An Intelligent Future for Medical Imaging: A Market Outlook on Artificial Intelligence for Medical Imaging

SA-CME

Alan Alexander, MD, MSc, Adam Jiang, AB, Cara Ferreira, PhD, Delphine Zurkiya, PhD

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Abstract

Radiologists today are under increasing work pressure. We surveyed radiologists in the United States across practice settings, and the overwhelming majority reported an increased workload. Artificial intelligence (AI), which includes machine learning, can help address these issues. It also has the potential to improve clinical outcomes and raise further the value of medical imaging in ways yet to be defined. In this article, we report on recent McKinsey & Company work to understand the growth of AI in medical imaging. We highlight progress in its clinical application, the investments that are backing it, and the barriers to broader adoption. We also offer a view on how the market will develop. AI is set to have a big impact on the medical imaging market and hence on how radiologists work, helping them to speed up scan time, make more accurate diagnoses, and ease their workload. As AI in medical imaging increasingly proves its worth, it is hard to imagine that AI will not ultimately transform radiology.

Key Words: Artificial intelligence, cloud, investments, machine learning, solutions

J Am Coll Radiol 2020;17:165-170.

INTRODUCTION

Radiologists today are under increasing work pressure. In a survey of 50 radiologists practicing in the United States, 90% reported their workload had increased over the last 3 years, and 28% said it had increased by more than 20% (Fig. 1). The primary reason, cited by 78% of those who reported a heavier workload was the increasing number of scans. As the academic literature affirms, the more scans conducted, the greater the need for radiologists to read them quickly yet accurately [1].

Artificial intelligence (AI), which includes machine learning (ML), can help address these issues. It also has the potential to improve clinical outcomes and raise further the value of medical imaging in ways yet to be defined. In this article, we therefore report on recent McKinsey & Company work to understand the growth of AI in medical imaging. We highlight progress in its clinical application, the investments that are backing it, and the barriers to broader adoption. We also offer a view on how the market will develop.

This article builds on our 2018 review of emerging technologies in medical imaging published in this journal, when we identified AI as an important trend that would shape the medical imaging market of the future [2].

PROGRESS IN THE APPLICATION OF AI IN MEDICAL IMAGING

There has been clear progress in the use of AI in different imaging modalities and different therapeutic areas since our last review. For example, one study this year showed AI was able to identify and distinguish between four different diseases in chest radiographs—pulmonary malignant

McKinsey & Company, New York, New York.

Corresponding author and reprints: Alan Alexander, MD, MSc, McKinsey & Company, 55 E 52nd Street, New York, NY 10022; e-mail: alanradiology@gmail.com.

The authors state that they have no conflict of interest related to the material discussed in this article.

1546-1440/19 ■ https://doi.org/10.1016/j.jacr.2019.07.019

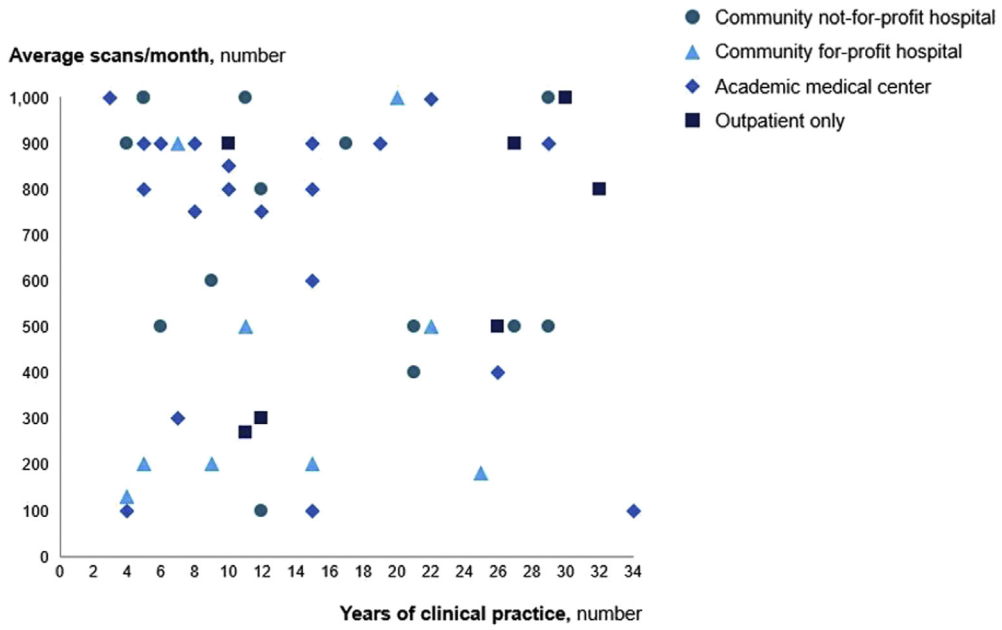

Fig 1. We surveyed 50 radiologists with a range of clinical experience, working in a range of practice settings, with different patient throughputs.

neoplasms, including primary lung cancers and metastasis; active pulmonary tuberculosis; pneumonia; and pneumothorax. That is an important development given the high prevalence of these diseases and AI's potential to help radiologists identify and prioritize patients with the most severe or complex cases. The study also demonstrated AI's effectiveness as a second reader in conjunction with a radiologist by, for example, enhancing lesion localization [3].

Another study showed AI-based computer-aided design software flagged fewer false-positives per image in digital mammograms than FDA-approved computer-aided design software, with no reduction in sensitivity [4]. And there have been noteworthy developments for AI in other areas too, such as the treatment planning of brain tumors and the identification of catheters and tubes in pediatric x-ray images [5,6].

INVESTMENTS IN THE SPACE ARE BOOMING

The technology's clear potential is driving a surge in investments in start-ups and growing interest from larger companies.

More Start-ups That Are Less Well-Funded

McKinsey's Startup and Investment Landscape Assessment scan, described fully in our previous publication, identifies global investments in new companies that are using innovative technologies relevant to the medical imaging market [2]. Our latest scan showed investments in AI-based medical imaging companies reached $1.17 billion between January 2014 and January 2019. That is double the amount we reported for the 2012 to 2017 period, and the number of companies in the market segment have more than tripled, to 113 from 32 previously. Worth noting, however, is that the median investment has fallen from $6.8 million to $4.8 million, and the average number of investments per company has fallen from 2.9 to 1.9 (E-supplement Fig. 1). In short, although investors continue to have a strong appetite for AI-related investments in medical imaging, high demand for their funding has resulted not only in many new start-ups, but smaller and less well-funded ones since 2017. This fragmentation, as we will discuss later, could partly explain the slow pace of adoption of AI in medical imaging.

Established Players Joining In

Large, established diagnostics companies have also been making investments in AI-assisted medical imaging, either through acquisitions or partnerships, or by building their own capabilities. For example, in November 2018, Samsung Electronics showcased AI products that detect breast lesions using ultrasound, lung nodules using chest x-rays, and intercranial hemorrhage using CT [7]. It also showed how AI could improve the image clarity and interpretation of MRIs in certain conditions, such as arthritis of the knee. That same month, Siemens Healthineers introduced an AI solution that highlights and measures potential abnormalities on a chest CT [8]. In parallel, GE Healthcare formed a partnership with Intel to apply AI to a range of medical imaging formats [9]. And in March, Philips acquired Carestream Health's health care information

systems unit, which has been utilizing AI to help diagnose and prioritize patients with osteoporosis, lung emphysema, coronary calcification, and fatty liver [10].

Many of these moves by diagnostic companies into AI-assisted medical imaging follow their earlier investments in cloud infrastructure to give them storage solutions for big data—the data that are now key for training the algorithms on which AI depends. In other words, growth in investments in AI is being supported by growth in investments in the cloud, amounting to over $435 billion in cloud-focused medical imaging transactions between January 2014 and March 2019, according to our latest Startup and Investment Landscape Analytics (SILA) scan. Most investments in cloud are by large, long-established health care–related companies or by software companies not previously invested in health care, such as Thermo Fisher, Parexel, or Digital Gateway, although there are some start-ups as well. This level of investment can only support the future growth of AI in medical imaging. In a world of AI, the utility of cloud-based storage is magnified, because developing accurate algorithms depends on the storage and manipulation of large data sets and computing power made possible on a cloud platform.

Finally, large tech companies such as Google, Apple, IBM, and Microsoft are also showing keen interest in AI-assisted medical imaging. For the time being, however, most are supporting others' AI solutions. Google, for example, has partnered with Zebra Medical Imaging, Change Healthcare, and Kanteron Systems, companies all involved in the application of AI in medical imaging [11-13]. Google is also offering Google Cloud as a data storage and ML development platform to many partners. Microsoft, meanwhile, has made investments in its artificial intelligence platform for developers with a view to improving medical imaging diagnostics [14,15], and Amazon now offers an AI-based service that rapidly de-identifies medical images [16]. And although none of the major tech companies have yet released a medical imaging solution, their partnerships indicate a keen interest to participate in this space.

RADIOLOGISTS ARE SLOW TO ADOPT AI—OUR SURVEY SUGGESTS WHY

Methods

We designed an 11-question survey intended for all subspecialties of radiologists to gauge radiologists' familiarity with AI and ML, assess their view of the future of AI in medical imaging, examine how cloud-based solutions potentially support the adoption of AI among radiologists, and estimate how radiologists' workloads are (or are not) changing. In addition, to better understand our survey population, we prefaced the survey with a series of background questions querying the respondents' medical subspecialty, imaging modalities read, primary practice setting, years of clinical practice, and monthly patient throughput. This full survey was released to a population of US radiologists via SERMO, Inc, a New York–based physician networking company that specializes in collecting and aggregating physician opinions. The survey was launched as a computer-assisted web interview limited to SERMO-verified radiologists and capped at 50 responses (incomplete responses were excluded).

Results

Despite clear progress in the application of AI to medical imaging and the considerable investments being made in the companies and technology that support it, radiologists are slow to adopt AI in their work. Only 56% said they currently use some sort of AI, and just 22% to 38% reported exposure to any of the five common use cases: tagging images to ensure those for critical patients are reviewed first; optimizing workflow for overall productivity; automating part of the image analysis; providing clinicians with decision support; and enhancing imaging quality. Only 10% regarded themselves as "very familiar" with any of these applications (Fig. 2).

So, what is preventing adoption today? The biggest barrier identified was radiologists themselves. Forty percent of survey respondents gave this as the main impediment to broader adoption of AI in medical imaging. That does not seem to be because they fear that AI has the potential to replace them in their traditional roles. Only 16% thought this would be the case. However, many expressed skepticism in the current diagnostic capabilities of AI, particularly with respect to more complex patients or disease states. The second biggest barrier identified was the lack of regulatory approval. Thirty-two percent of respondents saw this as the main impediment.

Although radiologists today view lack of regulatory approval as a major barrier to adoption, this may change if more algorithms are approved or if the FDA updates its regulatory framework for modifications to AI- and ML-based software as a medical device. The FDA has already recognized the transformative potential of AI and ML in the software and medical device industry, and as a result, in April 2019 published a discussion paper outlining a potential foundational approach to premarket review for AI- and ML-based software modifications [17]. To accommodate the adaptive nature of AI and ML algorithms, the discussion paper proposes a "total product lifecycle" regulatory approach that would ensure modifications are implemented according to

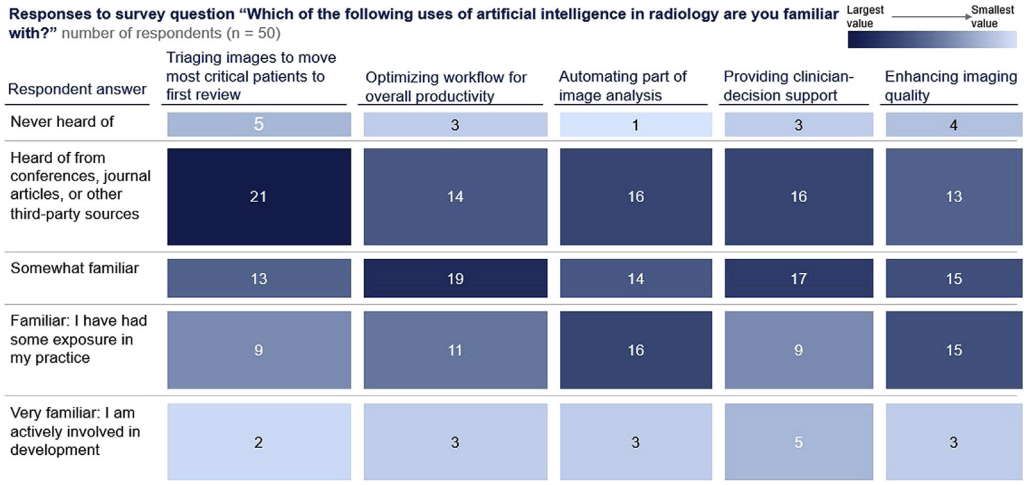

Fig 2. Many radiologists have some level of familiarity with artificial intelligence development, but very few are actively involved in it.

specified change protocols, maintain patient safety, and are continuously monitored for performance. Overall, these proposed changes would help clarify the approval process for AI and ML algorithms and more rapidly allow for safe and effective algorithm updates. Given that these updates were outlined in a discussion document and not intended to communicate the FDA's proposed (or final) regulatory expectations, AI and ML startups and established players should continue to stay abreast of updates to the regulatory framework and provide input to the FDA when appropriate.

Even under the current regulatory framework, however, we have seen an acceleration of FDA approvals for AI and ML algorithms. To date, the FDA has approved at least 16 AI-based applications. The first was in late 2016—an application from RiverRain Technologies to help detect lung nodules in CT scans. There was just one more in 2017, but the pace of approvals has since risen significantly. Fourteen have been approved since 2018 (E-supplement Fig. 2) [18,19].

HOW THE MARKET WILL DEVELOP

Our survey responses give clues as to how the future market for AI in medical imaging will unfold. We see three different stages of development—or market horizons—marked by progress in technology and market access (Fig. 3). Our research also indicates the types of applications that are likely to gain traction most quickly.

Three Horizons

In today's market—horizon 1—dozens of companies offer AI applications for medical imaging, although none do so at scale. This fragmentation impedes market development; a comprehensive solution, which addresses multiple

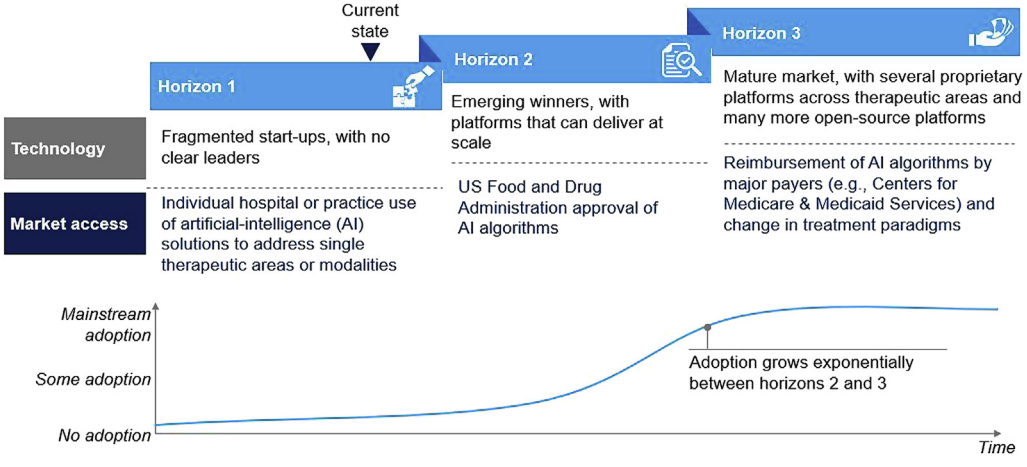

Fig 3. The market for artificial intelligence–based medical imaging can develop in three horizons.

modalities in multiple subspecialties and increases efficiencies (eg, faster scanning), is not currently offered. Additionally, this fragmentation of the market makes it difficult for health systems and physicians to differentiate and select solutions. Finally, physicians' doubts about AI's capabilities and the absence of regulatory approval further restrict progress. The result is that although individual hospitals and practices are using AI in some narrow use cases, adoption is far from widespread.

In horizon 2, investments in AI-related medical imaging will still be growing fast, but a few companies will begin to emerge as leaders, differentiating themselves from the competition with more accurate and often comprehensive solutions, and winning significant market share. They may be large incumbent diagnostic companies, digital technology giants, large health care providers, or yet unknown players.

In this horizon, as companies apply AI to more therapeutic areas, the FDA could potentially approve more AI products for medical imaging. This in turn will build confidence among physicians and other stakeholders, helping to build market penetration.

By the third horizon, the market for AI medical imaging will be stable, and adoption will have grown exponentially. Some smaller companies will have formed partnerships with larger ones or have been acquired. Others will have fallen by the wayside. In their place, established players will offer solutions across therapeutic areas, either on proprietary platforms that interact primarily with devices or systems within their own ecosystems, or on open source platforms that interact across all devices and systems.

At this stage of the market's development, FDA approval for increasing numbers of algorithms will have opened the door to reimbursement from health care payers, which is key to widespread market access. No AI solution for medical imaging is currently reimbursed by CMS or any other payer.

The Frontrunner Use Cases

We asked survey participants when they would expect certain applications to become mainstream—that is, with at least 20% penetration into radiology practice. Figure 4 shows the results. In terms of use cases, respondents felt the enhancement of imaging quality through AI would become mainstream first. Ninety percent said they expected this to happen in less than 5 years. The optimization of workflows and clinical decision support would be fast followers.

In terms of imaging modalities, 90% of survey respondents flagged CT as the modality most applicable to AI—perhaps not surprisingly, given the volume of CT scans interpreted, the time it takes for CT data to be transferred to a PACS, and the amount of data each scan produces. Moreover, the relative success of existing AI algorithms for CT scans and the volume of studies affirming their utility, such as recent FDA approval of multiple algorithms for triaging of intercranial hemorrhages from CT scan images, suggest conditions are ripe for AI-assisted CT scans to gain market share relatively quickly. CT was followed by MRI (60%), x-ray (56%), and PET (50%) in terms of its applicability.

Conclusions

AI is set to have a big impact on the medical imaging market and hence on how radiologists work, helping

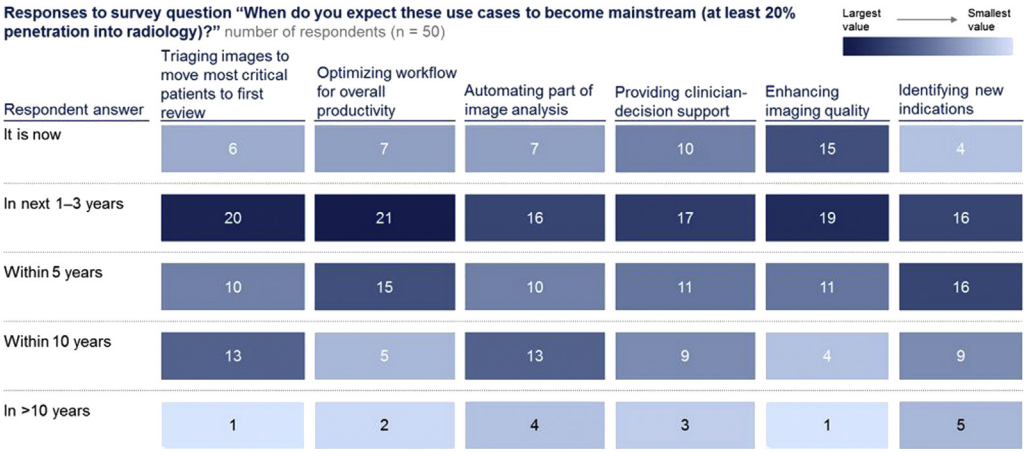

Fig 4. Survey results show that respondents expect image-quality enhancement—followed closely by supporting clinician-decision support, physician-workflow optimization, image triage, and image-analysis automation—to be the artificial intelligence use case making the fastest progress.

them to speed up scan time, make more accurate diagnoses, and ease their workload. The end result is likely to be better patient outcomes. How quickly the market develops depends in part on overcoming the skepticism that some radiologists feel about the technology's capabilities. FDA approval and reimbursement from payers are other speed bumps that AI companies will need to address. However, as AI in medical imaging increasingly proves its worth, it is hard to imagine that AI will not ultimately transform radiology.

TAKE-HOME POINTS

- Investments in AI-based medical imaging continue to grow exponentially—since our last review in 2018, the number of companies in the space has tripled to 113, and investments have more than doubled to $1.17 billion
- Despite these investments, AI solutions have not yet been adopted at scale in medical imaging and remain as limited solutions for specific conditions, imaging modalities, or disease states.
- Physician adoption and regulatory approval are the two biggest barriers to broader AI deployment, largely driven by physician skepticism of the utility of currently available AI software.
- AI is likely to gain ground quickly in CT and the enhancement of imaging quality, followed by other common imaging modalities (eg, MRI, x-ray, PET), and use cases (eg, optimizing physician workflow, image triage, clinician decision support).

ACKNOWLEDGMENTS

We thank Carla Blanco for analytics assistance, and Joanne Mason and Sue Lavin Jones for editorial assistance.

ADDITIONAL RESOURCES

Additional resources can be found online at: https://doi.org/10.1016/j.jacr.2019.07.019.

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