, should be used, since images encoded with proprietary and nonstandard compression schemes reduce interoperability, and decompression followed by recompression with a different irreversible scheme (such as during migration of data) will result in significant image quality degradation [62]. DICOM does not recommend or approve any particular compression scheme for any particular modality, image type or clinical application. The U.S. Food and Drug Administration (FDA) requires that when an image is displayed it be labeled with a message stating if irreversible compression has been applied and with approximately what compression ratio [64]. In addition, this technical standard recommends that the type of compression scheme (JPEG, JPEG 2000, etc) also be displayed, since this affects the interpretation of the impact of the compression. The DICOM standard defines specific fields for the encoding of this information and its persistence even after the image has been decompressed.~~
~~For other modalities, the FDA does not restrict the use of compression, but it does require manufacturers of devices that use irreversible compression to submit data on the impact of the compression on quantitative metrics of image quality (such as peak signal to noise ratio [pSNR]) [64]. Since it is known that such simple metrics do not correlate well with human assessment of quality or performance for diagnostic tasks [58], the claim of the manufacturer that irreversible compression is satisfactory may not be sufficient, and the burden remains on the responsible physician to assure that the image quality is sufficient to achieve a diagnostically acceptable goal.~~

E. Legal Challenges

The legal requirements for digital mammography are established by the FDA Final Rule [11] and by the state that has appropriate jurisdiction.

1. For acquisition and interpretation, the legal requirements are the same as those for film mammography.

2. Current FDA regulations require that facilities maintain mammography films and reports in a permanent medical record of the patient for a period of not less than 5 years or not less than 10 years if no additional mammograms of the patient are performed at the facility, or a longer period if mandated by state or local law. The record retention requirements may differ from state to state.

3. Security requirements for disaster recovery of digital imaging are greater than those for film-based imaging. A physically separated redundant archive increases safety of the data and may actually be required in some jurisdictions.

4. Circumstances become more complex for the patient who is seen in more than 1 state as well as for the practice that receives images from more than 1 state. Clearly, the requirements of each jurisdiction must be analyzed carefully.

5. Use of lossy compression for data storage, transmission, and retrieval is not allowed by the FDA.

VII. QUALITY CONTROL RECOMMENDATIONS

A. Acquisition

1. Manufacturer-specific QC procedures are ~~required~~ **approved by the FDA as an alternative standard** under the ~~current~~ FDA rules for digital mammography. ~~and must be followed.~~ Documents provided by the manufacturer of the digital mammography system define the procedures and limits for corrective action for periodic tests (daily, weekly, monthly, quarterly, and semiannually) performed by a designated QC technologist and for annual tests by a Qualified Medical Physicist. These documents are periodically updated, so the technologist and Qualified Medical Physicist need to stay abreast of updated versions of the documents.

2. The ACR Digital Mammography Quality Control Manual [9] for FFDM ~~digital mammography~~ **and DBT** systems has been approved by the FDA as an alternative standard to the manufacturer's recommended quality

assurance program. See the Mammography Quality Standards Act and Program [60].

3. Other requirements regarding the overall QA program mandated by the FDA must be carefully followed. QC for hardcopy devices used for printing of digital mammograms should include implementation of the DICOM GSDF standards for printers [37]. Specific manufacturer or ACR QC test procedures, frequencies, and corrective action limits must be followed for digital mammography displays, workstations, hardcopy devices, and verification of proper grayscale rendition of printed images compared to displayed images is necessary. MITA standards and document templates are available to assist in the recording of these processes [39,40].

B. Image Display and Processing

1. QC guidelines for display monitors include implementation of the DICOM GSDF standard [37] and the mammography-specific recommendations of AAPM Task Group**s** 18 **and 270** [49,50]. Recommendations are also provided in the ACR Digital Mammography Quality Control Manual **[9]** and the ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging **[53]**.

2. QC for image processing of digital mammograms should include interaction with radiologists and verification of reproducible image processing characteristics and proper rendition of images and correct functioning of task-dependent processing.

C. Storage and Archiving

Optimal components of digital storage and archiving include the following:

1. Verification of DICOM metadata in header and accuracy of information
2. Security and privacy protection
3. Backup and disaster recovery testing

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*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

Development Chronology for this Practice Parameter 2007 (Resolution 35)
Revised 2012 (Resolution 36)
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ACR 2022 COUNCIL FINAL ACTIONS DETAILED REPORT

The ACR Council convened on Sunday April 24, Monday, April 25, and Tuesday, April 26, 2022 at the Washington Hilton. The Council approved the following actions.

The sessions were attended by approximately 800 members, guests, and staff in person and virtually.

No.	RESOLUTION	TYPE	COUNCIL ACTION
1.	ACR Position on Registered Radiology Assistants Legislation	NEW POLICY	ADOPTED
2.	New Process for Comment and Approval of Practice Parameters and Technical Standards	NEW POLICY	ADOPTED AS AMENDED
3.	Ten Year Extension of Policies: (a) Radiation Oncology 8. ~~Electronic Brachytherapy~~ **Electronically-Generated, Low-Energy Radiation Sources (ELS)** (b) Public Health and Radiation Protection 4. Disposal of Low-Level Radioactive Waste (c) Public Health and Radiation Protection 11. Radiation Safety Officer (RSO) Training (d) Radiological Practice and Ethics 2. ACR Policy on Development of Practice Parameters and Technical Standards n. Maintenance of Competence in ACR ~~Standards~~ **Practice Parameters and Technical Standards** (e) Radiological Practice and Ethics 2. ACR Policy on Development of Practice Parameters and Technical Standards z. Practice Parameters and Technical Standards: Written with Other Organizations (f) Radiological Practice and Ethics 2. ACR Policy on Development of Practice Parameters and Technical Standards aa. Collaborative and Conflicting Society Guidelines (g) Radiological Practice and Ethics 2. ACR Policy on Development of Practice Parameters and Technical Standards bb. Practice Parameters and Technical Standards: Uniform CME Statements	POLICY RENEWAL	ADOPTED
4.	ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media	REVISED PP	ADOPTED
5.	ACR Practice Parameter for Continuing Medical Education (CME)	REVISED PP	ADOPTED
6.	ACR Practice Parameter on the Physician Expert Witness in Radiology and Radiation Oncology	REVISED PP	ADOPTED AS AMENDED

7.	ACR Practice Parameter for the Performance of Hysterosalpingography	REVISED PP	ADOPTED
8.	ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI)	REVISED PP	ADOPTED AS AMENDED
9.	ACR–**SPR** Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT)	REVISED PP	ADOPTED
10.	ACR–SPR Practice Parameter for the Performance of the Modified Barium Swallow	REVISED PP	REFERRED
11.	ACR–SPR–STR Practice Parameter for the Performance of Chest Radiography	REVISED PP	ADOPTED
12.	ACR–SPR–STR Practice Parameter for the Performance of Portable (Mobile Unit) Chest Radiography	REVISED PP	ADOPTED
13.	Paid Family/Medical Leave in Radiology, Interventional Radiology and Radiation Oncology	NEW POLICY	ADOPTED AS AMENDED
14.	Environmental Sustainability and Climate Change	NEW POLICY	ADOPTED AS AMENDED
15.	Ten Year Extension of Policies: (a) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies i. Implementation of the Clinical Practice of Interventional Radiology (IR) and Interventional Neuroradiology (INR) (b) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies v. Interpretation of Radiologic Examinations Not Directly Supervised or Monitored by the Radiologist (c) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies w. Managed Health Care (d) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies x. Medical Staff Privileges, Exclusive Contracts, and Economic Credentialing (e) Technologists and Allied Health Professions 9. Business Management Association (f) Technologists and Allied Health Professions 10. Educational Programs (g) Technologists and Allied Health Professions	POLICY RENEWAL	ADOPTED

	19. Radiology Technology Model Scholarship Agreement (h) Third Party Carriers and Compensation 22. Radiologists, Radiation Oncologists, and Self-Referral		
16.	ACR–SIR Practice Parameter for Endovascular Management of the Thrombosed or Dysfunctional Dialysis Access	REVISED PP	ADOPTED
17.	ACR–SIR–SPR Practice Parameter for the Performance of Arteriography	REVISED PP	ADOPTED
18.	ACR–SIR–SPR Practice Parameter for the Creation of a Transjugular Intrahepatic Portosystemic Shunt (TIPS)	REVISED PP	ADOPTED
19.	ACR–ASNR–ASSR–SIR–SNIS Practice Parameter for the Performance of Vertebral Augmentation	REVISED PP	ADOPTED
20.	**ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography (CT) in the Evaluation and Classification of Traumatic Brain Injury**	NEW POLICY	ADOPTED
21.	ACR–ASNR–SPR Practice Parameter for the Performance of functional Magnetic Resonance Imaging (fMRI) of the Brain	REVISED PP	ADOPTED
22.	ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography (CT) Perfusion in Neuroradiologic Imaging	REVISED PP	ADOPTED
23.	ACR–ASNR–ASSR–SPR Practice Parameter for the Performance of Computed Tomography (CT) of the Spine	REVISED PP	ADOPTED
24.	ACR–ASNR–SPR Practice Parameter for the Performance of Intracranial Magnetic Resonance Perfusion Imaging	REVISED PP	ADOPTED
25.	Partnership Track Associates and Substantial Changes in Practice Structure or Ownership	NEW POLICY	ADOPTED
26.	Reinstating the Statement on Medical Staff Privileges, Economic Credentialing and Support for State Legislation	NEW POLICY	ADOPTED
27.	Exclusive Contrast (Res. 2f 2021 Response)	NEW POLICY	ADOPTED
28.	Ten Year Extension of Policies: (a) General 9. ACR Advocacy Networks (b) Chapters 5. Young and Early Career Professional Section (YPS) (c) Finances 1. Membership Dues a. Collection of Chapter Dues	POLICY RENEWAL	ADOPTED

	(d) Advertising 2. Expansion of Public Information Efforts Regarding the Role of Radiology in the Provision and Economics of Health Care (e) Education 2. Resident and Fellowship Training Programs d. Radiation Oncology Residency Matching Program (f) Education 4. Miscellaneous Education Policies c. Subspecialty Certification (g) Legislative – Government 2. Funding (h) Workforce 4. Workforce Studies (see also Workforce in Radiologic Technology) (i) Workforce 5. ~~Shortage of Investigators~~ **Importance of Radiology Research**		
29.	**ACR–AIUM–SRU Practice Parameter for the Performance of Penile Ultrasound**	NEW PP	ADOPTED
30.	ACR–AIUM–SIR–SRU Practice Parameter for the Performance of Physiologic Evaluation of Extremity Arteries	REVISED PP	ADOPTED
31.	ACR–AIUM–SPR–SRU Practice Parameter for the Performance of Transcranial Doppler Ultrasound	REVISED PP	ADOPTED
32.	ACR–AIUM–SPR–SRU Practice Parameter for the Performing and Interpreting of Diagnostic Ultrasound Examinations	REVISED PP	REFERRED
33.	ACR–AIUM–SPR–**SSR**–SRU Practice Parameter for the Performance of the Musculoskeletal Ultrasound Examination	REVISED PP	ADOPTED AS AMENDED
34.	ACR–AIUM–SPR–SRU Practice Parameter for the Performance and Interpretation of Diagnostic Ultrasound of the **Thyroid and** Extracranial Head and Neck	REVISED PP	ADOPTED AS AMENDED
35.	ACR–SABI–SPR–SSR Practice Parameter for the Performance of Magnetic Resonance Imaging (MRI) of the Wrist	REVISED PP	ADOPTED
36.	ACR–NASCI–SPR Practice Parameter for the Performance of Quantification of Cardiovascular Computed Tomography (CT) and Magnetic Resonance Imaging (MRI)	REVISED PP	ADOPTED AS AMENDED
37.	ACR–ASSR–SPR–SSR Practice Parameter for the Performance of Spine Radiography	REVISED PP	ADOPTED
38.	Bylaws Amendment – Article X Rules of Order	BYLAWS	ADOPTED

39.	Bylaws Amendment – Article II, Section I Membership	BYLAWS	ADOPTED
40.	Neiman Health Policy Institute Named Fellowship	NEW POLICY	ADOPTED AS AMENDED
41.	Ten Year Extension of Policies: (b) Radiological Practice and Ethics 3. Position Statements a. Benefits and Limitations of Mammography (b) Radiological Practice and Ethics 3. Position Statements c. Colorectal Cancer Screening (c) Radiological Practice and Ethics 3. Position Statements f. Mammography: Diagnostic Mammography Arising from Screening Mammography (d) Radiological Practice and Ethics 3. Position Statements h. Multidisciplinary Management of Early-Stage Breast Cancer (e) Radiological Practice and Ethics 3. Position Statements m. Sonographic Evaluations (f) Radiological Practice and Ethics 5. Miscellaneous Radiological Practice and Ethics Policies z. Physics (g) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies j. Proprietary Clinical Pathways Policy (h) Radiological Practice and Ethics 5. Miscellaneous Radiologic Practice and Ethics Policies k. Radiologist Admitting Privileges	POLICY RENEWAL	ADOPTED
42.	ACR Practice Parameter for the Performance of Molecular Breast Imaging (MBI) Using a Dedicated Gamma Camera	REVISED PP	ADOPTED
43.	ACR–ACNM–SNMMI Practice Parameter for the Performance of Dopamine Transporter (DaT) Single Photon Emission Computed Tomography (SPECT) Imaging for Movement Disorders	REVISED PP	ADOPTED
44.	ACR–ACNM–SPR Practice Parameter for the Performance of Renal Scintigraphy	REVISED PP	ADOPTED
45.	ACR–SPR Practice Parameter for the Safe and Optimal Performance of Fetal Magnetic Resonance Imaging (MRI)	REVISED PP	ADOPTED AS AMENDED

46.	ACR–AAPM–SIIM Practice Parameter for Determinants of Image Quality in ~~Digital~~ Mammography	REVISED PP	ADOPTED AS AMENDED
47.	ACR–AAPM–SIIM–SPR Practice Parameter for Digital Radiography	REVISED PP	ADOPTED
48.	ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging	REVISED PP	ADOPTED
49.	Sunset the ACR–SPR Practice Parameter for General Radiography	SUNSET POLICY	ADOPTED
50.	Extension of Review Cycle for Two Practice Parameters	EXTEND PP	ADOPTED
51.	Extension of Review Cycle for One Practice Parameters	EXTEND PP	ADOPTED

ADOPTED AS AMENDED

The following Resolution(s) presented to the 2022 Council of the American College of Radiology have been adopted as amended by the Council:

(The amended language is specified by line numbers which correspond to the resolution as noted in the Reference Committee Reports. Language amended by the respective Reference Committee on Monday, April 25, 2022 ***bolded*** *reflecting* ***~~strikethrough~~*** *for deletions and* ***underline*** *for insertions in blue. Language amended by the Council during deliberation on Tuesday, April 26, 2022, is reflected in red.)*

Resolution No. 2 **New Process for Comment and Approval of Practice Parameters and Technical Standards**

BE IT RESOLVED,

that starting with the 2024 Annual Meeting there will be a new process for approval of Practice Parameters and Technical Standards (PP&TS) which will apply to all PP&TS, even those sponsored by multiple organizations, trialed for a period of not less than 2 years; and

BE IT FURTHER RESOLVED,

that all PP&TS will be made available during the field review process for ACR member comment simultaneously, with a common deadline. The comment period will be at least 6 weeks in length and no more than 12 weeks; and

BE IT FURTHER RESOLVED,

a virtual PP&TS meeting open to all ACR Members will be created which will occur at least 3 weeks before the Annual Meeting, with the structure of this meeting mirroring existing reference committee open sessions. Depending on the number of PP&TS up for approval, a small number of dedicated PP&TS reference committee(s) will be formed which will hear testimony on proposed PP&TS language at the dedicated PP&TS meeting; and

BE IT FURTHER RESOLVED,

non PP&TS resolutions will continue to follow the current meeting structure with reference committee hearings at the Annual ACR Meeting; and

BE IT FURTHER RESOLVED,

after hearing testimony at the dedicated, virtual PP&TS meeting, the reference committee(s) will formulate a final draft version of all PP&TS being considered which will be distributed to Council and to co-sponsoring organizations at least one week prior to the Annual Meeting; and

BE IT FUTHER RESOLVED,

the final draft version of the PP&TS will be presented to Council as a consent agenda. Persistent ACR member concerns may be resolved by extraction of an individual PP&TS by an ACR Councilor after a motion. Unextracted PP&TS will be passed with the consent agenda after a simple majority vote by Council; and

BE IT FURTHER RESOLVED,

that extracted PP&TS will go through the reconciliation process again for presentation at the next Annual Meeting unless Council determines, by a simple majority vote, that the PP&TS in question needs to be discussed at the current Annual Meeting due to the importance of having an active/updated PP&TS on the subject; and

BE IT FURTHER RESOLVED,

that should an extracted PP&TS be determined to warrant discussion at the current Annual Meeting, standard parliamentary procedure states that any discussion point not previously brought up during the dedicated, virtual PP&TS meeting is out of order; and

BE IT FURTHER RESOLVED,

extracted PP&TS will revert to the most recently approved version, until superseded by a newer version approved by Council.

BE IT FURTHER RESOLVED,

that at the end of the trial period of not less than two years, the ACR Council Steering Committee will gather specific comments from the leadership of each Collaborative Society involved in the trial PP&TS process.

Resolution No. 6 **ACR Practice Parameter on the Physician Expert Witness in Radiology and Radiation Oncology**

(Line 56)

Information, facts, and results of imaging studies performed after the incident ~~generally~~ should **never** ~~not~~ be used to formulate ~~an~~ **a standard of care** opinion.

Resolution No. 8 **ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI)**

(Lines 169)
Be certified by **the American Registry of Radiologic Technologists (ARRT)** ~~the American Registry of Radiologic Technologists (ARRT),~~ the American Registry of MRI Technologists (ARMRIT) **in MRI**, or the Canadian Association of Medical Radiation Technologists (CAMRT) as an MRI technologist (RTMR).

Resolution No. 13 **Paid Family/Medical Leave in Radiology, Interventional Radiology and Radiation Oncology**

BE IT RESOLVED,

that the American College of Radiology (ACR) recommends that diagnostic radiology, interventional radiology, radiation oncology, medical physics, and nuclear medicine practices, departments and training programs strive to provide 12 weeks of paid family/medical leave in a 12-month period for its attending ~~and trainee~~ physicians, medical physicists, and members in training as needed.

Resolution No. 14 **Environmental Sustainability and Climate Change**

BE IT RESOLVED,

that the ACR will join the Medical Society Consortium on Climate and Health, an organization with dozens of member medical societies which have come together to advance the goals of sustainability and climate change action[6]; and

BE IT FURTHER RESOLVED,

that the ACR will create a task force on radiology's environmental impact and climate change mitigation and adaptation strategies for radiology. This ACR task force will ~~study~~ collaborate with other interested stakeholders to develop a resource for radiology~~'s~~ practice self-assessment of environmental ~~footprint (including supply chains), shifting disease burdens and imaging utilization patterns related to climate change, and resilience~~ impact of radiology ~~practices and departments~~ applicable to ~~climate-related events~~ the diverse practices of ACR members, as well as the ACR itself. ~~Based on this information~~ Also, the task force will identify measures to address and mitigate the deficiencies found in the self-assessment, and disseminate these measures to the ACR members. ~~establish recommendations regarding the need for research, policy, education, and quality improvement initiatives dedicated to energy efficiency, waste reduction, decarbonizing diagnostic and interventional radiology imaging services, and improving resilience of radiology services to climate-related impacts. The findings and recommendations of this~~ The task force will ~~be~~ present~~ed in~~ an interim report in December 2022 and will ~~a final~~ report its progress to the ACR Council at the 2023 annual meeting.

Resolution No. 33 **ACR–AIUM–SPR–SSR–SRU Practice Parameter for the Performance of the Musculoskeletal Ultrasound Examination**

(Lines 609-610)

Video clips of structures of interest in transverse and longitudinal (or orthogonal planes) may be obtained to supplement static images.

Resolution No. 34 **ACR–AIUM–SPR–SRU Practice Parameter for the Performance and Interpretation of Diagnostic Ultrasound of the Thyroid and Extracranial Head and Neck**

(Lines 288-289)

Video clips of structures of interest in transverse and longitudinal (or orthogonal planes) may be obtained to supplement static images.

The AIUM and SPR representatives affirms that in their best judgement the proposed changes would be acceptable to AIUM and SPR. The representative from SRU was not available to affirm the proposed changes would be acceptable to SRU. The proposed changes are subject to ratification by AIUM, SPR and SRU

Resolution No. 36 **ACR–NASCI–SPR Practice Parameter for the Performance of Quantification of Cardiovascular Computed Tomography (CT) and Magnetic Resonance Imaging (MRI)**

(Lines 12-15)

Previous ~~**published**~~ practice parameters from the ACR have provided practitioners with the educational tools to perform ~~MRA, However~~, **This parameter deals** with ~~**continued improvements in the fidelity of advanced CT and MRI scanners and increasingly available advanced imaging methods, there is a clear need for new guidelines on the**~~ quantitative aspects of CT and ~~**MRI**~~ **MR** for cardiovascular imaging.

(Lines 517-526)

The normal **measurements of the LA** and right ~~atrial measurements.~~ **atrium (RA) are dependent upon the modality used to assess volumes.** Echocardiographic standards **using 2-D biplane measurements generally underestimate volumes**~~.~~ ~~however, suggest that the~~ **Limited data exists on the standardization of normative values [REFS A-E]. End-systolic measurements should be performed for both LA and RA linear and volumetric measurements. LA linear measurements are typically performed in the anterior-posterior (or left ventricular outflow tract) view, while RA linear measurements are performed on the 4-chamber view. For LA volumetric measurements, the pulmonary veins should be excluded. Cardiac MR is considered the gold standard for atrial volumetric** ~~**however, echocardiographic data are easily obtainable, and the normal left atrial LA anterior-posterior dimension is less than 4.0 cm during in end-systole and that the is ≤4.0 cm in men and ≤3.8 cm in women, whereas the area is ≤20 cm², and the RA** normal **area is ≤18 cm²** [30]. **However, cardiac MR is considered the gold standard for left atrial volumetric**~~ **measurements and function [53,54].**

(Lines1687-1700)

NEW REFERENCES:

A. **Kawel-Boehm, J CVMR, 2020, 22:87;**

B. **Mahabadi AA, JCCT. Quantitative assessment of left atrial volume by electrocardiographic-gated contrast-enhanced multidetector computed tomography. 2009;3(2):80-87,**

C. Stolzmann P et al, HJEr. Reference values for quantitative left ventricular and left atrial measurements in cardiac computed tomography. 2008;18(8):1625-1634;

D. Stolzmann P, et a; HJIr. Left ventricular and left atrial dimensions and volumes: comparison between dual-source CT and echocardiography. 2008;43(5):284-289;,

E. Stojanovska J, et al EAJAJoR. Reference normal absolute and indexed values from ECG-gated MDCT: left atrial volume, function, and diameter. 2011;197(3):631-637.),

The NASCI and SPR representatives affirm that in their best judgement the proposed changes would be acceptable to NASCI and SPR; subject to ratification by NASCI and SPR.

Resolution No. 40 **Neiman Health Policy Institute Named Fellowship**

BE IT RESOLVED,

that on the ten-year anniversary of the founding of the Neiman Health Policy Institute, the ACR membership acknowledges and states its appreciation for the NHPI's founding CEO, Richard Duszak Jr, MD, and his outstanding accomplishments and benefits provided to ACR members during the NHPI's first decade; and

BE IT FURTHER RESOLVED,

~~**that the Neiman Institute Fellowship in Clinical Effectiveness and Health Policy Research be designated as the "Richard Duszak Jr., MD Fellowship in Health Policy Research.**~~ **that the ACR shall name, rename or establish** ~~**seek to establish**~~ **a Neiman Health Policy fellowship or grant that will be named in honor of Richard Duszak Jr., MD.**

Resolution No. 45 **ACR–AAPM–ACNM–SNMMI–SPR Technical Standard for Therapeutic Procedures Using Radiopharmaceuticals**

(Lines 115-118)

Individuals who are ABR certified in either the Therapeutic Medical Physics or Diagnostic Medical Physics subfield may be qualified with ~~**additional**~~ **appropriate training in radiopharmaceutical therapy consistent with AAPM Report 249 and procedure-specific training in the radiopharmaceutical therapies being performed at their institutions [5]**

AAPM, ACNM, SNMMI and SPR representatives affirm that in their best judgement the proposed changes would be acceptable to AAPM, ACNM, SNMMI and SPR; subject to ratification by AAPM, ACNM, SNMMI and SPR.

Resolution No. 46 **AAPM–SIIM Practice Parameter for Determinants of Image Quality in Digital Mammography**

(Lines 89-96)

Once a system has been purchased, calibrated, and acceptance tested, regularly scheduled quality control (QC) procedures performed by the technologist and annual testing (or as needed) by the Qualified Medical Physicist are required to maintain compliance with the FDA regulations. ~~of the FDA Currently,~~ **These regulations allow mammography quality assurance programs** the ~~**responsibility for**~~ **option to follow** the ~~**development and**~~

~~**provision of**~~ **system specific** QC testing procedures for ~~**the image acquisition system is the specific manufacturer of**~~ **FFDM and DBT systems required to be prescribed** by the image acquisition device~~.~~ ~~Manufacturers of mammography equipment are responsible for developing system-specific QC test procedures.~~ ~~**However**~~ **manufacturer, or those found in** the **recently-approved** ACR Digital Mammography Quality Control Manual **[9]** ~~**has recently been approved by the FDA as an alternative standard to the manufacturer's recommended quality assurance program for full-field digital mammography (FFDM) and DBT systems**~~.

AAPM and SIIM representatives affirm that in their best judgement the proposed changes would be acceptable to AAPM and SIIM; subject to ratification by AAPM and SIIM.

REFERRED

The following Resolution(s) presented to the 2022 Council of the American College of Radiology have been referred to the BOC with instruction to report back to the Council in 2023:

Resolution No. 10	**ACR–SPR Practice Parameter for the Performance of the Modified Barium Swallow**
Resolution No. 32	**ACR–AIUM–SPR–SRU Practice Parameter for the Performing and Interpreting of Diagnostic Ultrasound Examinations**

The 2022 Speaker and Vice Speaker wish to thank the Council Members, Reference Committees, collaborating Societies, and visitors for their valuable contributions to these deliberations.