VIEWPOINT

INNOVATIONS IN HEALTH CARE DELIVERY

Adapting to Artificial Intelligence
Radiologists and Pathologists as Information Specialists

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Editorial

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Artificial intelligence—the mimicking of human cognition by computers—was once a fable in science fiction but is becoming reality in medicine. The combination of big data and artificial intelligence, referred to by some as the fourth industrial revolution,[1] will change radiology and pathology along with other medical specialties. Although reports of radiologists and pathologists being replaced by computers seem exaggerated,[2] these specialties must plan strategically for a future in which artificial intelligence is part of the health care workforce.

Radiologists have always revered machines and technology. In 1960, Lusted predicted "an electronic scanner-computer to examine chest photofluorograms, to separate the clearly normal chest films from the abnormal chest films."[3] Lusted further suggested that "the abnormal chest films would be marked for later study by the radiologists."[3] Lusted's intuitions were prescient: interpreting radiographs is pattern recognition; computers can recognize patterns and may be helpful because some roentgenographic analyses can be automated.

Nearly 60 years after Lusted's prediction, Enlitic, a technology company in Silicon Valley, inputted images of normal radiographs and radiographs with fractures into a computerized database.[4] Using deep learning, a refined version of artificial neural networks, the computer developed rules that not only identified radiographs with fractures but highlighted the fractures. The computer received the image data rather than rules for their interpretation. The computer was not programmed regarding what to detect but developed algorithms necessary for fracture detection using deep learning.[4] Deep learning is an autodidact—like an outstanding radiology resident, the more images it analyzes, the better it gets. The IBM prototype for artificial intelligence, Watson, can identify pulmonary embolism on computed tomography (CT) and detect abnormal wall motion on echocardiography.[5] Watson has a boundless capacity for learning—and now has 30 billion images to review after IBM acquired Merge. Watson may become the equivalent of a general radiologist with super-specialist skills in every domain—a radiologist's alter ego and nemesis.

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This progress in imaging has changed the work of radiologists. Radiology, once confined to projectional images, such as chest radiographs, has become more complex and data rich. Cross-sectional imaging such as CT and magnetic resonance, by showing anatomy with greater clarity, has made diagnosis simpler in many instances; for example, a ruptured aneurysm is inferred on a chest radiograph but actually seen on CT. However, this has come at a price—the amount of data has increased markedly. For example, a radiologist typically views 4000 images in a CT scan of multiple body parts ("pan scan") in patients with multiple trauma. The abundance of data has changed how radiologists interpret images; from pattern recognition, with clinical context, to searching for needles in haystacks; from inference to detection. The radiologist, once a maestro with a chest radiograph, is now often visually fatigued searching for an occult fracture in a pan scan.

The amount of data continues to increase in imaging, both extractable by the human eye and extractable only by software.[6] Thus, radiology has moved from a subjective perceptual skill to an objective science. Data have empowered radiologists but also challenged them computationally because of their abundance and complexity. This has paved the way for the role of computers, which extract fine information about tissues invisible to the human eye and process those data quickly and accurately.

How should the changes in imaging, coupled with artificial intelligence, further change the work of radiologists? To avoid being replaced by computers, radiologists must allow themselves to be displaced by computers. While some radiographic analyses can be automated, others cannot. Radiologists should identify cognitively simple tasks that could be addressed by artificial intelligence, such as screening for lung cancer on CT. This involves detecting, measuring, and characterizing a lung nodule, the management of which is standardized.[7] A radiology residency or a medical degree is not needed to detect lung nodules. Likewise, radiologists are overtrained to interpret portable chest radiographs obtained in the intensive care unit to confirm that support lines are in proper position. These studies are not challenging and may be ideal for automation and delegation to artificial intelligence.

The primary purpose of radiologists is the provision of medical information; the image is only a means to information. Radiologists are more aptly considered "information specialists" specializing in medical imaging. This is similar to pathologists, who are also information specialists. Pathologists and radiologists are fundamentally similar because both extract medical information from images.

Pathologists have embraced machines and technologies. Some tasks once performed manually by pathologists have been automated, such as cell counts, typing and screening of blood, and Papanicolaou tests, leaving pathologists with more complex tasks. Artificial intelligence can perform the more complex tasks of pathologists and, in some instances, with superior accuracy. A recent study showed that computers could predict the grade and stage of lung cancer better than pathologists.[8] Even though such studies need larger-scale validation with more diverse tissue types, it is clear in both radiology and pathology that many tasks can be handled by artificial intelligence. To underscore the commonality between radiology and pathology, researchers using operant conditioning trained pigeons to spot abnormal calcifications on mammograms and detect breast cancer on histology.[9]

Because pathology and radiology have a similar past and a common destiny, perhaps these specialties should be merged into a single entity, the "information specialist," whose responsibility will not be so much to extract information from images and histology but to manage the information extracted by artificial intelligence in the clinical context of the patient.

The information specialist would not spend time inferring conditions between competing shadows on radiographs, scroll through hundreds of images looking for pulmonary embolus on CT, or examine slides for "orphan Annie"–shaped nuclei. Artificial intelligence could perform many such tasks. The information specialist would interpret the important data, advise on the added value of another diagnostic test, such as the need for additional imaging, anatomical pathology, or a laboratory test, and integrate information to guide clinicians. Radiologists and pathologists will still be the physician's physician.

Together, the information specialist and artificial intelligence could manage individuals and populations. If a single artificial intelligence unit could do the work of many radiologists, then a single information specialist could manage many units of artificial intelligence. This would truly scale the influence of radiologists and pathologists. If artificial intelligence becomes adept at screening for lung and breast cancer, it could screen populations faster than radiologists and at a fraction of cost. The information specialist could ensure that images are of sufficient quality and that artificial intelligence is yielding neither too many false-positive nor too many false-negative results. The efficiency from the economies of scale because of artificial intelligence could benefit not just developed countries, such as the United States, but developing countries hampered by access to specialists. A single information specialist, with the help of artificial intelligence, could potentially manage screening for an entire town in Africa.

Information specialists should train in the traditional sciences of pathology and radiology. The training should take no longer than it presently takes because the trainee will not spend time mastering the pattern recognition required to become a competent radiologist or pathologist. Visual interpretation will be restricted to perceptual tasks that artificial intelligence cannot perform as well as humans. The trainee need only master enough medical physics to improve suboptimal quality of medical images. Information specialists should be taught Bayesian logic, statistics, and data science and be aware of other sources of information such as genomics and biometrics, insofar as they can integrate data from disparate sources with a patient's clinical condition.

There may be resistance to merging 2 distinct medical specialties, each of which has unique pedagogy, tradition, accreditation, and reimbursement. However, artificial intelligence will change these diagnostic fields. The merger is a natural fusion of human talent and artificial intelligence. United, radiologists and pathologists can thrive with the rise of artificial intelligence.

The history of automation in the broader economy has a reassuring message.[1] Jobs are not lost; rather, roles are redefined; humans are displaced to tasks needing a human element. Radiologists and pathologists need not fear artificial intelligence but rather must adapt incrementally to artificial intelligence, retaining their own services for cognitively challenging tasks. A unified discipline, information specialists would best be able to captain artificial intelligence and guide medical information to improve patient care.

ARTICLE INFORMATION

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REFERENCES

1. The return of the machinery question. *The Economist*. June 25, 2016. http://www.economist.com/news/special-report/21700761-after-many-false-starts-artificial-intelligence-has-taken-will-it-cause-mass. Accessed November 15, 2016.

2. Chockley K, Emanuel E. The end of radiology? three threats to the future practice of radiology [published online September 18, 2016]. *J Am Coll Radiol*. doi:10.1016/j.jacr.2016.07.010

3. Lusted LB. Logical analysis in roentgen diagnosis. *Radiology*. 1960;74:178-193.

4. Jha S. Will computers replace radiologists? *Medscape*. May 12, 2016. http://www.medscape.com/viewarticle/863127. Accessed November 15, 2016.

5. McMillan R, Dwoskin E. IBM crafts a role for artificial intelligence in medicine. *Wall Street Journal*. August 11, 2015. http://www.wsj.com/article_email/ibm-crafts-a-role-for-artificial-intelligence-in-medicine-1439265840-lMyQjAxMTI2NjA3NTAwMDUxWj. Accessed October 4, 2016.

6. Gillies RJ, Kinahan PE, Hricak H. Radiomics: images are more than pictures, they are data. *Radiology*. 2016;278(2):563-577.

7. Lung-RADS Version 1.0 Assessment Categories. April 28, 2014. http://www.acr.org/~/media/ACR/Documents/PDF/QualitySafety/Resources/LungRADS/AssessmentCategories.pdf. Accessed October 4, 2016.

8. Yu KH, Zhang C, Berry GJ, et al. Predicting non-small cell lung cancer prognosis by fully automated microscopic pathology image features. *Nat Commun*. 2016;7(7):12474.

9. Levenson RM, Krupinski EA, Navarro VM, Wasserman EA. Pigeons (*Columba livia*) as trainable observers of pathology and radiology breast cancer images. *PLoS One*. 2015;10(11):e0141357.