

How a Rock Band, a Recording Company, and a Nobel Laureate Developed Computed Tomography

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Introduction: Computed Tomography (CT) is an indispensable element of medical care used throughout the world, and first developed for clinical use by Hounsfield in 1971. The largest source of monetary support for Hounsfield's work was from his employer, Electrical Musical Industries, Ltd. (EMI) and, in turn, the most lucrative source of income for EMI through the 1960's was their recording contract with the English rock band, The Beatles. The purported link between The Beatles' productive oeuvre with EMI and Hounsfield's discovery of CT has not been well established. We endeavored to elucidate the technological and creative talents that linked Hounsfield with EMI and The Beatles and which ultimately led to one of the greatest medical innovations of the 20th century.

Sources and Methods: We used GoogleScholar, PubMed, and primary sources to research the life of Godfrey Hounsfield, the history of Electric and Musical Industries, Ltd (EMI), and The Beatles in reference to the development of CT. We used the EMI Archives Trust (London), and the archives of the Institute of Electrical and Electronics Engineers (IEEE) UK and Ireland (London). We obtained unpublished photographs courtesy of private collections.

Results: EMI translated its electronic prowess during WWII into the recorded music business, purchasing Capitol Records in 1955. EMI would sign The Beatles in 1963 and EMI profits rose 80% that first year. Sir Godfrey Hounsfield began a successful scientific career with EMI in 1951. With financial support from EMI's research division, Hounsfield began developing what would become the first CT-scanner in 1967. By directing x-ray beams through the body at 1 degree angles, with a detector rotating in tandem on the other side, he could measure the x-ray attenuation of different tissues inside the body. These values were then analyzed via a mathematical algorithm to produce a 2-dimensional image of a slice of the body. Hounsfield worked with James Ambrose, a radiologist, to conduct the first clinical CT-scan at Atkinson Morley Hospital in 1971 in a patient with a brain tumor. EMI entered the medical equipment business thereafter and heavily marketed the CT-scanner using the financial resources EMI derived from its record sales. By 1976, EMI could not produce enough CT-scanners to fill demand and ultimately would cede the medical imaging business to competitors, and devote itself to the music industry. In 1979, Hounsfield, and Allen Cormack, a South African physicist who independently theorized the basis of CT imaging, would win the Nobel Prize.

Conclusions: 'Let it be' known that it was only 'yesterday' when a recording company, a rock band, and a radar scientist revolutionized medical imaging with the development of computed tomography.

Keywords: Computed Tomography, Godfrey Hounsfield, EMI, The Beatles

Prior to radiography, a physician's primary tool for diagnosis was the physical exam, which was quickly discovered to be not as discriminating as one would hope. Some early case series showed that up to 25% of patients presenting with pain due to a right-sided ureteral stone underwent surgery for appendicitis or pelvic disease before the correct diagnosis was made. (1) In 1901, Howard Atwood Kelly, one of the 'big four' physicians at Johns Hopkins, developed the technique of the wax-tipped catheter which was cystoscopically

placed up the ureter to diagnose ureteral and renal calculi based on scratches observed on the wax of the catheter. (2) Röntgen's discovery of x-rays in 1895 would usher in the era of radiography. In 1906, Voelker and Von Lichtenberg would describe retrograde pyelography with collargol, a colloidal silver compound. Osborne in 1923 described excretory urography. After experimentation with many contrast media, many of which were toxic, Moses Swick discovered Uroselectan, an iodinated compound, which allowed the safe

performance of intravenous pyelography. (3)

The sinking of the Titanic in 1912 indirectly led to the development of SONAR (SOund Navigation And Ranging). (4) Both SONAR and RADAR (RAdio Detection And Ranging) and their military applications formed the basis for the development of medical ultrasonography. The story behind the development of Magnetic Resonance Imaging (MRI) began with Tesla's discovery of a rotating magnetic field in 1882 and is filled with multiple Nobel Prize winners describing and characterizing the NMR phenomenon. However MRI technology was not applied to medicine until the 1970s. (5)

The development of computed tomography (CT) ushered in a new era in medical radiology. CT imaging was invented by Godfrey Hounsfield, an innovative scientist with EMI. EMI had been founded in the 1930s to pursue the most innovative technologies in the sciences and the arts and their work led both to the development of RADAR and television equipment as well as to a large canon of western music. EMI's investment in The Beatles, a British quartet (1960-1969), whose near total oeuvre was recorded at EMI's Abbey Road studios (London), proved to be a major financial boom and further cemented EMI's role in groundbreaking efforts (Figure 1). We wished to elucidate the relationship between Hounsfield's discovery and his development of the CT scan while at EMI and determine to what extent EMI's connection with The Beatles contributed to that effort.

SOURCES

We reviewed the medical literature regarding the life of Godfrey Hounsfield, the history of Electric and Musical Industries, Ltd (EMI), and The Beatles as they relate to the development of CT. We used primary source

materials from EMI Archives Trust (London), the Institute of Electrical and Electronics Engineers (IEEE) UK and Ireland (London), and the Nobel Prize speeches and laureate lectures at www.nobelprize.org. EMI stock prices were obtained from the New York Times financial stock prices listings as found through the NYT 'Times Machine' at timesmachine.nytimes.com.

RESULTS

In My Life

Godfrey Newbold Hounsfield was born on August 28, 1919 in Newark, England and was the youngest of five children. His father was an engineer in the steel industry, who after World War I, bought a small farm and became a farmer (Figure 2). (6,7) At an early age young Hounsfield became interested in all things mechanical on the farm. He was educated at the Magnus Grammar School in Newark (now Magnus Church of England School) and though he did well in math and science, Hounsfield never excelled at school and his father thought his poor performance was due to "intellectual retardation." His early life on the farm allowed him the freedom to invent and investigate—from launching homemade gliders off haystacks to launching water-propelled tar barrels when he fondly recalled that "I almost blew myself up during (these) exciting experiments...it may now be a trick of the memory but I am sure that on one occasion I managed to get one to an altitude of 1000 feet!" He would write "this was the time of my first attempts at experimentation, which might never have been made had I lived in a city. In the village there are few distractions... and I was free to follow the trail of any interesting idea that came my way." (6,8-9)

He enrolled in City and Guilds College in London in 1939 but with the outbreak of World War II, Hounsfield



Figure 1. (Left) The front door for EMI's Abbey Road Studio, St. John's Wood, London. **(Right)** The famous 'zebra crossing' outside Abbey Road Studio, looking due north, and featured on the cover of The Beatles' 1970 "Abbey Road" album. (Credit: Claudio Caridi /Alamy Stock Photo; Martin Norris Travel Photography /Alamy Stock Photo)

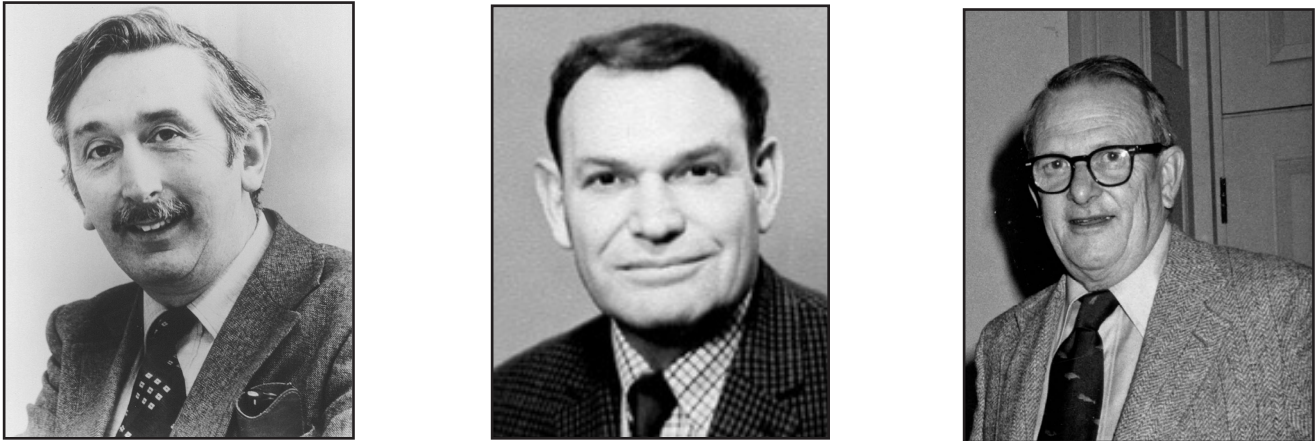


Figure 2. Pioneers in the Development of CT Imaging. **(Left)** Godfrey Hounsfield (1919-2004), the EMI engineer who invented the CT with **(Middle)** James Ambrose (1923-2006), a radiologist, conducted the world's first CT imaging in 1971; **(Right)** Allan Cormack (1924-1998), physicist, theorized the calculations that made CT imaging possible. Hounsfield and Cormack were co-winners of the 1979 Nobel Prize (All Photos, Public Domain)

enlisted in the Royal Air Force and attended the Air Force Cranwell Radar School and worked as a radar mechanic instructor at the Royal College of Science in South Kensington. (6,7) His work impressed Air Vice-Marshall Cassidy who helped him earn a grant to attend the Faraday House Electrical Engineering College in London, from which he graduated in 1951 with a degree in electrical and mechanical engineering. (6,7)

Yesterday

The company known as Electric and Musical Industries, Ltd (EMI) began in 1897 as the Gramophone company, focused on recorded music. With World War I and then the Great Depression, the company stumbled with record sales falling by more than 80%. (10,11) In 1931, Gramophone and one of its chief rivals, Columbia, merged to form EMI, Ltd. During the time following World War II, EMI emerged with significant experience in defense related electronics, developing the technology behind radar and thus helping Britain and its allies during the war. Hounsfield joined EMI as an engineer working on radar and guided weapons in 1951. He would climb the ranks, and in 1958 lead the team that designed the first all-transistor computer (EMIDEC 1100) and would eventually become chief of medical research. However, because of EMI's lack of experience in the market, it failed to leverage its innovation into economic success. (11) Fortunately for EMI, around that time, the recorded music industry began to become more profitable. In 1955, EMI acquired Capitol Records in the United States, the home of such artists as Frank Sinatra,

and would sign a recording contract with The Beatles in 1962, a quartet of musicians from Liverpool. The group, under the management of a Brian Epstein, agreed to the terms of 1 farthing per double sided disc (i.e., a 'single' record) worth today about 3 cents/record.(10,11)

You (Don't) See Me

Medical imaging during Hounsfield's time was primarily reliant on the x-ray. Wilhelm Conrad Röntgen, a German mechanical engineer and physicist, produced and detected x-rays in 1895 and won the first Nobel Prize in Physics in 1901. Thus by Hounsfield's time, x-rays were the primary mode of medical imaging and had gained widespread acceptance. Hounsfield recognized the limitations of x-ray in visualizing soft tissues and came up with the idea for computed axial tomography during one of his traditional country walks, as he pondered using a computer to calculate x-ray absorption patterns of biologic tissues.

"One of the suggestions I put forward was connected with automatic pattern recognition... which was eventually to become the EMI-Scanner and the technique of computed tomography," Hounsfield wrote. (8,9) "As might be expected, the programme (sic) involved many frustrations... and some amusing incidents, not least the experiences of travelling across London by public transport carrying bullock's brains for use in evaluation of an experimental scanning rig in the Laboratories."

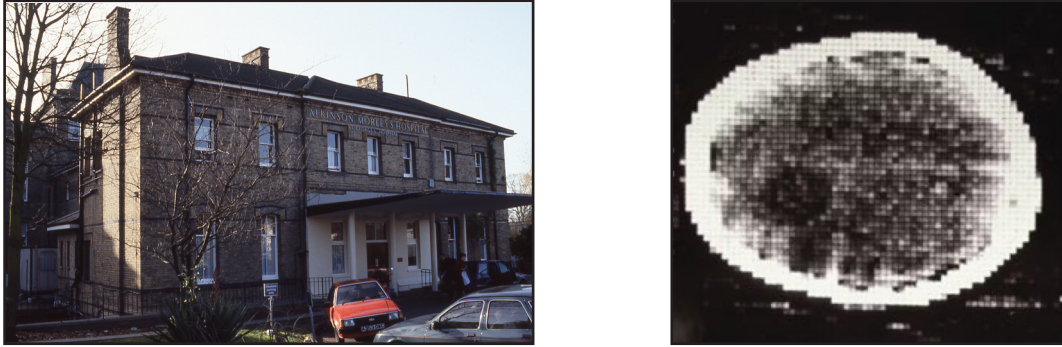


Figure 3. (Left) Atkinson Morley Hospital, November 1992, site of the world's first installed CT scan. (Photo courtesy of Harriet Richardson, University of Edinburgh, 2023). The hospital closed in 2003 and is set to become a retirement community. **(Right)** The first CT image of the human brain showing pathology, a right sided tumor, performed on October 1, 1971 at Atkinson Morley's Hospital by Sir Godfrey Hounsfield and Dr James Ambrose (Public Domain)

With a Little Help From My Friends

As Hounsfield worked on developing computed tomography, he realized he needed to collaborate with a physician, preferably a radiologist, for his invention to gain acceptance and credibility. This was one of his keys to success. He was rejected by many radiologists until he met Dr. James Ambrose (Figure 2). James Abraham Edward Ambrose (1923-2006) was born in Pretoria, South Africa. He served in the Royal Airforce and flew Spitfires in the Middle East and southern France. In 1945 he completed his studies at Cape Town University before going to England to study radiology at Middlesex Hospital in 1952. In 1959 he was appointed senior registrar at Atkinson Morley's Hospital in Wimbledon

and in three years was a consultant (Figure 2). The hospital was one of the largest centers for neurosurgery in the London area and Ambrose specialized in providing images of soft tissue of the brain (Figure 3). Ambrose was recognized in the profession as an authority in the diagnosis of neurological diseases. Ambrose, to his credit, was perceptive enough not to dismiss Hounsfield's proposal and immediately recognized the potential of Hounsfield's vision. (22)

Money, That's What I (Need)

In order to build and test his scanner, Hounsfield needed a lot of help. The initial seed funding came from EMI, but he also had to solicit the UK Department of Health



Figure 4. One of the world's first clinically used CT machines, installed in Atkinson Morley Hospital, Wimbledon, England, 1971. (Public Domain)



Figure 5. The Beatles, February 9, 1964, with Ed Sullivan (1901-1974), the US TV impresario. The Beatles were an English quartet whose EMI record sales from 1962-1969 allowed EMI to support Hounsfield's research that led to the development of the CT scan. Pictured are (Left to Right): Messrs: Sir Richard Starkey (1940-), George Harrison, (1943-2001), Ed Sullivan, John Lennon (1940-1980), and Sir J Paul McCartney (1942-) (Public Domain)

and Social Security for an additional £2,500. (10) He also needed Ambrose's help to work on the clinical aspects of testing the scanner. He would need even more funding when he realized his radiation source was too weak as his initial scan times took 9 days! Another £12,000 later, using x-rays, the scan times were down to a mere 9 hours.

The initial scans were focused on the head. They tried scanning formalin-fixed pathology specimens but these did not result in good resolution and delineation of tissue structure. Freshly killed bovine brains had the problem of the ventricles being filled with blood, resulting from the animals initially being shocked before slaughter. Thus, Ambrose came up with the idea to have the cows killed under kosher regulations, providing the first clear visualization of the anatomic structure of the

brain. (6)

The first bovine scans were a printout of numbers, where each "pixel" was the numeric tissue density coefficients that would later bear Hounsfield's name. The single digit Hounsfield units consisted of the fluid in the ventricles. By converting the numeric values for the Hounsfield units to grayscale (from -1000 HU which is black to 3000 HU which is white; air is -1000 HU, bone is +1000) the first CT-scan images were developed.

I'm Looking Through You

In 1971, the first human patient, a woman with a suspected tumor, was scanned using EMI's Mark I scanner at Atkinson Morley's Hospital. The equipment used a translate-rotate gantry with an 80 x 80 matrix yielding a spatial resolution of 0.5cm. Reconstruction



Figure 6. Memorial plaque acknowledging the critical role of the Beatles' record company EMI in the development of the CT scan: "On October 1, 1971, a team, at the EMI Research Laboratories on this site produced an image of a patient's brain, using the world's first clinical X-ray computerized tomography scanner, based on the patented inventions of Godfrey Hounsfield. The practical realization of high-resolution X-ray images of internal structures of the human body marked the beginning of a new era in clinical medicine." (Courtesy Nick Wainwright, IEEE, London, 2022)

took all night but produced a recognizable image of a brain tumor (Figures 3 and 4). The first EMI production model required 4 minutes per slice and 7 minutes per reconstruction. The first description of a CT scan in the literature was published by Hounsfield in the *British Journal of Medicine* in 1973. (12-14)

Ambrose would be the first to describe the neuroanatomy visualized via computed tomography. It was also his idea to use contrast to further add diagnostic value to the scans. In April 1972, Ambrose demonstrated the technology in a lecture at the Radiological Society of North America. (8) We owe James Ambrose much in regards to the clinical application of CT, unfortunately his contributions are barely recognized today. (12,15)

All Together Now

In order to understand how EMI was able to fund medical research, we have to discuss EMI's most significant signing—The Beatles. A few years after Hounsfield joined EMI, a 16-year-old John Lennon and 14-year-old Paul McCartney, both of Liverpool England,

formed a band called the Quarrymen. The following year, Paul's friend George Harrison joined the band. The name of the band underwent a few iterations prior to becoming The Beatles in 1960 (Figure 5). After being rejected by Decca Records (because Decca felt that guitar music was "on the way out"), they signed with EMI's Parlophone label in 1962, with their first recording at EMI's Abbey Road Studios in London. The first single was "Love Me Do". (11) They went through multiple drummers until August, 1962 when they settled on Richard Starkey, who later became known as Ringo Starr. It was during the development phase of the initial CT scanner that 'Beatlemania' hit. In The Beatles' first year with the company, EMI's profits rose 80%. (16) In February, 1964, The Beatles began their first tour of the United States with three performances on the Ed Sullivan Show. Their first appearance on February 9th, was seen by a reported 73 million viewers. By April, 1964, The Beatles' EMI records occupied the top 5 positions of the *Billboard Hot 100*, a feat which has not been yet repeated. The Beatles' prolific output, mostly penned by Messrs. McCartney and Lennon, was an unheralded

financial boon for EMI, allowing them to sign other 'British Invasion' artists such as the Rolling Stones, the Hollies, and Pink Floyd and channel much needed resources into the medical research division, Central Research Laboratories (CRL). The price of EMI common stock price on the New York Stock Exchange (NYSE) doubled from 1964-1968 (data not shown). The Beatles continued to be musically active until 1969 and EMI's last recording with them was in April, 1970. (17)

Here Comes the Sun

Allan Macleod Cormack (1924-1998) was a physics professor at Tufts University and in 1955 while on sabbatical, visiting his alma mater the University of Cape Town, was asked to supervise the use of radioactive isotopes at a local hospital (Figure 2). He realized how imprecise planning for radiotherapy was but saw the problem as a mathematical one. He thus developed the mathematical basis used to determine the distribution of attenuation coefficients of different tissues in the body. Hounsfield and Cormack had never met and were unaware of each other's work. (18)

In 1979, both Hounsfield and Cormack were awarded the Nobel Prize for Physiology or Medicine for the development of the CT scanner, the "greatest advance in radiologic medicine since the discovery of the X-ray." (15) The Nobel assembly cited Cormack for doing the mathematical analyses that laid the groundwork for the computerized technique and Hounsfield as the "central figure" in its practical development. (19) Cormack published his analyses of the mathematical problem in 1963 and 1964 and Hounsfield applied for a CT scanner patent in 1968. (18) During Cormack's Nobel Banquet speech on December 10, 1979, he stated "There is irony in this award, since neither Hounsfield nor I is a physician. In fact, it is not much of an exaggeration to say that what Hounsfield and I know about medicine and physiology could be written on a small prescription form!" (20)

Revolution

Similar to The Beatles' 'British Invasion', EMI's scanner would revolutionize medical imaging and 'invade' the United States. In the summer of 1972, EMI launched Hounsfield and Ambrose on a successful lecture tour of the United Kingdom and the United States, speaking to radiologists and other physicians. In 1973 the first three CT scanners were installed in the United States at the Mayo Clinic in Rochester, Minnesota, the Massachusetts General Hospital in Boston, Massachusetts, and the Presbyterian-St. Luke's Hospital in Chicago, Illinois. (7) Just four years later, there would be over 1000 scanners in the U.S. In 1973 and

1974, EMI enjoyed a monopoly on the new technology, translating it into sizable profits. Unfortunately, EMI could not capitalize on its 'first mover' advantage. Corporate expansion strained its financial resources and GE, a leader in conventional X-ray equipment, dominated the market by developing a third-generation scanner using a new fan-beam technology, leading to significantly faster scan times. (21) Shortly thereafter, Philips and Siemens would soon enter the market as EMI had difficulty keeping up with the advancing industry and EMI's stock pricing reflected its changed financial picture.

Here, There, and Everywhere

Hounsfield was lauded in hospitals and countries on both sides of the Atlantic and would go on to win numerous awards and prizes. He was awarded honorary degrees from at least 10 colleges and universities, was elected to the Royal Society in 1975 and he would be knighted, becoming Sir Godfrey, in 1981. His name is immortalized in the 'Hounsfield scale', a quantitative measure of radiodensity used in evaluating CT-scans.

He gave his Nobel lecture, complete with overhead slides and archived on film, on December 8th, 1979 at the Karolinska Institute in Stockholm. Hounsfield's advice to aspiring Nobel winners was "not to worry too much if you don't pass your exams, so long as you feel you have understood the subject. It's amazing what you can get by with the ability to reason things out by conventional methods." Hounsfield would die at the age of 84; he never married, saying that remaining a bachelor had allowed him to devote most of his life to science.

The End

The development of the CT scanner and Hounsfield's story personifies many elements of game-changing innovation. Many invent; few persevere, and the time and work Hounsfield spent overcoming unheard of obstacles in order to develop new technology cannot be quantified or fully appreciated. Hounsfield was a consummate collaborator and credited many for furthering his work. His work with Ambrose was the single most important factor in his success and acceptance by the medical community. Hounsfield enjoyed the challenges of theory but also appreciated the practical aspects of innovation including his obtaining a patent in 1968 at least 3 years before the technology demonstrated any clinical value. Importantly, none of Hounsfield's work would have been possible without the creative environment and financial support of EMI which, in turn, was greatly due to Beatles' record sales (Figures 6).(10)(23) Hounsfield and Ambrose revolutionized how the world could view the internal

structure of the human body. It is difficult to imagine modern music without the influence of The Beatles. It is equally difficult to imagine modern medicine without the CT scan. Without the support of EMI and its groundbreaking work, it may have been impossible for either The Beatles or CT scans to have come into existence.

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