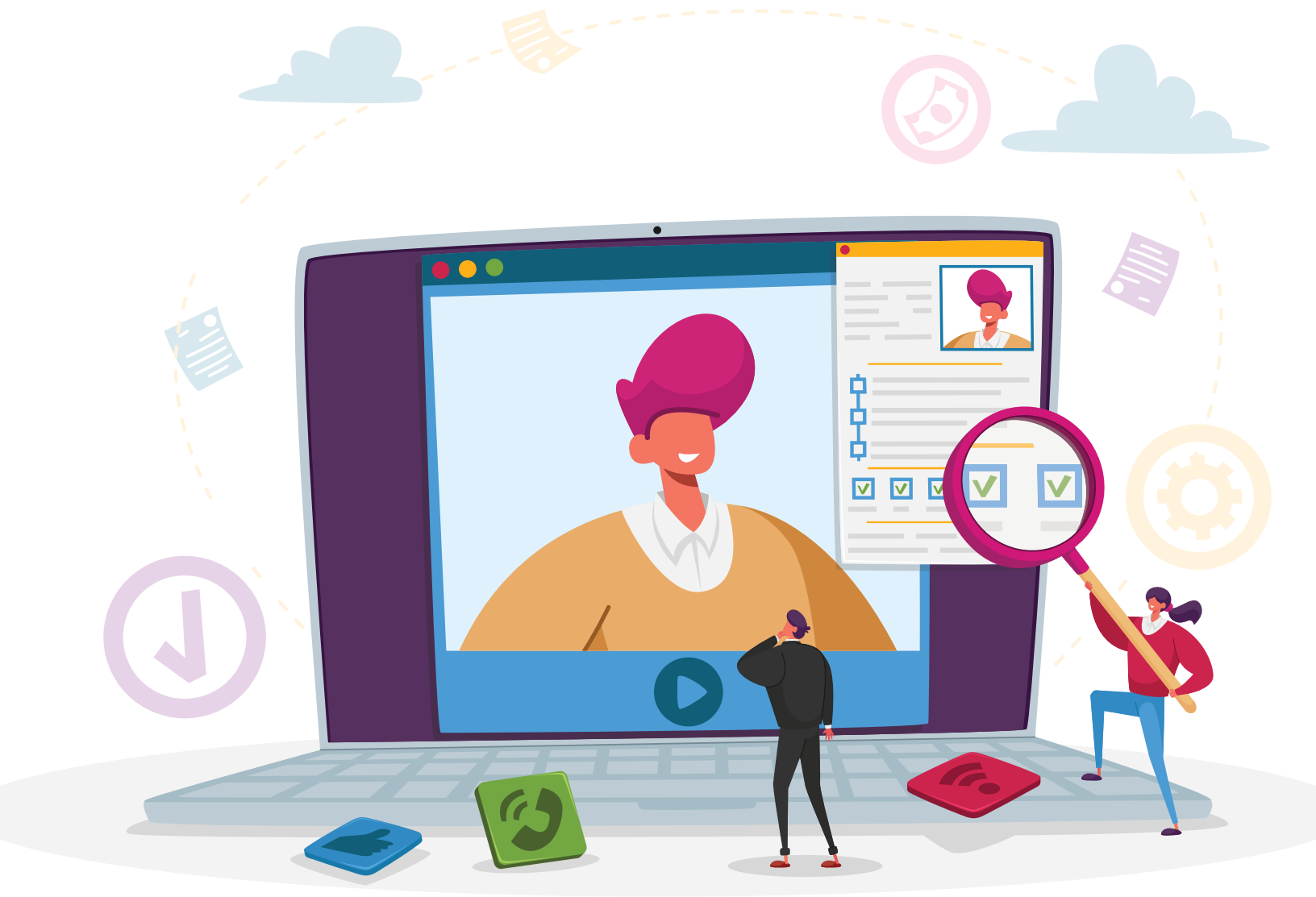


IMAGING 3.0 IN PRACTICE

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EYE ON THE FUTURE
Leveraging technology to
advance patient care



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IMAGING 3.0 IN PRACTICE

Eye on the Future Leveraging technology to advance patient care

Radiology has evolved to become the first truly digital medical specialty. Built on Wilhelm Röntgen's serendipitous discovery of X-rays in 1895, the profession has embraced numerous technological advancements over the years, from the introduction of CT and MRI modalities to the proliferation of interventional procedures and screening examinations. Now, with artificial intelligence (AI) and other advanced informatics coming online, technology remains at the core of the specialty, and we must continue to employ it for the benefit of our patients.

With the shifting focus toward increasingly complex data management in clinical care, imaging endures as an objective and non-invasive source of critical information. This emphasis on informatics and data science means that the radiologist's role of bridging the gap between diagnosis and appropriate treatment has never been more important. It is our responsibility to ensure that we interpret imaging in conjunction with all other relevant available information to empower referring providers and patients to make the best care decisions.

With this in mind, radiologists are developing, adopting, integrating, and leveraging informatics and AI to synthesize data and provide enduring value to patient care. This issue of *Imaging 3.0 in Practice* details how radiologists are mobilizing AI algorithms, 3D printers, interactive reporting devices, and other advanced technologies to solve some of the most complex challenges in healthcare today. The stories and resources herein provide actionable insights for working with these technologies to enhance patient care.

While radiologists are well positioned to harness the power of these tools to lead care delivery into the future, we can't be passive. We must invest personal and institutional resources, time, and effort into expanding our own knowledge and skill base and into positioning our practices for the evolving care paradigm. When we embrace technology that has a positive impact on care, we advance our primary mission: helping patients.

Christoph Wald, MD, MBA, PhD, FACR

Chair, ACR Informatics Commission

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SHARE YOUR STORY

Have a case study idea you'd like to share with the radiology community? To submit your idea, please visit [acr.org/Suggest-a-Case-Study](https://www.acr.org/Suggest-a-Case-Study).

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Integrating AI into the Clinical Workflow

Radiologists at a Massachusetts Hospital integrate artificial intelligence into their workflow to help triage critical cases.

KEY TAKEAWAYS

- Radiologists at Lahey Hospital & Medical Center have integrated six artificial intelligence (AI) algorithms into their clinical workflow.
- The algorithms help diagnose and triage imaging studies for potentially critical findings, prioritizing potentially positive studies and improving patient care.
- The Lahey team encourages all radiologists to familiarize themselves with AI. To help, the ACR Data Science Institute® has developed a web-based catalog called *AI Central*,™ which radiologists can use to learn more about AI algorithms that have clearance from the Food and Drug Administration.

As emergency radiology section chief at a Level 1 trauma center, Jeffrey A. Hashim, MD, knows what it's like to face a backlog of cases. Particularly when working overnight, Hashim says that cases can often pile up. In the past, with no way of knowing which cases were most critical, Hashim and his colleagues at Lahey Hospital & Medical Center in Burlington, Massachusetts, would read through the worklist from top to bottom, quickly opening and scanning each case for urgent findings and hoping they didn't miss anything in the process. It was all "a little anxiety provoking," Hashim admits.

But now, Hashim and his team have help: A suite of artificial intelligence (AI) algorithms combined with workflow orchestration software is triaging cases and moving those with potentially critical findings — including pulmonary embolisms, intracranial hemorrhages, and cervical fractures — to the top of the worklist, alleviating some of the pressure on the radiologists. "I've definitely seen a decrease in my level of anxiety because we know that these algorithms are operating in the background and will detect most of the things that we need to pay attention to right away," Hashim says. "Minutes often matter in these situations. These tools give us peace of mind and are potentially helping us save lives."

Findings detection for improved workflow support is what most radiologists can expect as more practices begin integrating AI into their systems, says Christoph Wald, MD, MBA, PhD, FACR, chair of Lahey's radiology department and chair of the ACR Commission on Informatics. "AI-generated results are increasingly influencing how radiologists prioritize their work," he says. "This could be particularly relevant in scenarios where there is a mismatch between the number of studies to be read and the size of the workforce, for instance during night or weekend shifts when a large number of studies are directed to a smaller number of radiologists than during the regular business hours. The same might apply in certain teleradiology settings in which



Jeffrey A. Hashim, MD, emergency radiology section chief at Lahey, says the AI algorithms help his team prioritize cases with potentially critical findings.

cases from many sites may be aggregated and presented to designated interpreting radiologists in consolidated reading lists."

Recognizing an Opportunity

Radiologists at Lahey began integrating AI algorithms into their workflow in 2018. At the request of referring physicians, the first algorithm they implemented was one that helps detect stroke and shares the diagnosis with providers. "The stroke team asked us to deploy that tool as part of our comprehensive stroke center efforts," says Wald, who is also a professor of radiology at Tufts University School of Medicine. "The solution had been used in most of the big stroke trials and was emerging as part of the standard of care in stroke."

While the benefits of the stroke detection algorithm were proven, AI's impact on radiology in general was unclear at the time, and the Food and Drug Administration (FDA) had cleared only a few algorithms for clinical use. Still, Wald was eager for his colleagues to



Related Resource

ACR's AI Central is a catalog of FDA-approved algorithms and supporting materials to help radiologists make informed decisions about AI implementation. Visit AI Central at acr.org/FDA-Cleared-AI-Algorithms

“We felt that if there was any benefit to be had from AI while we were still figuring out how well it actually worked, it was in case prioritization.”

—Christoph Wald, MD, MBA, PhD, FACR

experiment with the technology. “With the velocity of AI development and the promise it holds for assisting and complementing radiologists in their practice, I felt that we needed to expose our department to clinical AI implementation,” Wald says. “Our approach was mostly designed as a learning journey so that we could become familiar with the vendor contracts and understand firsthand how the technology works in the clinical setting.”

Wald and his team were particularly interested in implementing case prioritization tools, like those that Hashim and his colleagues use to triage cases that require immediate attention for potentially life-threatening conditions. “We felt that if there was any benefit to be had from AI while we were still figuring out how well it actually worked, it was in case prioritization,” Wald explains. “It seemed safe because our radiologists were never too far behind on the worklist anyway. We felt that we could pick up that benefit while we were learning about AI’s detection accuracy.”

Given AI’s potential advantages, Lahey’s radiologists were excited about the technology, but they were unsure how it would impact their work. “I’m sure a few were a little ambivalent at first and wondered, ‘How good is it? Will it replace radiologists?’” acknowledges Mara M. Kunst, MD, neuroradiology section chief at Lahey Hospital & Medical Center. “But the devil is always in the details, and the more we read about it and the more we experienced it, the more we found that AI is a tool that can assist us but not replace us. AI is designed to answer very specific questions. As radiologists, we must read the whole study because we’re the experts, and while the AI is good, it’s not 100% accurate.”

Contracting with a Vendor

Without any data scientists on staff to develop or deploy AI tools, Lahey’s radiologists decided to work with a vendor that Wald met through an ACR event. Wald liked two things in particular about the vendor: It had one AI algorithm that was already FDA cleared for detecting intracranial hemorrhage and several other algorithms in development, and it was willing to collaborate with the department’s worklist vendor to synchronize the algorithms and worklist for case prioritization. “I talked to a few companies and this one seemed easy to work with and agile,” Wald recalls. “Plus, they had a suite of tools under development that focused on critical findings, which was a pretty good match for what we do.”

With a vendor in mind, Wald asked the radiology department’s information technology (IT) team to conduct a review to confirm that the company adhered to best practices, including using both a U.S.-based cloud data center for secure image processing and sophisticated data encryption technology to protect patient information. He also connected the vendor with the neuroradiology team, which gathered a few hundred cases to help evaluate the intracranial hemorrhage algorithm’s detection accuracy. “We were a testing site, so we were interested in seeing how well the algorithm performed,” says Kunst, who led the effort. “The results were in line with what the vendor advertised — with sensitivity and specificity between 90-95%.”

Once the IT team finished its review and the neuroradiology team completed its testing, Wald and other radiology leaders negotiated a price and signed a contract with the vendor. Over the ensuing two years, they worked with the vendor to integrate six algorithms into the department’s workflow as the algorithms received FDA clearance.



Christoph Wald, MD, MBA, PhD, FACR, chair of Lahey’s radiology department and chair of the ACR Commission on Informatics, led AI implementation within the practice.

Integrating the Algorithms

At the start of the integration process, the AI and worklist vendors collaborated to sync their tools for case prioritization. “We wanted to appropriately move those cases that the AI algorithms flagged with positive findings to the top of the worklist so that we could prioritize and read them more quickly,” Hashim explains. “We also needed to see the AI findings clearly, so the vendors created a red (positive) and green (negative) badging system that is visible next to the patient name within the worklist. That way, the radiologist would know whether the AI had detected either a positive or negative finding in the study in one glimpse at the worklist.”

The radiologists also discovered during the post-integration phase that they needed to know when an algorithm was still processing a study; otherwise, they would sometimes sign off on a case before the AI had analyzed it — which resulted in a potential missed opportunity to leverage the technology, Wald says. To that end, the vendor added an additional gray badge that indicates when the AI is processing a case. “As a radiologist, you don’t want to sign off on a report and then have the AI come back saying that it found something that you might have missed,” Hashim says. “You

want to have an opportunity to consider the AI output and include any findings in your report as appropriate.”

For this reason, the practice introduced another safeguard: When an AI result arrives after the corresponding imaging study report is “final,” an obvious alert pops up on the screen of the radiologist of record. This message lets the radiologist know that an AI result is now available on a study they have already signed off on. From there, the user interface offers the radiologist a one-click option to return to the study, facilitating additional review of the images with knowledge of and the ability to correlate with the AI result.

In addition to syncing the algorithms with the worklist, the team wanted to ensure that the AI never posted its representative findings to the hospital’s picture archiving and communications system (PACS) to avoid other providers seeing the outputs before the radiologists. “The moment a result posts to the PACS, it is visible to the entire healthcare enterprise,” Wald explains. “You have no idea who sees it, when they see it, what conclusions they draw from it, and what clinical actions they take. We wanted to ensure that the radiologists could review the outputs and decide whether to incorporate them into their reports. At this point, radiologists use only the vendor’s custom viewer to review AI results and keep all of the AI findings within radiology.”

Working with AI

Even with several algorithms now integrated into their workflow, the radiologists’ work remains relatively unchanged. They still read every case. The only difference is that they read the cases that the algorithms flag for positive findings sooner than they might have otherwise, and they consider the AI outputs in the process. “We’ve established a nice workflow, using the AI as a second reader and checking to see if it’s caught anything before we sign off on our reports,” Kunst says. “It’s a nice tool to have in your back pocket.”

In some cases, the algorithms have detected findings that the radiologists have missed. For instance, before the vendor instituted the processing badge, Wald recalls signing off on a case that the algorithm later flagged for pulmonary embolism (PE). When he reviewed the images again, Wald realized that the AI had noted a small PE that he had missed.

“In an instance like that, you call the referring clinician and let them know that you’ve changed your mind about the results,” Wald explains. “It’s just like when a colleague sees your case the next day in the peer learning system or conference, and they see something that you did not see. It’s not uncommon to fine-tune a report shortly after it was made based on additional clinical information or colleague feedback. Usually this requires additional communication and documentation but doesn’t have a significant adverse impact on patient care. On the contrary, radiologists



Mara M. Kunst, MD, neuroradiology section chief at Lahey, says that AI is a tool that can assist but not replace radiologists.

should never leave an opportunity on the table to improve their report and the care it informs.”

While the AI has occasionally bested the radiologists, it has more frequently missed the mark by reporting false-positive findings. The radiologists track how well the algorithms perform using a feedback loop that the vendor incorporated into the system. If the radiologist agrees with the AI, they note the finding in their report and click a concordance button within the system. If they disagree, they omit the finding from their report and click a discordance button within the system.

“This feedback gives the vendor access to a radiologist-generated ground truth for how their algorithms are actually performing in the real world,” Wald says. “The more the vendor can learn about how their algorithms are performing, from both a usability and functionality standpoint, the more opportunity exists for them to develop tools that help radiologists add additional value to the care team and improve future versions of the algorithms.”

Understanding the Benefits

The vendor isn’t the only one learning when the radiologists use the algorithms. The radiologists may benefit as well. For instance, if the algorithms flag findings in a particular area of an imaging study that a radiologist has overlooked in their initial review, the



The AI and workflow vendors created a red (positive) and green (negative) badging system that clearly displays the algorithms findings. In this example, the algorithm detected right weakness but not trauma.

radiologist knows to double-check that area before signing off on their reports, Kunst explains. "It can be mutually beneficial: You give the AI feedback and the vendor learns, and with careful retrospective analysis, it may help radiologists learn which areas require closer attention," she explains. "It really becomes a partnership and can add to our peer learning efforts."

This partnership ultimately leads to improved patient care because the radiologists can do their jobs better and more efficiently, as has been the case in the emergency room. "Our section was struggling with case prioritization, especially when only one of us is working at night and two or three traumas hit the deck at the same time," Hashim explains. "With our commitment to excellent patient care, we really needed to solve this problem. These algorithms help us identify acute findings more rapidly so that we can communicate them to the clinical team, which can take interventions early and aggressively."

Although the algorithms work well for workflow prioritization and show promise in other areas, the tools won't displace radiologists anytime soon, Wald says. "Most of the time, radiologists are perfectly capable of making all of the key diagnoses, but occasionally they benefit from having the AI," he says. "Radiologists report that they like the 'second look' nature of the technology. But like any other tool, AI has limitations. It's a good tool for addressing specific tasks, but it certainly doesn't work well enough to replace the radiologist."

Adding More Tools

With the successful integration of these algorithms, Lahey's radiologists are considering adding more AI tools to their workflow. Wald is especially interested in algorithms that can do things that are difficult for radiologists to execute alone but that are meaningful to referring physicians and patient care, such as lung emphysema or liver fat quantification. "We're focused on algorithms that can perform quantitative analysis and other tasks that we, as radiologists, cannot easily do," he explains. "That's a big value add that matches the current and future demand in our practice. AI is

expensive to integrate, so we want to be sure that we adopt algorithms that help us improve care, complement our professional work, and enhance our work product."

Wald recommends that other practices also take a thoughtful approach when adopting AI. To help, he says, the ACR Data Science Institute has created AI Central,[™] a catalog of FDA-cleared algorithms and supporting materials. "The FDA has already cleared more than 110 algorithms, so groups should definitely take time to compare them and figure out which ones will best help them achieve their goals," Wald contends. "AI Central includes the FDA clearance summaries, information about the AI marketplaces in which a specific algorithm can be found, performance indicators from the submission documentation, and vendor contact information to help radiologists make informed decisions about which AI algorithms they might want to consider."

While Wald and his team advocate that radiologists take a measured approach when adopting AI into their workflows, they encourage all radiologists to familiarize themselves with the tools and learn how to leverage them for better patient care. "It's a good idea to get comfortable with the technology because it's going to be around in the future," Hashim says. "When integrated properly, these tools can add meaningful value to our profession. We must embrace this technology to ensure we're doing all we can to help the patients we serve."

*By Jenny Jones, Imaging 3.0
publications manager*

Now It's Your Turn >>>>

Follow these steps to begin integrating AI algorithms into your own practice and tell us how you did at imaging3@acr.org or on Twitter with the hashtag #Imaging3.

- » Identify a use case for AI in your practice, whether it's workflow prioritization, finding detection, or quantitative analysis.
- » Compare vendors using AI Central to determine which one can best help you achieve your goals.
- » Work with the vendor to integrate the algorithm into your existing workflow so that the tool is easy for radiologists to use.

AI ASSISTANT'S TOP 10 BLOG POSTS



The ACR Data Science Institute's *AI Assistant* blog offers valuable information and perspectives from radiologists, patients, data scientists, and other stakeholders about AI in medical imaging.

Learn more about the latest trends in medical AI with these 10 most-popular blog entries:

1. Democratizing AI for Radiology
acrdsi.org/Democratizing-AI
2. Four Barriers to Integrating AI into Radiology Practice
acrdsi.org/Barriers-AI
3. Standardization and Structure: Report Requirements for the Future of Radiology
acrdsi.org/Standard-Report
4. Four Steps Radiology Residents and Fellows Can Take Now to Prepare for AI in Practice
acrdsi.org/4-Steps-RadRes
5. The Buzz AI Is Beating Doctors Is Trendy But False
acrdsi.org/The-Buzz
6. The Seemingly Simple Task of Exploring FDA-Cleared Algorithms for Medical Imaging
acrdsi.org/Explore-FDA-Algorithms
7. How to Share Big Data for Artificial Intelligence
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8. My Department's Experience with AI
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9. AI Use Cases 101
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10. AI Has the Potential to Elevate the Way We Practice
acrdsi.org/Potential-to-Elevate



Patient-Friendly Radiology Reports

Radiologists in Colorado collaborate on an interactive and educational tool to help patients read and understand their radiology reports.

KEY TAKEAWAYS

- With increased access to radiology reports through patient portals, patients are eager to understand their imaging results.
- A radiology group and medical imaging center partnered to offer a radiologist-developed tool that creates patient-friendly radiology reports.
- Among patients who access their radiology reports with the tool, 86% report a positive experience.

Natalie Law had been suffering from chronic migraines for years, but when the headaches grew severe, she knew she needed medical attention. In December of 2017, Law visited her primary care physician (PCP), who ordered an MRI. When her PCP asked her to come into the office to review the MRI results, Law knew the news couldn't be good.

The images revealed meningioma, a tumor that forms on the brain membrane and spinal cord. Law was devastated. "It was the last thing I expected," says Law, a social worker and hospital liaison with a rehab skilled nursing facility in Parker, Colorado. "When I received the diagnosis, I was riddled with anxiety. It was overwhelming to process."

Since then, Law's care team, including technologists at Touchstone Medical Imaging and radiologists at Diversified Radiology, has monitored her meningioma with regular MRI scans. After each scan, Law has suffered anxiety about whether the tumor has grown and how it has changed while waiting days for a doctor to call to discuss her scans.

"It was hard when I had to wait for the doctor to call and explain the findings to me," she says. "I started searching for answers online and ended up looking at things that had nothing to do with my situation. My immediate thought was, 'I'm going to die,' and I was so scared."

In late 2020, Touchstone Medical Imaging and Diversified Radiology empowered Law and other patients in their care when they partnered to introduce a new patient portal with a radiologist-developed reporting interface called Scanslated. The portal allows patients to access their reports sooner, and the interactive interface includes definitions and explanations of medical terminology and diagrams of the anatomy to help patients better understand their imaging results.

Law says the new system has eased her anxiety and allows her to participate more fully in her care. "Now, I know what the terms mean and can ask more relevant questions



Jennifer L. Kemp, MD, FACR, vice president of Diversified Radiology and a body imaging subspecialist in Denver, Colorado, recognized the value in the interactive reporting interface to help patients understand their imaging results.

during the consultations with my doctor," she says. "I'm no longer living in constant fear of the unknown."

Seeing a Need

Law is not alone. Research indicates that as patients receive increased access to their radiology reports, they want language that helps them understand those reports, which are traditionally written with the referring physician in mind. When reports are written in lay language, patients can better prepare for appointments and they are empowered in their care.¹

"When patients better understand their radiology reports, they are more engaged in their healthcare," says Jennifer L. Kemp, MD, FACR, who at the time was vice president and a body imaging subspecialist at Diversified Radiology. "They are better positioned to advocate for the care they need when they have

discussions with their physicians and are more likely to adhere to treatment recommendations if they understand the reasoning behind those recommendations. This means that, ultimately, patients will have better outcomes.”

With this in mind, Kemp led an effort at Diversified Radiology, the radiology group that reads images for Touchstone Radiology, to implement a patient portal with interactive patient-friendly reports to help patients understand their imaging results. The project was just one of several patient-centered care efforts that Kemp and the Diversified team has initiated in recent years. In 2017, for example, Kemp helped develop an immediate results delivery program that enables radiologists to speak with patients about radiology results over the phone (read more about this initiative at acr.org/Imaging3-InstantResults).

Kemp got the idea to implement the interactive interface when she met Nicholas T. Befera, MD, during his interview for a vascular and interventional radiologist position with Diversified and was eager to learn more about the interactive, patient-friendly reporting tool that he co-developed called Scanslated.

“I’m passionate about patient-centric radiology because I want the entire patient experience to be easier in radiology, and I want patients to see the value that radiologists bring to the table,” Kemp says. “Scanslated is the first company that I was aware of that offered a patient-friendly radiology report interface, and I was immediately interested.”

Developing a Solution

Befera, who is now assistant professor of radiology at Duke University Medical Center, created the Scanslated tool in 2016 with Ryan G. Short, MD, assistant professor at Mallinckrodt Institute of Radiology at the Washington University School of Medicine. Befera and Short, both fellows at Duke Medical Center at the time, conceived the idea for the patient-friendly reporting tool after patients who accessed their reports through a patient portal began calling with questions about their studies.

“Patients were accessing their reports and having difficulty understanding them,” Befera

says. “We recognized the opportunity to improve the patient experience and increase the visibility of radiologists. We wanted a patient-centered report that could engage and empower patients in a way that hadn’t been possible before.”

To that end, Befera and Short developed software that analyzes radiology reports and provides explanations (written in patient-friendly language) for over 7,000 radiology terms and phrases along with hundreds of interactive diagrams that explain areas of the body in the context of the report. For example, the interface defines *axilla* as “another name for the armpit area. This area is important in breast exams because a small amount of breast tissue extends into it. The axilla also contains lymph nodes.” It also includes a diagram indicating the exact area where the axilla is located.

“It isn’t just a dictionary,” Befera explains. “These are plain-language explanations of terms and phrases that are commonly found in radiology reports. We built the phrase bank over time and are continuously adding to it. All of our explanations are written by board-certified radiologists. They include definitions for non-radiology terms used in a radiology context. Something like ‘unremarkable’ is a great example. The meaning is different in a radiology report than in a dictionary.”

To test the effectiveness of the interface on improving the patient experience, Befera and Short piloted a study. The study asked users on an online crowdsourcing program to review a standard radiology report, a patient letter modeled after the Mammography Quality Standards Act requirements, or the Scanslated interactive patient-centered report.

Befera, Short, and their research team collected data on participant preferences between these three groups for two hours. After that, they surveyed the participants. The results of the survey indicated that participants who accessed the Scanslated report and those who received the patient letter had much better understandings of the radiology reports than those who only had access to the radiology report. Patients who had access to Scanslated were also much more satisfied with the interpreting radiologist, whose



Nicholas T. Befera, MD, assistant professor of radiology at Duke University Medical Center, co-developed Scanslated, an interactive tool that helps patients understand their imaging reports.

photograph, name, and contact information are included as part of the interface.²

Making a Plan

Based on the impressive pilot results, Kemp saw a lot of potential for leveraging the tool at Diversified Radiology, which serves 68 hospitals, clinics, and imaging centers in Colorado and Kansas. After Befera joined the Diversified team in September of 2018, he and Kemp immediately began discussing how they might implement the tool within the radiology group. “We knew we couldn’t roll it out everywhere at once,” Kemp says. “So, we had a conversation about the easiest way to get this initiative off the ground the fastest.”

After discussing the tool with Diversified’s CEO and president, Kemp and Befera decided to approach Touchstone Medical Imaging, an imaging center that partners with Diversified’s radiologists for reading studies. “We knew that Touchstone had a large presence in the area, which could provide more patients with access to the interface and its benefits,” Kemp says, “and we know that they also have an interest in patient-centric care.”

Kemp and Befera reached out to Touchstone's administrative leaders and set up an appointment to meet with them to discuss the tool. In a presentation to the group, Kemp and Befera shared statistics about the value of patient portals, emphasized the challenges that patients face when navigating and understanding radiology reports, and offered Scanslated as a solution.

Touchstone saw offering Scanslated's services as an extension of the patient-centered practices they value. "When the physicians from Diversified Radiology first reached out to us about incorporating this into our shared approach to patient-centric care, we immediately recognized the opportunity to differentiate ourselves from other outpatient imaging centers and to better connect with patients," says Tyler Rauenzahn, Touchstone's vice president of operations for Colorado, Montana, and Nebraska. "We just needed to see exactly how the technology would work in the real world."

Implementing the System

With interest from the Touchstone team and their referring providers, Kemp and Befera turned to the technology. At the time, Touchstone did not have a patient portal, so their first step was for Scanslated's software developers to build a patient portal through which patients could access their imaging

reports. "Once we had buy-in, we had to figure out from an IT perspective how to allow our systems to talk to each other safely as we connected the Scanslated portal at Touchstone with the radiology reports developed at Diversified," Kemp says. The team implemented a HIPAA-compliant two-step verification process to ensure patient records would remain secure.

It took almost a year to develop and integrate the systems, but by November of 2020, Touchstone was ready to launch the tool in a pilot program that focused on a singular modality, X-ray, at three of its 10 imaging centers in Denver. "With any new technology that involves patient care, it's important to roll it out incrementally to make sure it works as intended," Rauenzahn explains. "We wanted to understand how this technology was received among patients who had undergone X-rays before expanding it to modalities used for more acute issues. It was also easier for us to navigate the early phases of the pilot with one type of modality."

Promoting the System

To encourage patients to access their patient-friendly reports via the patient portal, Befera and Kemp distributed flyers to all of Touchstone's participating centers. The flyers explained how the tool works: After a patient receives a scan at Touchstone,



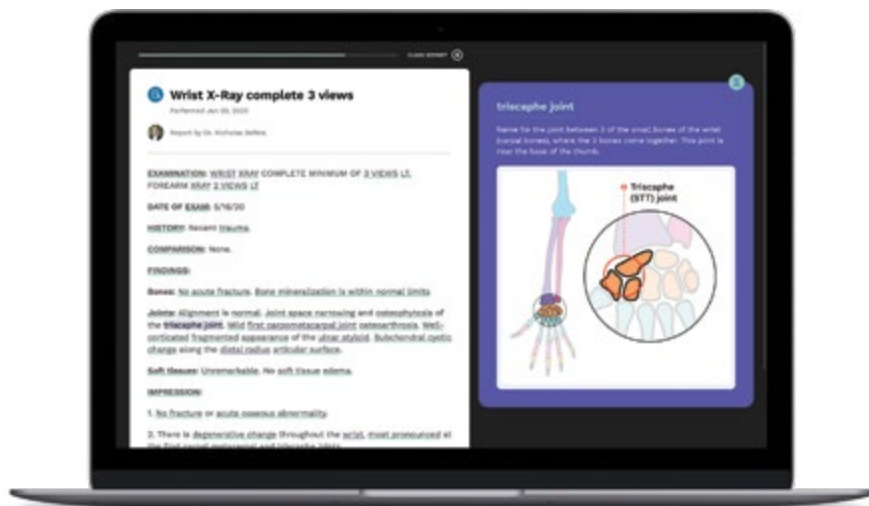
Tyler Rauenzahn, Touchstone Medical Imaging's vice president of operations for Colorado, Montana, and Nebraska, says the interactive reporting interface is an extension of the group's patient-centered care efforts.

the radiology images are sent to Diversified. Once the radiologist reads the images and completes the report, they send their report to Scanslated and the tool automatically annotates it. After that, the system sends an automated text message to the patient with an invitation to access the report via the patient portal.

"Delivering the link via text message allows us to manage the process and ensure that any communication that needs to occur with the referring provider happens before patients access their imaging reports," Rauenzahn says. "Receiving reports in an interactive format with easily consumable language and without having to hunt down a separate link to a website creates a radiology experience that we believe differentiates Touchstone from other providers in our region."

To help patients understand how to access and view their reports, Befera and Kemp developed postcards to distribute to patients. The postcards explain that patients will be contacted through text messaging when their reports are available in the portal, usually within a day.

The cards also describe the secure link that patients will use to access their reports and



Scanslated's patient-friendly interface includes interactive diagrams that explain areas of the body in context with the radiology report.

how to log into the system on their computer or mobile device and navigate the two-step verification process using their name, date of birth, and phone number.

After logging in, they are able to access current and former imaging reports — including studies that occurred before Touchstone began using the tool.

Reviewing the Results

Since Touchstone and Diversified began piloting and subsequently expanding the implementation of the patient-friendly reporting tool, nearly 8,000 patients have viewed over 9,100 reports. Patient response has been overwhelmingly positive, with 86% of patients pleased with the tool. According to one patient's response to a feedback survey: "The educational diagrams and definitions make me, as the patient, feel like I have some insight over my own health instead of feeling left in the dark. Knowledge is a great thing a doctor can give a patient!"

In December of 2020, Touchstone rolled out the program to all of the modalities at seven of its Denver centers. Just in time for the holidays, Law received an unexpected gift — the chance to read and understand her most recent MRI. "Having access to my radiology reports in a way I can understand has helped me cope with accepting that this tumor is a part of me, but it doesn't define me," she says. "I now feel like I have the tools and knowledge to advocate for myself. That is incredibly empowering and so good for my mental health."

Law says that the tool has been helpful to both her and her husband as they navigate her care. "I wish I had this when I was initially diagnosed," she says. "It has helped me take back control. I haven't even touched Google to look up medical questions since I've had access to Scanslated."

Monitoring Results

Patients aren't the only ones who have been happy with the tool. Despite initial concerns about call volume and challenges associated with communicating difficult results, referring providers have also offered positive feedback. "Referring providers were very supportive of

the Scanslated reports throughout the pilot. Early anecdotal feedback indicates we're heading in the right direction," says Rauenzahn, who emphasizes that Touchstone's referring providers share an appreciation for the value of patient-centric care.

Touchstone is continuing to monitor results and feedback from both patients and referring providers while evaluating opportunities to expand this service to all of its imaging centers. The tool has also allowed radiologists to feel more connected to patients. "Radiologists provide a lot of value, but we are often in the background and the patients don't know about the work we do. This is a chance for radiologists to add value to the patient experience in a way that patients can see," Befera says.

In turn, Law feels more connected to her radiologists. She even looks to see if she recognizes the radiologist who read her report. "It sounds strange," she says, "but you are building a relationship with a person you don't know. It is comforting to know I have a number I can call and a hand that I can reach out to if I need it. I'm not alone."

By Chelsea Krieg, freelance writer

ENDNOTES

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Now It's Your Turn >>>

Follow these steps to begin integrating patient-friendly reporting systems into your practice, and tell us how you did at imaging3@acr.org or on Twitter with the hashtag #Imaging3:

- » Put yourself in the patient's position. Consider how imaging reports come across to people without medical training and brainstorm opportunities to institute patient-friendly reports.
- » Consider integrating a patient-friendly reporting interface into your patient portal.
- » Track the impact of your patient-friendly reporting system and make changes and updates to the tool as needed.

MAKING THE MOST OF ARTIFICIAL INTELLIGENCE



The ACR Data Science Institute (DSI) offers a variety of tools and resources to help radiologists derive value from AI in the field.

DSI USE CASES are scenarios in which AI might improve medical imaging care. They help to ensure that AI tools provide needed information, can be implemented into workflows, and have the potential to improve patient care.

acrdsi.org

AI-LAB™ offers radiologists tools designed to help them learn the basics of AI and participate directly in the creation, validation, and use of healthcare AI.

aillab.acr.org

AI CENTRAL™ is a catalog of FDA-cleared algorithms and supporting materials that guides radiologists in selecting the most appropriate AI tools for their clinical setting.

acr.org/FDA-Cleared-AI-Algorithms



DATA SCIENCE
INSTITUTE
AMERICAN COLLEGE OF RADIOLOGY



An Extra Set of Eyes

Radiologists in Virginia are trialing a beta version of an application that uses artificial intelligence to detect findings on CT exams.

KEY TAKEAWAYS

- Radiologists at the University of Virginia Health System have implemented an application that uses computer algorithms to aid in imaging interpretation.
- The technology currently detects coronary calcium scores, pulmonary emphysema, liver steatosis, spine compression fractures, and bone mineral density in chest, abdomen, and pelvis CT scans.
- The app helps the radiologists identify findings that they might not have been able to detect otherwise, potentially leading to enhanced patient care.

It is widely believed that artificial intelligence (AI) and machine learning programs will eventually proliferate throughout radiology. Still, some radiologists are reluctant to adopt these technologies for fear the tools could one day supplant them — although, many experts agree, that won't happen any time soon.¹

Other radiologists, like those at the University of Virginia (UVA) Health System, recognize the value of AI and its related technologies to streamline their workflow and detect findings that they may be unable to see on their own. They understand that these intelligent tools and algorithms, which can learn to identify findings on imaging studies, will empower radiologists to deliver more effective and efficient care, much like new modalities and quality standards have in the past. So when UVA's radiologists got an opportunity to test a beta version of a software application that leverages AI to detect findings on certain imaging studies, they eagerly embraced it.

Now, the app is allowing UVA's radiologists to focus on acute findings while helping them identify pertinent incidental findings that they might not have seen in the past and provide additional information to referring physicians for improved patient care. "We believe that computer algorithms have the long-term potential to help radiologists perform their daily clinical work by enhancing their abilities to interpret large numbers of complex medical images," says Cree M. Gaskin, MD, professor and chief of musculoskeletal imaging and intervention, associate chief medical informatics officer, and vice chair of informatics and operations at UVA. "We became interested in this particular application because it already offers several clinically relevant algorithms in a system that integrates well with our PACS."

The App

The app UVA's radiologists are trialing for research and evaluation purposes is called the Radiology Assistant from Israeli-based medical technology company Zebra Medical Vision, which draws on an extensive library of anonymized imaging cases to inform its algorithms. In beta testing, the app includes algorithms that identify five findings on chest, abdomen, and pelvis CT scans: coronary calcium scores, pulmonary emphysema, liver steatosis, spine compression fractures, and bone mineral density. Soon, the app will also include algorithms that detect additional findings on body imaging as well as findings on breast and brain imaging.

UVA's radiologists began using the app this spring and are already reporting benefits from its integration. Specifically, the app is reminding the radiologists to include these relevant incidental findings in their reports, which is helpful given the large volume of cases they read each day and is particularly useful for residents who are learning to read exams and report findings. What's even more impactful is that,



Cree M. Gaskin, MD, professor and chief of musculoskeletal imaging and intervention, associate chief medical informatics officer, and vice chair of informatics and operations at UVA, led the integration of a beta version of an application that uses artificial intelligence to help radiologists identify findings.

“I’ve been talking with my colleagues and residents a lot about AI and machine learning because I want everyone to be aware of this emerging technology and understand that it’s just like any new modality or tools that we use.”

—Arun Krishnaraj, MD, MPH



Arun Krishnaraj, MD, MPH, associate professor and chief of the body imaging division and vice chair of quality and safety at UVA, believes artificial intelligence tools, like the app, will make radiologists more accurate and efficient.

in the case of bone mineral density, the app is helping the radiologists identify findings that they couldn’t see before.

“We’re familiar with noting coronary calcium, pulmonary emphysema, spine compression fractures, and steatosis of the liver, but we were previously unable to comment on bone density unless osteopenia or fractures were visible, meaning the disease was already advanced,” explains Arun Krishnaraj, MD, MPH, associate professor and chief of the body imaging division and vice chair of quality and safety at UVA. “Now we’re including low bone density because the app is prompting us even before we can visually identify findings of the disease. It’s like having an extra set of eyes to help us provide additional information to referring physicians for optimal patient care.”

A Measured Approach

While UVA’s radiologists are regularly using the app now, Gaskin and his team took a measured approach to implementing it. Initially, they installed the app on a workstation that only Gaskin could access in the musculoskeletal division. From there, he loaded chest, abdomen, and pelvis CTs to see how the app would respond and how it would impact the radiologists’ workflow. “We didn’t want to put something on all of the workstations that would be distracting or cumbersome,” Gaskin explains. “Isolating the initial implementation allowed us to resolve any problems before pulling in anyone else.”

Once it was clear the app would be easy to use, Gaskin began showing it to the department’s body imaging radiologists. He emphasized that the tool would integrate seamlessly into their workflow while

enhancing their quality and contribution to patient care. “Showing tools like this in the flesh allows the radiologists to see how unobtrusive they are and how they can add value by helping to identify findings that radiologists couldn’t see otherwise,” Gaskin says.

After observing the app in action, the radiologists understood its potential to improve care and agreed to install it on their workstations. “I’ve been talking with my colleagues and residents a lot about AI and machine learning because I want everyone to be aware of this emerging technology and understand that it’s just like any new modality or tools that we use,” Krishnaraj says. “So when the radiologists in my division saw the app, they generally already had this mindset that this technology is going to make us better, more efficient, and more accurate.”

How It Works

To the radiologists, the app appears as a simple icon on their workstations while the identification of these specific findings happens automatically in the background. It starts when imaging acquisition is completed and the CT scanner sends the images to the picture archiving and communications system (PACS). The PACS then forwards copies of the images to an on-site server dedicated to the app, which uses algorithms to read the images and then stores its findings for each relevant study on the server.

When a radiologist opens one of these studies in PACS, the app recalls the stored results and uses a color-coded system to relay the findings to the radiologist. If all of the findings are normal, the icon turns

green, and the radiologist takes no further action with the app. If any of the findings are abnormal, the icon turns red, prompting the radiologist to click on the icon to review the results. “With the color-coding, you can look out of the corner of your eye and see whether any abnormalities are detected,” Gaskin explains. “No time is lost to observe the color, and only a single click is necessary to review abnormal results.”

After reviewing the app’s findings, the radiologist can decide whether to include them in the report. For example, if the app indicates that a patient’s bone density is abnormal and the patient has no history of osteoporosis or other bone-density issues, the radiologist might recommend a dedicated dual-energy X-ray absorptiometry (DEXA) scan for further evaluation. But if the medical record shows that the patient has already been diagnosed with osteoporosis, the radiologist would not include the recommendation in the report because the referrer and patient are likely already aware of the condition and treatment is likely already underway. “The app aids in detection of specific findings, but the radiologist remains the clinical expert,” Gaskin says.

Industry Partner

In testing the app, the radiologists are providing feedback to the vendor about its functionality and interface. They also intend to track cases in which they've recommended DEXA scans to see whether patients get the scans and whether the results match the app's findings. "If the app incidentally detects low bone density and a DEXA scan confirms its existence, the patient can start treatment to prevent fractures and other symptoms that could lead to a diminished quality of life downstream," Krishnaraj explains. "Now, suddenly, we've impacted that patient's life, and we've helped lower the costs to the healthcare system as a whole by addressing the issue much earlier than we would have in the past."

UVA's radiologists are hopeful about the app's capabilities and look forward to implementing additional algorithms as they become available. They view their work in assisting with the development of this and other advanced technologies (UVA's radiologists are also part of

the IBM Watson Health Imaging cooperative) as part of their responsibility to ensure patients receive the best possible care. "We're interested in advancing technology and improving care, so it makes sense for us to partner with industry to achieve that," Gaskin says. "We understand what tools are needed to improve care and our industry partners have the expertise to develop these tools. Both sides need each other."

While some radiologists may be apprehensive about integrating such advanced technologies into their workflow, UVA's radiologists are enthusiastic about adopting them and encourage others to do the same. "AI, machine learning, and computational assessment algorithms aren't something to be avoided but rather embraced," Gaskin says. "These tools have a real potential to enhance, but not replace, what radiologists do, allowing us to expand our expertise beyond traditional image interpretation to deliver better and more affordable care to our patients."

*By Jenny Jones, Imaging 3.0
publications manager*

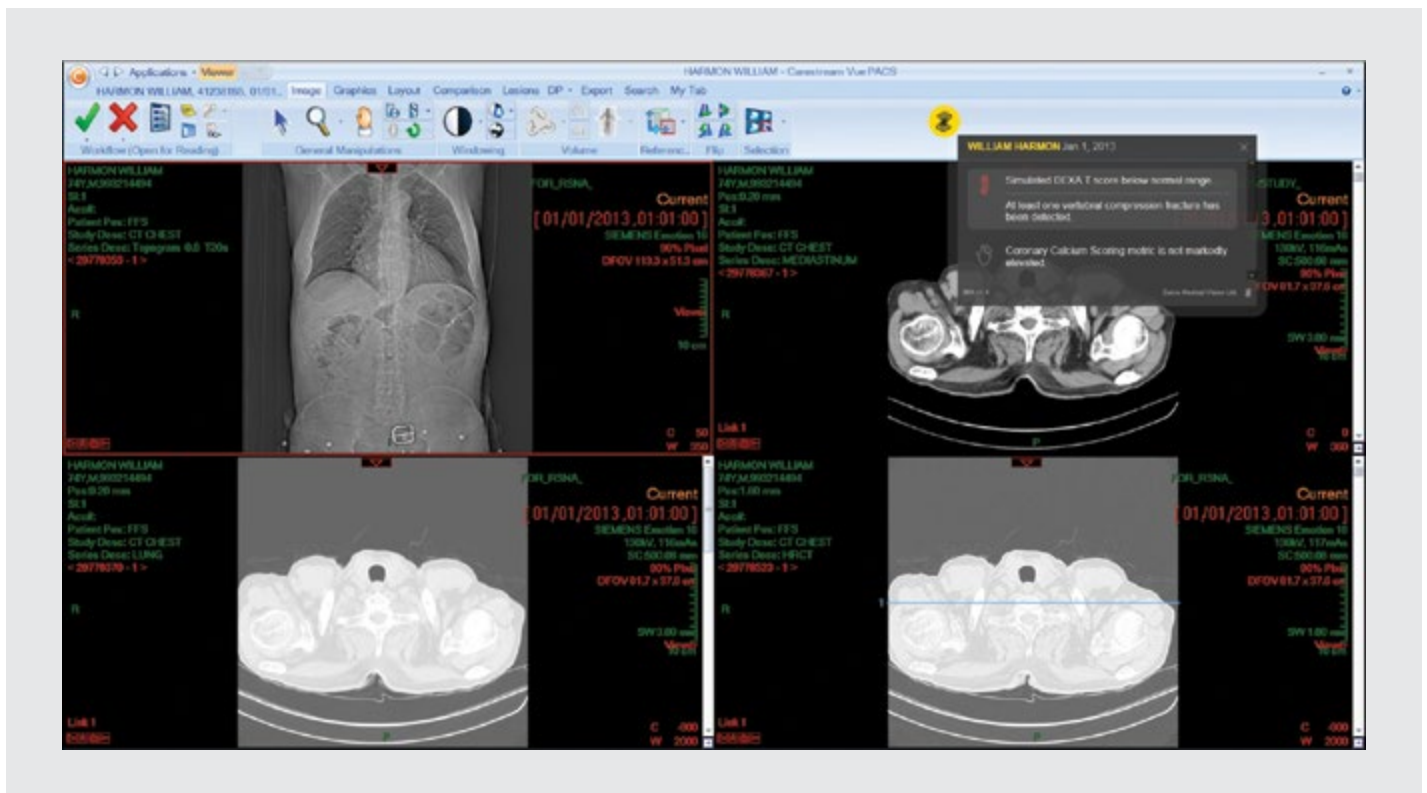
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Now It's Your Turn >>>

Follow these steps to begin integrating AI into your own practice and tell us how you did at imaging3@acr.org or on Twitter with the hashtag #Imaging3.

- » Educate your team about AI, machine learning, computational assessment algorithms, and other advanced technologies, emphasizing their potential to enhance the radiologist's role in patient care.
- » Cultivate partnerships with industry leaders who are developing advanced AI technologies, and consider becoming a testing site.
- » Introduce the technologies in a thoughtful way to ensure radiologists' workflow is not disrupted in the process.



When the radiologist clicks on the icon, the app displays its findings. The radiologist can then decide whether to include the results in their reports.

HOW ARE ACR members using AI?



The ACR Data Science Institute® conducted its first survey of ACR members to understand how radiologists are using AI in clinical practice. While the survey results indicate modest use of AI in current clinical practice, most respondents were satisfied with their overall experience and found it provided value to them and their patients.

OPPORTUNITY FOR GROWTH



33% Respondents **CURRENTLY USING AI** as part of their practice.

CURRENT USES OF AI



Image interpretation



Worklist management



Image enhancement



Automated measurements



Departmental operations

FUTURE PLANS



20%

Practices not currently using AI plan to purchase AI tools in the **NEXT FIVE YEARS.**

CAUSES OF INCONSISTENT PERFORMANCE

Respondents reporting inconsistency **POINTED TO BIAS AS A MAJOR CAUSE.**

94%



NEED FOR PERFORMANCE MEASURES

Respondents indicating they want some form of external **VALIDATION OF AI MODELS ACROSS REPRESENTATIVE DATA SETS.**

60%

Respondents indicating they want to be able to assess the **PERFORMANCE OF AN AI MODEL ON THEIR OWN PATIENT DATA** before deploying it into their clinical workflows.

POPULARITY OF SELF-DEVELOPED ALGORITHMS



More of those using AI in clinical practice were using **ALGORITHMS THEY CREATED THEMSELVES** vs. any single commercially developed algorithm.



MOST POPULAR ALGORITHMS



9.8%
Self developed



9.0%
Screening mammography



6.4%
Pulmonary embolus



5.9%
MR brain analytics



5.7%
Brain hemorrhage

READ THE FULL ARTICLE IN THE JACR AT [BIT.LY/JACR_AI](https://bit.ly/JACR_AI).

Bridging the Communication Gap

To keep families connected with COVID-19 patients, an interventional radiologist and a gynecologic surgeon partnered to develop a communication lifeline.

KEY TAKEAWAYS

- When hospitals like Weill Cornell halted intensive care unit (ICU) visitation to slow the spread of COVID-19, nurses and physicians struggled to keep families informed while providing critical patient care.
- An interventional radiologist and a gynecologic surgeon leveraged app-based walkie-talkies to help concerned families connect with ICU patients through a program called the VoiceLove Project.
- Social workers in ICU and palliative care extended the service to families who can't physically visit their relatives in the hospital, enabling them to connect anytime from anywhere in the world.

Like so many people affected by the pandemic, Albert Palmares could not visit his mother while she was hospitalized for COVID-19. As facilities like Weill Cornell Medical Center tightened their safety precautions to slow the spread of COVID-19, Palmares and other families felt the anguish of isolation as their relatives fought a debilitating disease alone.

Although modern technology offers some contact-free communication, phone calls and video chats come with limitations in a hospital setting. "The only way I could talk to my mom was via iPads when the nurses were available to help," says Palmares, a medical student studying in the Philippines, who called the hospital every day to ask if a nurse would hold up an iPad so that he could chat with his mom. "This just added more responsibilities for the nurses who were busy taking care of patients."

When Palmares returned to the U.S. to support his mom's recovery, he learned about Weill Cornell's new VoiceLove Project, which enabled him to speak directly to his mother anytime, from anywhere, using an app that relayed real-time messages to a small walkie-talkie-style device installed at her bedside in the intensive care unit (ICU). If she was up to it, his mother could also respond by simply pushing a button on the screenless device, which was originally designed as a safe, easy alternative for parents to stay in touch with their children.

The simple technology allowed Palmares and other families to talk to immobilized ICU patients without staff intervention. "Using the device to communicate with her was valuable to our whole family," Palmares says. "It gave us hope and peace of mind that she'd hang on to our words and pull through."

Palmares heard about the VoiceLove Project from Marc H. Schiffman, MD, an interventional radiologist at Weill Cornell who developed the initiative with gynecologic surgeon Tamatha B. Fenster, MD, MS, to



To help ICU physicians during the COVID-19 pandemic, gynecologic surgeon Tamatha B. Fenster, MD, MS, and interventional radiologist Marc H. Schiffman, MD, spearheaded the VoiceLove Project to keep families connected to patients in isolated care at Weill Cornell.

help alleviate constrained communication between stressed medical staff and concerned families coping with COVID-19. By leveraging the walkie-talkie-style devices to solve a multidimensional clinical problem, the VoiceLove Project has made a powerful impact on patient care during the pandemic.

"Even though we can't control the pandemic, the one thing we could control was communication — bringing humanity into a sad situation by allowing families to stay connected during a traumatic time," Fenster says. "There's no reason to let people suffer from separation and lack of communication when we have access to such a simple technology to fix the problem."

Seeing a Critical Communication Strain

When COVID-19 cases began surging in New York City by April of 2020, Fenster volunteered to help in Weill Cornell's busy ICU. She was ready to report for duty, but because

so many physicians across the state offered their aid, the ICU no longer needed her medical assistance. With “a burning desire to help in the height of the pandemic,” Fenster began looking for ways to offer non-clinical support instead.

She heard the hospital’s morning report one day, highlighting how physicians in Weill Cornell’s pop-up ICUs were trying to provide patients’ families with daily updates since the virus had halted visitation. Realizing the challenge of balancing communication with critical care, Fenster conceived the idea to act as a liaison between strained medical staff and families desperate to connect with their loved ones in the ICU.

Fenster called Schiffman, a longtime friend and colleague, and asked him to join a virtual meeting with other attending physicians, nurses, and social workers stationed in the ICU. During the call, Fenster proposed a program called Critical Care Connect, in which she and other volunteers would accompany inundated ICU teams on daily rounds and then call each patient’s family with status updates.

The physicians were relieved to have help, and Schiffman and Fenster began rounding with an ICU team the next day, on Saturday, April 18. As soon as they started making calls, they realized that families wanted more than a brief medical update. “We found that the families didn’t really care about the blood pressure or other medical minutia that we thought was important to share,” Fenster says. “They just wanted to talk to their loved ones. They wanted human connection.”

Recognizing that telephone updates weren’t providing the level of interaction that families craved, medical professionals had been using the FaceTime app on iPads to let family members like Palmares communicate with patients in isolated care. Schiffman and Fenster tried to facilitate these video chats as part of Critical Care Connect, but the challenges piled up quickly.

The video experience made some families uncomfortable. “Their loved ones, who looked healthy just a few weeks ago, were now intubated and hooked up to ventilators,” Fenster says. “That can be a distressing sight to see, so it didn’t give the families solace.”

Call coordination presented other obstacles because it required time and

personal protective equipment (PPE) when medical providers didn’t have much to spare. “During the COVID-19 surge, patients’ families commonly asked us to hold up an iPhone or iPad so that patients could hear their voices,” says Christine Lennon, MD, an anesthesiologist working in a pop-up respiratory ICU at Weill Cornell. “We tried to accommodate these requests when possible, but every time we entered a patient’s room, we had to fully don PPE, which was in short supply. We had to minimize the risk of exposure to the staff while also being mindful of PPE utilization. We had to weigh the emotional needs of our patients and their families against the time and resources required to facilitate these calls.”

Schiffman and Fenster quickly noticed that families were desperate to contact COVID-19 patients beyond the daily medical updates, but they needed a way to communicate without putting the nurses and physicians at increased risk of exposure. “We couldn’t justify using additional PPE just to hold up an iPad for each patient, especially when these brief calls weren’t really helping families,” Schiffman said. “We knew there had to be a better way.”

Brainstorming Better Tools

Recognizing that the hospital desperately needed a more efficient mode of connecting families with patients in the ICU, Schiffman and Fenster immediately began brainstorming options for contact-free communication. They toyed with the idea of walkie-talkies, which could affordably enable two-way conversation, but they would have required coordination to distribute the devices. After searching Google for walkie-talkie alternatives, they discovered Relay — a small, simple push-to-talk speaker that sends and receives messages through a coordinating smartphone app.

After his shift one Saturday night, Schiffman drove to a Target store in Harlem and purchased two Relay devices, which retail for about \$50 each. The next morning, after rounding with the ICU team, he began calling families and asking if they wanted to speak to their relatives in the ICU by downloading the app to convey a message through the speaker placed by the patient’s bedside.



A small hands-free speaker mounted to a patient's bedside relays messages sent from family members anywhere in the world, using an app-based walkie-talkie technology originally designed to let parents contact children without a smartphone.

“The first few families who tried it were so grateful and relieved to finally speak to their loved ones,” he recalls. “Instead of waiting around by the phone all day, desperate to get a call from the hospital, families could use the Relay app anytime, from anywhere in the world, to broadcast a message directly into the patient’s room. As soon as we tried it, we knew we were on the right track.”

To expand this effort, Schiffman knew they’d need more devices. That afternoon, he contacted Relay’s executives, who agreed to donate enough devices for all of the patients on ventilators at Weill Cornell. They even waived the device’s standard monthly subscription fee and streamlined the app interface so that patients’ families could simply open the app and push a button to talk, without entering personal details or billing information.

Later that evening, Schiffman and Fenster emailed their respective department chiefs, explaining their idea to deploy these devices to connect families with patients isolated in the ICU. With their support, Schiffman and Fenster then emailed the hospital’s chief operating officer, who scheduled a

videoconference the next morning to discuss their plans for administering the program. “We knew that if we were going to approach the highest levels of hospital administration to green-light this idea, we’d need a complete proposal that addressed the problems we saw in the ICU and the solutions this device offered,” Fenster says. “As a bonus, the hospital could deploy the devices free of charge.”

After the IT team spent a few days evaluating the software for patient privacy and compliance, Schiffman and Fenster received the final sign-offs to launch the initiative within one week of proposing the idea. “The solution had to be immediate,” Schiffman explains. “It was really to the credit of the Relay executives and the hospital administrators who responded so quickly to move this idea forward. Everyone knew that if we didn’t act fast, people were going to miss their chance to say goodbye to their relatives in isolated care.”

Translating Tech to a Medical Setting

Schiffman and Fenster gradually began deploying more Relay devices in the busiest ICU at Weill Cornell. Within a few weeks, they had distributed about 15 devices across two units. Although the ICU nurses were nearly as relieved as the families to have a hands-free communication option, the staff quickly observed a few limitations of the device.

First, they noticed that the sticky-note-sized device was difficult to place in ICU rooms, where people and equipment moved around frequently. “When you moved the

bed, the device would fall to the ground, and the plug kept getting disconnected,” Fenster explains. “The whole idea is to be hands-free. If the nurse has to keep plugging it in, it defeats the purpose.”

Another feature that made nurses nervous was the button in the center of the Relay speaker that, when pressed, could send messages in response. “In a hospital setting, any device that has the suggestion of two-way communication can be a little bit unnerving,” Fenster says, “because you don’t want to accidentally press the button or broadcast private information.”

The nurses also worried that the tiny holes in the speakers couldn’t be thoroughly disinfected, potentially posing risks for cross-contamination. As these concerns mounted, Fenster and Schiffman began brainstorming again to adapt the consumer device for the medical setting. “We started sketching a case to hold the speaker,” Fenster says. “We came up with a clamshell case that allowed the device to be Velcroed to a bedrail or wheelchair and offered a protective cover that prevented the button from being accidentally pressed and eliminated any cross-contamination. If the case did get soiled, you could just discard it and get a new one.”

Fenster contacted an industrial designer she knew from college to bring their sketches to life. He volunteered his time to 3D print a prototype case that addressed all of the nurses’ concerns about the speaker. Fenster and Schiffman began ordering cases from several local factories, then driving from

Brooklyn to New Jersey to pick up the products.

To mass-produce cases more quickly, they decided to vacuum-mold 1,000 PVC plastic shells through a supplier overseas. Though the production costs quickly added up, Fenster and Schiffman were committed to giving back during the pandemic and covered the costs out of their own pockets.

The cases turned the program into a home run, formalizing the VoiceLove

Project around mid-May of 2020. By the time the cases were produced, the effort had already grown to deploy 40 devices across four ICUs at Weill Cornell, helping families send patients nearly 12,000 messages totaling 3,000 minutes.

Building Buy-In

Although Schiffman and Fenster hoped to expand the initiative as fast as possible, they wanted to ensure they rolled it out properly. To that end, they developed a thorough process to onboard ICU teams unit by unit.

To start, they scheduled videoconferences with nursing directors and senior social workers, who decided which individual units could benefit most from the program based on the volume of requests from families calling frequently to connect with COVID-19 patients. Then, Schiffman and Fenster coordinated in-service training for each unit’s team. “Anytime you’re introducing something novel in a hospital, it’s a challenge because you have to explain that it will actually simplify their job, not add more work,” Fenster says. For that reason, they kept the training quick and simple.

The 15-minute training consisted of a five-minute video that explained the VoiceLove Project, a live demonstration showing how to attach and use the device, and a short PowerPoint that shared testimonials from staff and families who had used it.

The key to building buy-in from each unit was winning over the social workers, who were responsible for explaining the program to families. Fenster and Schiffman equipped them to introduce VoiceLove with simple, three-step instructions that walked families through downloading the app, logging in, and pushing a button to send a message.

“As social workers, we weren’t allowed to go into COVID-19 rooms because of limited PPE. We felt so helpless, and the families felt so disconnected,” says Avery Ornstein, LCSW, a senior social worker at Weill Cornell who covered the ICU during the pandemic. “Having this program was such an amazing link to connect families and bridge this gap by giving them direct access to their loved ones.”

After helping families set up the app, social workers gave the Relay device to a nurse, who would hang the speaker by the



To make Relay’s off-the-shelf consumer device appropriate for medical settings, Schiffman and Fenster had a plastic case designed to protect the small speaker from cross-contamination.

patient's bedside while they were checking vitals or administering medication. The easy installation fit into existing workflows, saving nurses from using precious time or extra PPE. "The VoiceLove Project allowed us to focus our energies on delivering medical care," Lennon says. "During the COVID-19 surge, a lot of us were operating at maximum capacity, so relieving that one burden of family communication really made a big difference."

Improving Patient Care

Many patients' families referred to VoiceLove as a lifeline to their loved ones in the ICU. Without depending on the availability of busy nurses, people like Palmares could use the device to send messages, prayers, songs, and other spontaneous updates whenever they wanted. "Relatives from around the globe were chiming in to encourage and pray for my mom," Palmares remembers. "It was therapeutic for us, and hopefully also for her, to have that connection when we couldn't visit her."

The app works with cellular networks and Wi-Fi to provide unlimited range, allowing family members access from anywhere in the world. "The VoiceLove device enabled multiple family members to communicate freely without feeling like they were burdening the medical staff," Lennon says. "This program helped relieve that feeling of guilt they felt for taking additional time from medical teams that were already stretched thin."

Most importantly, the VoiceLove Project gave power back to patients' families during the pandemic. "What this program provided — more than communication, more than connection — was control," Fenster says. "It provided a sense of empowerment in a situation where people felt helpless. It allowed them to reach out to their family member on their own timeline, whenever they wanted to tell their dad they loved him. It gave them back the control over communication that they were completely robbed of during COVID-19."

As much as families appreciated this unlimited access, certain reactions suggest that patients benefited just as much from the exchange. "The first time I set up a VoiceLove device for one of my patients, his daughter said prayers in his native language," Lennon

recalls. "I could see that he recognized her voice, and his demeanor distinctly brightened in that moment."

Schiffman saw countless examples of positive responses like this, even from patients under sedation. "One patient in particular had not shown much mental status, and discussions had begun about withdrawing care," he says. "But about 10 minutes after hooking up the device, when his grandchild's voice popped over the speaker, his eyes moved. In the following days, every time another family member spoke, you'd see a facial expression or a tear in his eye. We saw obvious changes happening after hearing the family's voices — making it evidently clear that this was making a difference for patients."

Some research suggests that family presence and participation can reduce ICU patients' psychological stress and potentially aid in recovery. Schiffman and Fenster are currently applying for grants to study the program's impact on comatose patients. "We should do everything we can to maximize family participation in this unprecedented situation of social isolation," Lennon says. "There are real benefits to the patients' medical outcomes when they have the emotional support of their loved ones."

Innovating Beyond the Pandemic

Six months after launching the VoiceLove Project in April, Schiffman and Fenster had deployed more than 160 donated Relay devices throughout 11 units at Weill Cornell. As more nurses, social workers, and families heard about the walkie-talkie devices being used to connect with COVID-19 patients, they requested access.

These requests gradually expanded the initiative beyond the ICU into palliative care units, where families were desperate to speak to their relatives one last time before withdrawing care. "Families have repeatedly said that this experience is going to give them comfort for the rest of their lives," Schiffman says.

Even though hospital visitation slowly reopened at Weill Cornell in early June to allow one visitor per patient, the devices are still being widely used. Social workers are starting to administer the in-service training for new units, as Fenster and Schiffman

develop plans to deploy the program at other hospitals in their network.

"We see innumerable applications for this device to continue to connect patients with their families — not just during the pandemic, but afterwards," says Schiffman, suggesting that radiology patients could use the VoiceLove devices when they don't have cell phone access or reception while waiting for exams. In neonatal ICUs, parents could use the devices to sing to their newborn babies before holding them. Likewise, the device could connect families with patients in pre-op and post-op settings with limited physical visitation.

Although an interventional radiologist and a gynecologic surgeon might seem like an unlikely pair to spearhead an urgent communication initiative, Schiffman points out that radiologists are known for constantly applying new technologies to medicine.

"Technology is going to drive a lot of change in medicine going forward, and as radiologists, we're in a unique position to pioneer technical innovations that can really improve patient care," he says. "Not all medical technologies have to be designed specifically for a hospital. By adapting this simple existing technology to work in a hospital setting, we're helping people stay connected in the short-term and reshaping hospital communication over the long-term."

If you would like to obtain VoiceLove for your hospital, please email: voicelovedoctors@gmail.com.

By Brooke Bilyj, freelance writer

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- » Evaluate how simple consumer technologies might improve the patient- and family-centered care experience.
- » Collaborate with frontline medical staff to adapt existing technologies into demanding hospital workflows without adding time or hassle.
- » Consider the families' needs and concerns when contact with patients is limited, instead of assuming that they find brief medical updates meaningful.



A Moral Duty

Radiologists and engineers design a 3D-printed surgical mask in response to shortages of personal protective equipment.

KEY TAKEAWAYS

- Radiologists and engineers at Vanderbilt University Medical Center have developed a 3D-printed surgical mask in response to the national shortage of personal protective equipment.
- The team leveraged existing resources to create a design that is intended to be used with almost any 3D printer to create a mask that fits most face shapes.
- Once design testing is completed, the team plans to share the digital file with healthcare providers impacted by the COVID-19 pandemic and other health crises around the world.

When the team that leads the 3D-printing lab at Vanderbilt University Medical Center (VUMC) heard that the nation's physicians and other healthcare providers on the front lines of the COVID-19 pandemic were running low on personal protective equipment (PPE), they saw an opportunity to help.

With many frontline providers forced to reuse single-use N95 masks or even use homemade cloth face coverings as inadequate alternatives to the masks that filter 95% of airborne particles, the team focused on leveraging the lab's 3D-printing technology to develop a comparable N95 mask substitute. Now, the team is testing their design — which they plan to share freely so that others can easily make the masks using any 3D printer.

Associate Professor of Radiology and Pediatrics Sumit Pruthi, MD, founded VUMC's 3D-printing lab in 2018 and has been overseeing the N95 mask replacement project since early March of 2020. He is working with a team on the project: diagnostic radiology resident Cameron E. Henry, MD, and 3D engineers Brent D. Griffith and Gary R. Drake.

"We became aware that hospitals and other facilities were exhausting their supply of PPE and that frontline physicians and nurses were reusing and trying to sterilize PPE," says Pruthi, who is also chief of pediatric neuroradiology and pediatric radiology fellowship director at Monroe Carell Jr. Children's Hospital at Vanderbilt. "We know that without proper equipment, providers are at risk for infection, so we saw it as our moral duty to direct all of our efforts to create something that could reduce the use of PPE."

Recognizing that COVID-19 spreads through airborne particles and that N95 masks were in short supply, Pruthi and his team decided to make a surgical mask that could filter these contagions. Their goal was to design a mask that was simple enough to make on any 3D printer without requiring a lot of material or time. The team ultimately



Sumit Pruthi, MD, pediatric radiology fellowship director, radiology and pediatrics associate professor, and chief of pediatric neuroradiology at Monroe Carell Jr. Children's Hospital at Vanderbilt, is overseeing a project to produce 3D-printed surgical masks in response to the personal protective equipment shortage.

designed a reusable mask made of antimicrobial plastic to cover the wearer's nose and mouth with two removable valves that hold disposable exhalation and inhalation filters, which can be cut from existing N95 masks.

"We're basically using the same N95 filtration material that has been tried and tested by the Food and Drug Administration for the exhalation and inhalation areas of the mask, except that we're using only 1/12 of the N95 material and 3D printing everything else," Pruthi explains. "With our design, if a physician has three N95 masks, he or she can cut them into 18 different pieces, and those pieces will become, essentially, 18 masks."

Leveraging Existing Resources

Pruthi was inspired to develop PPE after he received an email from a company that had designed a 3D-printed, hands-free door opener to help stop the spread of germs

“I thought, ‘We have an established 3D-printing lab; we need to do something like this to help our colleagues in the healthcare community.’”

—Sumit Pruthi, MD

that can transmit viruses like those that cause COVID-19. “The company was freely distributing the digital file, which can be used to make the door opener on any 3D printer,” Pruthi says. “When I saw that email, it really piqued my interest, and I thought, ‘We have an established 3D-printing lab; we need to do something like this to help our colleagues in the healthcare community,’ and that’s how it all started. I reached out to the 3D-printing team, and they were eager to help.”

When Henry learned about Pruthi’s plans to develop PPE, he suggested that the team leverage existing materials to make surgical masks. “Given that this is a respiratory illness, I started with the masks because it seems that prevention of the spread of the disease is what’s most important right now. My main goal was to make something that would protect people as both a fluid barrier and a filtration unit,” Henry explains. “That said, we weren’t looking to reinvent the wheel in terms of making a mask from new material. Our goal was to conserve material so that one N95 mask that one would traditionally wear would provide six masks’ worth of materials if allocated correctly and cut appropriately to serve as filters in our 3D-printed mask.”

Along those same lines, Henry and the team didn’t want to spend a lot of time creating a new design from scratch. Instead, they searched a crowd-sharing 3D design website for mask concepts that others had already developed. “We saw several models, and some of the designs were really good structurally, but a lot of them had problems with fit,” Henry explains. “They didn’t work across a variety of faces — be it thin faces or round faces. So, we decided to

take a model that we thought had a solid foundation and customize it.”

Developing a Prototype

Part of the customization effort involved considering appropriate materials from which to print the masks. They ultimately settled on an antimicrobial plastic called Plactive AN1, which is widely available, relatively inexpensive, and easily manipulated to create a safe and effective fluid barrier. “We wanted to be sure that if we sent our printer file to someone, they would be able to get the material and print the masks with a low-cost printer,” Pruthi explains. “The other thing we considered was the time that it takes to print the masks. In some cases, 3D printing can be time-consuming, especially for complex designs. We wanted a model that is relatively quick to print on pretty much any 3D printer.”

The team then concentrated on achieving a universal fit. They used a digital application to scan several face models to create a mask that would fit most face shapes. “I averaged the models to give us a general fit for almost any face type,” Henry says. “But if someone wants to have a more personalized fit, they could use this app with an image of their own face to get a custom fit. We wanted people to have the flexibility to make it their own while ensuring that the mask provides a high level of protection against airborne particles and fluids for most wearers.”

From there, the team fine-tuned the mask’s fit and the inhalation and exhalation valve placement. “We reiterated model after model based on what we thought would make it easy to breathe in and out — with valves that would cover a little bit of the



Diagnostic radiology resident Cameron E. Henry, MD, came up with the idea to make surgical masks, recognizing that COVID-19 is a respiratory illness and appropriate masks are critical for protecting frontline healthcare providers.

nose and a little bit of the mouth,” Henry says. “We were trying to see where preferentially air goes and where air might leak. We went through at least four or five masks to achieve that preferential airflow with an appropriate seal.”

Testing the Mask

It took the team about two-and-a-half weeks to develop a universal mask prototype. Now they are conducting synthetic blood and saccharin testing to ensure the mask performs as intended. “Testing is critical to making sure the mask is safe for providers to use and that it provides the fluid and filtration barrier that it should,” Pruthi says. “It’s easy to come up with a prototype, but testing is the big hurdle. That’s where being patient, being cautious, and being meticulous come into play.”

In addition to testing the mask’s performance, the team is also conducting tests to verify that the mask can be replicated on any 3D printer. “We’re really trying to refine the process because you can have five different 3D printers, and you can set them on many different parameters, and you will get microscopic and even macroscopic differences in the mask,” Henry says. “We’re

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“I see this project as a step toward expanding 3D printing in medicine for the long term and reaching populations in need.”

—Cameron E. Henry, MD



The reusable mask is made of antimicrobial plastic to cover the wearer's nose and mouth with two removable valves that hold disposable exhalation and inhalation filters, which can be cut from existing N95 masks.

trying to standardize the process so you can print an effective respirator using the pre-defined settings on any 3D printer.”

Sharing the Design

Once all of the testing is completed, the team plans to share their design file with other healthcare providers who need N95-quality masks as they respond to the COVID-19 pandemic and other medical emergencies worldwide. “I’m not looking at this as a one-off for the COVID-19 pandemic and that’s it,” Henry says. “Hundreds of places around the world are constantly under public health crises and don’t have large supply chains at their disposal. I see this project as a step toward expanding 3D printing in medicine for the long term and reaching populations in need.”

With that in mind, Pruthi says that radiologists are well positioned to lead the expansion of 3D-printed technology in medicine. “Many of the 3D printing labs in North America, particularly in academic medical centers, are led by radiologists, and that’s because 3D printing often starts with imaging,” Pruthi explains. “As radiologists, we understand imaging best; therefore, we are the first line of quality control in 3D printing for medical applications, and we are positioned to contribute. This is a unique opportunity for us as radiologists to meet the needs of providers affected by this PPE shortage and health-care crises around the globe.”

*By Jenny Jones, Imaging 3.0
publications manager*

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- » Identify a personal protective equipment need that you and your team can help address.
- » Create a design that will work for most people who need the equipment that you develop.
- » Test and validate your prototype to ensure it performs as intended and is easily replicated.

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