From Röntgen to Magnetic Resonance Imaging: The History of Medical Imaging

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Medical imaging has advanced in remarkable ways since the discovery of x-rays 120 years ago. Today’s radiologists can image the human body in intricate detail using computed tomography, magnetic resonance imaging, positron emission tomography, ultrasound, and various other modalities. Such technology allows for improved screening, diagnosis, and monitoring of disease, but it also comes with risks. Many imaging modalities expose patients to ionizing radiation, which potentially increases their risk of developing cancer in the future, and imaging may also be associated with possible allergic reactions or risks related to the use of intravenous contrast agents. In addition, the financial costs of imaging are taxing our health care system, and incidental findings can trigger anxiety and further testing.

This issue of the NCMJ addresses the pros and cons of medical imaging and discusses in detail the following uses of medical imaging: screening for breast cancer with mammography, screening for osteoporosis and monitoring of bone mineral density with dual-energy x-ray absorptiometry, screening for congenital hip dysplasia in infants with ultrasound, and evaluation of various heart conditions with cardiac imaging. Together, these articles show the challenges that must be met as we seek to harness the power of today’s imaging technologies, as well as the potential benefits that can be achieved when these hurdles are overcome.

In November 1895, Wilhelm Röntgen saw the bones of his hand on a photographic plate on the other side of an electron beam tube. As he was experimenting with this technology, Röntgen also imaged the bones in his wife’s hand. The photograph of her hand and wedding ring, the first of many radiographs to be taken over the next 120 years, set in motion a new way of viewing the human body, which eventually led to the lifesaving technologies of today.

Röntgen’s research in Germany was soon replicated in the physics laboratories of Europe and America. In January 1896, a 3-hour radiograph taken at Davidson College in Davidson, North Carolina, showed opaque metal bullets, pins, and rings. A month later, a technique that involved less radiation was used to image a Colles fracture in a student at Dartmouth College in Hanover, New Hampshire.

Physicians quickly began to exploit the medical applications of radiographs, which at that time used glass plates for the visualization of images. Thanks to this new invention, skeletal trauma could be assessed in ways that had not previously been possible, and radiographs became part of military medicine during World War I. Marie Curie, who had just a few years before won a Nobel Prize for her research into radiation, drove a truck with portable x-ray equipment near the battlefields of France. This mobile unit not only allowed shattered bones to be visualized, aiding doctors in treatment, but also recorded the effects of gas gangrene. During and after the war, radiographs were also used to view tuberculosis and other lung lesions, and barium studies of the gastrointestinal tract soon followed.

Coming quickly on the heels of these medical breakthroughs, the word “x-ray” became a commercial catchphrase that was appropriated to sell almost everything. Advertisements touted “x-ray” golf balls, for a straight and longer flight, and “x-ray Waltzes” to go with “x-ray whiskey” that led to use of “x-ray” prophylactics. In the 1930s, 1940s, and 1950s, shoe stores commonly used shoe-fitting fluoroscopic boxes, which showed the bones of the foot inside an outline of the shoe.

In the late 1940s, the long-term risks of radiation exposure began to be quantified. Today, radiation exposure has been linked to several adverse effects, including cancer, and ordering clinicians must weigh these risks against the value of the imaging study. In their commentary in this issue, Armao and Smith [1] discuss the health risks of ionizing radiation from computed tomography and present strategies for radiation dose reduction. In a sidebar [2], they also discuss the risk of incidental findings that may result from imaging; such unexpected findings often worry both patients and physicians, and they can lead to additional imaging and further clinical work-up.

Despite knowing the dangers associated with imaging, many people remain fascinated by its potential and continue to employ this technology for a variety of purposes, some of which are not medically indicated. For example, obstetri-
Pediatricians commonly use ultrasound to perform necessary monitoring of a fetus during pregnancy, but ultrasound is also employed by commercial ultrasonography suites to provide pregnant women with keepsake photographs of their babies. As Goodnight and Chescheir discuss in their sidebar, ultrasound is safer than radiography, but taking keepsake prenatal photos is still an abuse of this technology [3].

In the commentary accompanying the Goodnight and Chescheir sidebar, Flick [4] notes that today's doctors face pressure from patients when ordering imaging studies. Even when best-practice standards do not support additional imaging, patients may request—or even demand—that the doctor order certain tests. Additionally, as patients increasingly rate their physicians online, doctors may feel pressure to maintain patient satisfaction and may worry about the repercussions if they decline to provide tests on demand.

Tapp, McWilliams, and Dulin [5] suggest that patient engagement can facilitate informed decision making, in which patients and providers work together to decide which imaging studies are necessary. This commentary notes some of the factors that contribute to overuse of imaging, including fee-for-service reimbursement, a dearth of comparative effectiveness research, concerns about medical malpractice, and lack of awareness about the risks associated with different imaging modalities. Fortunately, professional and specialty societies are offering support to the ordering physician by making recommendations that list conditions for which imaging is not indicated.

Implementation of radiation safety procedures began in the 1930s with the advent of lead aprons and lead gloves, continued with the introduction of thyroid shields and leaded protective eyewear for interventional radiologists, and now includes sharply narrowed x-ray beams and rapid exposures with 3-phase generators. Radiation safety officers in hospitals and physician offices constantly monitor the amount of radiation patients receive from procedures ranging from plain radiographs to computed tomography scans.

Minimizing radiation exposure is especially important when imaging children and infants, as immature tissues are more susceptible to radiation-induced damage. When computed tomography is performed on children, the radiation dose must be reduced to account for the child's smaller size. In some cases, radiation exposure can be avoided entirely by using alternative imaging modalities. In a sidebar in this issue, Townsend [6] suggests that ultrasound is often a best-practice substitute for computed tomography in pediatric populations.

A major benefit of ultrasound is that it does not expose patients to ionizing radiation. Instead of using x-rays, ultrasound devices emit sound waves, and the echoes returning to the sound transducer can be used for screening or diagnosis. Another benefit of ultrasound is its portability, which allows this technology to be used easily at the bedside. As Fitch discusses in his commentary [7], ultrasound allows pediatricians to detect congenital hip dysplasia in the nursery bassinet at an early age, but there are questions about whether ultrasound screening for this condition should be universal or targeted and about whether and when treatment should be initiated. Although early treatment is essential for some types of congenital hip dysplasia, other abnormalities may be normal variants that will resolve without treatment.

The development of the 3-gallon image intensifier in the 1960s was a major breakthrough in reducing the amount of radiation associated with fluoroscopy. This advance allowed radiologists to image the beating heart using radio-opaque contrast materials, and the ability to visualize arteries and veins throughout the body paved the way for interventional radiology. Building on this field, techniques were then developed that allowed clinicians to image the heart noninvasively. As Hartman discusses in his commentary [8], advances in cardiovascular imaging include echocardiography, cardiac magnetic resonance imaging, and cardiac computed tomography.

Film replaced glass plates for visualizing radiographic images in the mid-1920s, and digital sensors have recently begun to replace film in most clinical settings. This transition to digital imaging provides benefits for plain radiography—for example, radiologists can read films remotely from an off-site location. What is more important, digitalization of imaging made possible the full range of advanced technologies available today. With computed tomography, magnetic resonance imaging, and ultrasound, normal or pathologic organs can now be visualized in such detail that the digital image is almost a duplicate of the actual organ. The shades of gray seen on computed tomography images have illuminated pathology in ways that were never thought possible, and the wealth of information contained in cross-sectional or planar images of anatomy and pathology is akin to having a global positioning system for the human body.

When this digital information is connected to a clinical information system, radiologists can readily access additional information while they are reading a particular scan, which facilitates more accurate diagnoses. The transfer of imaging information has also been expedited by the advent of picture archiving and communication systems (PACS). Using these systems, digitized images can be rapidly accessed on any terminal, which not only helps radiologists and clinicians to provide better patient care but also promotes education of medical students and residents.

In addition to improvements in computed tomography and magnetic resonance imaging, nuclear medicine has also seen dramatic advances. Nuclide imaging began 50 years ago with inside-out gamma ray imaging of the thyroid, bones, and brain, and it has since made remarkable progress. For example, positron emission tomography can now provide information on tumor activity, which can be especially valuable when these images are correlated with a computed tomography scan of the lesion. In the future, it is hoped that molecular imaging will advance to the point where it will be
possible to use a radioactive marker for earlier detection of malignancies in the kidneys, pancreas, ovaries, and other abdominal organs.

Although today’s technology offers images of higher quality, more information can sometimes lead to diagnostic confusion. As Laster discusses in his commentary [9], dual-energy x-ray absorptiometry is a valuable tool for osteoporosis screening and for monitoring of bone mineral density, but there is debate about who should receive this testing and how often it should be used. Similarly, Freimanis and Yacobozzi [10] address the challenges of breast cancer screening, including concern about false-positive results. Although mammography remains the primary technique for breast cancer screening, some studies have failed to link mammography with lower mortality rates, and questions remain as to the ages at which women should undergo screening and which methods should be used. A significant concern is that false-positive results can lead to patient worry and confusion, and the number of women experiencing such anxiety may grow as mammography results are increasingly accompanied by caveats.

Finally, clinicians should consider the financial costs of diagnostic medical imaging. The commentary in this issue by Bradley and Bradley [11] presents data on the growth of these costs over the past several years and discusses efforts that have been undertaken to rein in costs. Echoing statements from other authors, they note that medical imaging is increasingly a driver of health care costs, and they argue that cost effectiveness must be a consideration when best-practice guidelines are being developed.

The history of medicine reflects ongoing progress in our ability to see both normal anatomy and the underlying causes of illness and injury. Andreas Vesalius provided the first accurate depiction of gross anatomy approximately 500 years ago, giving doctors a better understanding of the organs and their arrangement within the body. In the 19th century the microscope showed us cells, thus opening up microbiology as a new arena of study. Continuing in this tradition, today’s imaging modalities show increasing levels of detail about both the structure and function of various organs, and further advances in technology and interpretation will undoubtedly advance medicine and reveal new and exciting vistas.

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References