

Nobel Prize in Medicines 1979



Allan M. Cormack



Godfrey N. Hounsfield

The Nobel Prize in Physiology or Medicine 1979 was awarded jointly to Allan M. Cormack and Godfrey N. Hounsfield "for the development of computer assisted tomography"

An X-ray examination usually implies the passage of X-rays through an organ with a resulting image of the organ on X-ray film. The dark areas on the film vary according to the anatomy and the structure of the tissues being X-rayed.

A peculiarity of this picture is that it is two-dimensional. In the reproduction the dimension of depth is lost. This means that an overall picture of the lungs, for example, is a composite one in which all the details in the path of the rays are overlapped. In order to acquire any depth perception, one must complement frontal exposures with lateral exposures. The radiologist's interpretation of possible changes in the lungs is based on his knowledge of the normal anatomy of the lungs and of the properties of the pathological abnormalities. But the nature of the final X-ray image makes judgement in certain cases undeniably subjective. Therefore, in many situations there is a need to be able to isolate the image of a section of an organ from the overlying structures by so-called tomography (from

the Greek tomos, a cut, and graph, written). Many technical solutions have been tested during the course of the years but none have been found to be entirely satisfying. For purely physical reasons one can never achieve a complete eradication of other sections of the organ, and the picture's contrast is reduced. This is true even when one allows the radiation beam to run parallel to the examined section so that the rays proceed from one edge to another. There are other limitations to conventional radiological diagnostics. One is that X-rays cannot be utilized to more than 25 %; another the X-ray film has a relatively low sensitivity in the reproduction of the variations in tissue density.

In computer-assisted tomography these problems have been ingeniously solved. When the method was introduced into medical care six years ago it quickly became apparent that it signified something revolutionarily new, with great repercussions with X-ray diagnostics and the medical disciplines that make use of it.

The basic feature of the method is that the X-ray tube, in a definite pattern of movement, permits the rays to sweep in many directions through a cross-section of the body or the organ being examined. The X-ray film is replaced by sensitive crystal detectors, and the signals emitted by amplifiers when the detectors are struck by rays are stored and analyzed mathematically in a computer. The computer is programmed to rapidly reconstruct an image of the examined cross-section by solving a large number of equations including a corresponding number of unknowns. The image presented on the screen of the oscilloscope is drawn in a fine system of squares, a so-called matrix, in which each individual square corresponds to a part of the examined organ. Each element expresses the permeability of X-rays of the corresponding part of the organ. A fundamental peculiarity is that the image elements do not influence each other while the image is being reconstructed. In other words, there is no overlapping of elements in the image. Because the sensitivity of the crystal detectors and amplifier is more than 100 times as great as X-ray film, computed tomography can detect very subtle variations of tissue density. This means that the density resolution is exceptionally high. For all practical purposes one achieves a correct image of a thin section of organ tissue.

The first computer tomograph was constructed to be used for examining the skull, with special emphasis on diseases of the brain. The method soon experienced an enormous breakthrough in the radiological diagnosis of neural diseases. The reason is the precision and sensitivity of computed tomography. Extensive special examinations, such as contrast encephalography and pneumaencephalography, that is, X-ray examination with a contrast medium in the vessels, and filling the brain cavities with air following lumbar puncture, provide very valuable information, but nevertheless indirectly. The need for these types of encephalography is now reduced. Computed tomography, on the other hand, provides in each section a very detailed picture of the brain and its cavities as well as the fluid-filled spaces surrounding the brain, i.e., the cisterns and subarachnoid spaces, everything visible directly on the picture. This means that pathological changes in the brain and its surroundings can be well demonstrated by the computed tomogram. Their position, size and shape can be estimated and their nature can often be determined. The number of black gradations in the squared pattern of the image is greater than an observer can perceive, but can be extracted from the image and denoted numerically. This appreciably simplifies determination of the nature of the disease. Hemorrhages, and such changes in the brain arising from a blood clot blocking circulation, cause the same symptoms but can be distinguished by computed tomography. Tumors and conditions brought on by inflammation, senile changes in the brain, hydrocephalus and malformations in the brain can all be revealed. The method is invaluable in developing new methods for operating on brain tumors. So rich is the detail that the computed tomogram is reminiscent of the picture one gets of the brain at autopsy.

Computer-assisted tomography cause no discomfort to the patient, who lies comfortably on his back during the examination. This makes it possible to examine even very sick individuals in an acute phase of their illness. The effect of the treatment can be monitored. All centers in the world with access to a computed tomograph attest to the fact that the method has meant an enormous advance in diagnostics, therapy, development and research within the specialty of neurological diseases.

With modern computed tomographs it is possible to examine every organ in the body. In certain connections the method is superior to all other methods. In other situations it complements other techniques, such as ultrasound, isotope diagnostics with the gamma camera.

A very important area of application, which is rapidly growing in importance, is the radioactive treatment of tumors. Heretofore the weakest link in planning radiation treatment has been the difficulty in determining, with desired precision, the position, size and shape of tumors in the innermost regions of the body. This involves the problem of delimiting tumors from surrounding tissue. With computed tomography it is possible to carefully analyze all these factors, from a scaled image of the body on a level with the tumor. This facilitates the choice of suitable radiation field and optimal ray quality. When the tumor shrinks during treatment, which can be shown by computed tomography, the radiation can gradually be changed so that more resistant sections of the tumor can be irradiated more intensely than surrounding tissue. Well-informed observers believe that computer-assisted tomography has introduced a new era in radiation therapy. The entire field is the subject of intensive research.

This year's Nobel Prize in physiology or medicine has been awarded to Allan M Cormack and Godfrey N Hounsfield for their contributions toward the development of computer-assisted tomography, a revolutionary radiological method, particularly for the investigation of diseases of the nervous system.

Allan Cormack is professor and head of the institution of physics at Tufts University in Medford, Massachusetts, USA. He was the first, from a theoretical point of view, to analyze the conditions for demonstrating a correct radiographic cross-section in a biological system. He published his analysis of the problem in two scientific publications in 1963 and 1964. He understood that the problem was basically a mathematical one. It was a matter of finding a reasonable two-dimensional function that described how X-rays attenuate in each individual part within a slice when one knows the mean values of the rays' absorption, the so-called line integrals, along a number of straight lines within this

slice. He was convinced that the problem had great principle interest and foresaw that, if it could be solved, there would be possible applications within medicine, such as radiotherapy and positron-camera diagnostics. He was not aware then that the key mathematical problems had been considered earlier in an altogether different connection and deduced his own method of calculation. In extensive model experiments, in which he used gamma radiation that has a shorter wave-length than X-rays, he showed that the agreement between theory and experiment was good. Cormack's reconstruction mathematics is one of several possible ones that can be used. His contributions to the development of the theory of computer-assisted tomography was early and anticipated the coming development by several years by being the first to state the principles for reconstructing a cross-section of tissues in an organ based on these X-ray projections. The reason Cormack's discovery did not come to be industrially applied is not known, but it can be assumed that the computers of the time lacked sufficient capacity to enable the method to be applicable to medical care.

Godfrey Hounsfield, who is chief of the medical research division of Electric and Musical Industries, Middlesex, England, is the central figure in computer-assisted tomography. He has made the really decisive contributions for introducing computed tomography in medicine by constructing the first computed tomography system practicable in medical care. Thus, he described a complete system for computed tomography in his patent application in 1968. The patent was granted in 1972. An advance communication about the method came in 1971, a more extensive report with a supplement of clinical viewpoints by Ambrose followed in 1972, and a detailed description of the system appeared in the December, 1973, issue of the British Journal of Radiology. This work and the patent papers are epoch-making in medical radiology. The achievement is no less significant because all the components forming the basis for the construction and operation of the computed tomograph had been described earlier in non-medical publications. Hounsfield was obviously unaware of Cormack's contributions and developed his own method for reconstruction of the image. With an unusual combination of vision,

intuition and imagination, and with an extraordinarily sure eye for the optimal choice of physical factors in a system that must have offered very great problems to construct, he obtained results which in one blow surprised the medical world. It can be no exaggeration to maintain that no other method within X-ray diagnostics has, during such a short period of time, led to such remarkable advances, with regard to research and number of applications, as computer-assisted tomography.

Hounsfield's system, which was directed at examinations of the skull and brain, started a development which in a few years led to the so-called fourth generation of computed tomographs. In these, technical improvements and more rapid analytical reconstruction methods have raised performance still farther, work in which Hounsfield has taken active part.

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