

HISTORY OF MEDICINE

The CT Scan after 50 Years — Continuity and Change

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Fifty years ago, in 1971, the first computed tomographic (CT) scan revealed a frontal lobe tumor in a 41-year-old woman. The scan was performed in a town best known for an annual tennis tournament (Wimbledon, England), and the machine was manufactured by a company best known for music recordings (EMI). EMI had become extraordinarily successful by selling the music of a popular English band known as the Beatles. Like many Beatles songs, the CT scanner was an instant hit.¹ Only 8 years later, the Nobel Prize in Physiology or Medicine was awarded to two pioneering researchers who had helped develop the machine, Godfrey Hounsfield and Allan Cormack.^{2,3} Whereas initial CT scans were slow and limited to the head (see image), over subsequent decades, scanners have become ever faster and more powerful. Today, a half-century after its invention, the CT scanner has become part of the underlying fabric of routine medical care, producing amazing images that enable accurate diagnoses and efficient therapy for millions of patients each year.

How should we think about this anniversary? On the one hand, the invention of the CT scanner was one step in a long-lasting conceptual revolution in medical thought, as physicians began to believe that diseases are caused by physical lesions. The radical nature of this concept is often unappreciated because it seems so, well, obvious. But every idea has to start somewhere. For centuries, the best and brightest human minds had thought that most diseases involved an imbalance in a set of

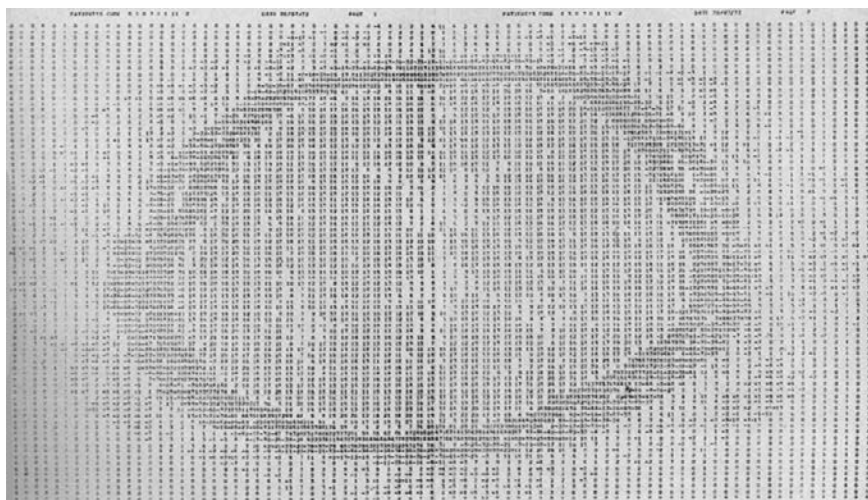
ineffable bodily humors, manifested by symptoms that patients relayed to their caregivers. But out of the chaos of postrevolutionary France arose the notion that disease was not an imbalance in humors but entailed actual physical lesions, and that these lesions could be identified in a living body. In 1816, when René Laennec invented the stethoscope in Paris hospitals, he did more than create a useful tool that can be considered an exemplar of the ways in which physicians localize lesions within the body — he described a new way of conceptualizing disease.⁵

This change had enormous implications. For if disease could manifest not only as patient-described symptoms but also as physician-ascertained structural changes, the mere existence of a lesion could establish that a person who felt well was actually ill. As the clinical gaze came to focus on questions about a lesion's location and characteristics, physicians ran the risk of failing to appreciate the patient as a sick person and seeing them instead as a repository of potentially diseased organs.

Another dramatic step in the effort to localize lesions came in 1895, when a small-town German physicist realized that rays produced by a cathode tube could pass through human flesh and leave shadows on a photographic plate. The invention of the x-ray machine amazed the world. But x-rays had limitations that soon became obvious. For one, the radiation could be dangerous. In addition, x-rays produced a two-dimensional image, and one part

of the body could block the rays from reaching another part. The bones in the head made it essentially impossible to create an image of the brain using x-rays. The CT machine offered a solution to the second problem by creating three-dimensional images with no overlap of structures. It also derived useful information by measuring variation in tissue density. In one sense, the CT scan was just another development in a centuries-long quest to more precisely visualize lesions in the human body.

On the other hand, the invention of the CT scanner marked a radical change. For the first time, digital computers were integral to acquiring and analyzing medical information. CT scanners use two-dimensional projections to create an image of a three-dimensional object. This process is based on a mathematical model that was first articulated in 1917 (in a paper having nothing to do with medicine) and that came of age in a world of slide rules and pen-and-paper calculations. But creating a CT scan requires intensive mathematical calculations. The invention arrived right on the cusp of the computer revolution. The first general-purpose microprocessor chip, the Intel 4004 processor, was invented in 1971. The next few years saw the advent of high-speed, computer-controlled multi-test analyzers in clinical pathology laboratories as well as the first portable calculators, which weighed nearly 2 pounds and could do only basic arithmetic calculations. (They seemed amazing at the time.) These innovations were rapidly followed by a cornu-



Computer Printout of an Early CT Scan.

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copied of computer-driven devices, with which many of us have become somewhat overfamiliar during the Covid-19 pandemic.

This ever-increasing raw computer power made practical the three-dimensional images that are the *raison d'être* of CT scanners. To make the first CT image, it took 9 days to collect the data and 2.5 hours to reconstruct the image. The first clinical CT machine took 4.5 minutes to gather data and 20 minutes to reconstruct the image. Today, the typical CT scan takes only seconds. CT scans have evolved from comprising dozens of images to comprising thousands of images — an advance that has been accompanied by a massive increase in the amount of information embedded in a scan. But with this power has come questions. Is this additional information useful? If so, how can it best be extracted from the digital data set? Such questions also apply to the mass of information derived from chemical autoanalyzers.

Since the invention of the x-ray machine, clinicians have directly examined medical images to make diagnoses and treatment decisions

— but does the massive increase in the digital size of CT images mean that we now need artificial intelligence to extract the relevant clinical information? Moreover, creating these additional images requires additional radiation, and CT scans now account for the majority of human radiation exposure. Are the additional images worth the risk? How can we reduce the radiation associated with CT scans?

EMI originally estimated that the worldwide market for CT scanners would be about 25 machines. This projection turned out to be an underestimate, in part because CT scanners quickly became faster and more versatile. Whereas the initial scanners were limited to images of the brain, by 1975, scanners could create images of the entire body.

But the CT scanner's invention coincided with a rapid increase in the costs of medical care. When the CT machine was invented in 1971, health care accounted for 7.7% of the U.S. gross domestic product (GDP), which seemed like an enormous amount at the time. In 1983, there were already millions of CT scans being done each

year in the United States, and health care's share of the GDP had increased to 10%. Health care now accounts for nearly 18% of the GDP. Although the rise in health care costs is clearly multifactorial, the use of medical technology is responsible for a substantial share of these costs, and imaging technologies are a major contributor. CT scanners are not inexpensive machines; they can cost up to \$2.5 million. There are currently nearly 15,000 CT scanners in the United States.

CT scans undoubtedly enable enhanced diagnosis and more precise treatment for many people, but they are also found on most lists of overused tests. Perhaps the reason takes us back to the conceptual revolution that began more than 200 years ago. Physicians are predisposed to do what the stethoscope does — to find the lesion. This drive has led us to develop even more tools: the MRI scan, the PET scan, and more. Our task going forward will be to determine when finding the lesion can help relieve symptoms and save lives and when it does little to improve the health of the patient.

Disclosure forms provided by the author are available at NEJM.org.

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