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HISTORICAL ARTICLE

IN SEARCH FOR THE THIRD DIMENSION: FROM RADIOSTEREOSCOPY TO THREE-DIMENSIONAL IMAGING

R. Van Tiggelen[1]

The radiographic image is the bidimensional projection of a tridimensional volume. Interpretation of such an image is sometimes uneasy as we cannot determine ot which level the shadows are located. To dissociate the superimposed shadows, the radiologist may rely on different techniques including fluoroscopy, profile view, radiostereoscopy, conventional tomography, transverse axial tomography or really three-dimensional imaging techniques such as computer assisted (axial) tomography, ultrasound, and magnetic resonance imaging. This paper makes a short historical overview of these different techniques.

Key-word: Radiology and radiologists, history.

The radiographic image is the sum of the shadows of all the objects located between the radiation tube and the photographic film. It is thus the bidimensional projection of a tridimensional volume. Interpretation of such an image is sometimes uneasy as the level at which the shadows are located cannot be determined. To dissociate the superimposed shadows, the radiologist may rely on the profile image … or use fluoroscopy while mobilizing the patient. As both methods lacked accuracy, it was clear that other means to picture the 3rd dimension had to be investigated.

Radiostereoscopy

Long before the discovery of X-rays, binocular vision in relief had been deeply investigated. The main research study remaining is that of Sir Wheatstone (1802-1875), professor in experimental philosophy at King's College in London (1). In 1838, he demonstrated before the Royal Society of London the contribution of physiology of the vision by detailing the principles of stereoscopy.

In their application to radiology, all the used procedures consist of obtaining two images without patient mobilization , but by moving the X-ray tube in a well determined course. Some proponents advocated the use of an X-ray tube featuring two anodes and two cathodes to avoid any tube movement at all.

The first application in radiology might be related in the article by E. Thomson (1853-1937) in The Electrical Engineer of March 11th 1896 entitled "Stereoscopic Roentgen Pictures" (2).

It appears that, as soon as in 1896, G. Contremoulins (1869-1950) practiced stereography for vascular studies on corpses on which he applied opacification (3, 4). Subsequently, numerous trials concerning measurements by means of stereography were performed. They proved the feasibility to use the stereoscopic parallax to localize and determine the depth of a metal foreign body within the body of a patient.

In Belgium, foremost the military physician E. Henrard (1870-1940) elaborated this technique from 1900 on.

Throughout the world, the growing interest in the technique stimulated both the concept and the manufacturing of equipment for stereoscopic viewing (fig. 1), some of which was used during the great war, particularly that of Wheatstone commercialized by Victor (USA).

Although stereoscopy rendered services, it never had a great success. On the other hand, stereography is used currently by most of the radiologists. Stereoscopy found itself overtaken by tomography except in the USA where it survived much longer until the discovery of slice radiography, or tomography, in the mid 1930s thanks to J. Kieffer (1897-1972). Stereography remained in use until the end of the 20th century, most particularly in cardiovascular radiology (5).

Conventional tomography

To dissociate superimposed shadows at different levels, a better method allowing radiographic visualization restricted to one level by eliminating all other levels before or behind it had to be developed. In other terms, a method to obtain one or more radiographic slices through one or more interesting levels by erasing all other levels had to be investigated. These radiographic slices are more or less comparable with microscopic slices of histologists and pathologists.

In 1914, by mobilizing only the X-ray tube (with the patient and film immobile), K. Mayer (1882-1946) of Poznan obtained a method erasing the parasitic shadows, which he publicized in 1916 in his paper "Differential Radiologic Diagnosis in Diseases of the Heart and Aorta" (6).

In fact, however, true tomography was not reached yet by mobilizing just one of the parameters of the triad (tube-patient-film). In true tomography, the homothetic movement of two elements of the triad is required. The movement applied may be linear, oval, elliptic, in the form of an 8, hypocycloidal, or spiral.

Then, in 1915, by moving simultaneously the X-ray tube and the fluoroscopic screen connected by a lever, C. Baese (?) of Florence developed a radio-stereometer used during the Great War in the health formations to localize the projectiles inside a soldier's body. This method was only used in radioscopy (tomoscopy) because the Italian engineer didn't realize that the technique was

From: 1. Curator of the Belgian Museum of Radiology.
Address for correspondence: Dr R. Van Tiggelen, Curator of the Belgian Museum of Radiology, Queen Astrid Military Hospital, Bruynstreet 2, B-1120 Brussels, Belgium.

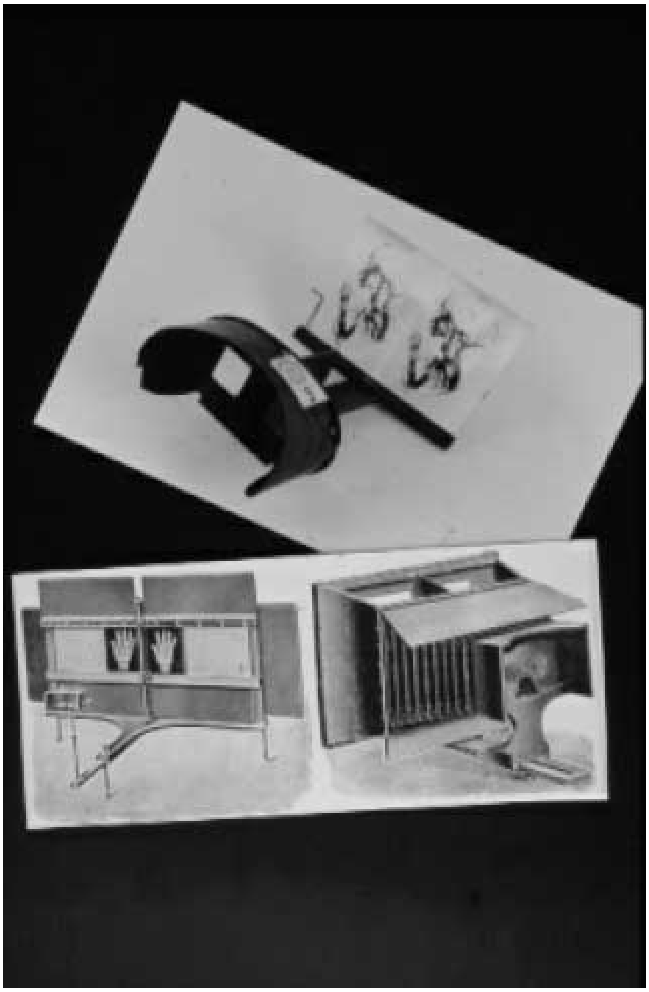

Fig. 1

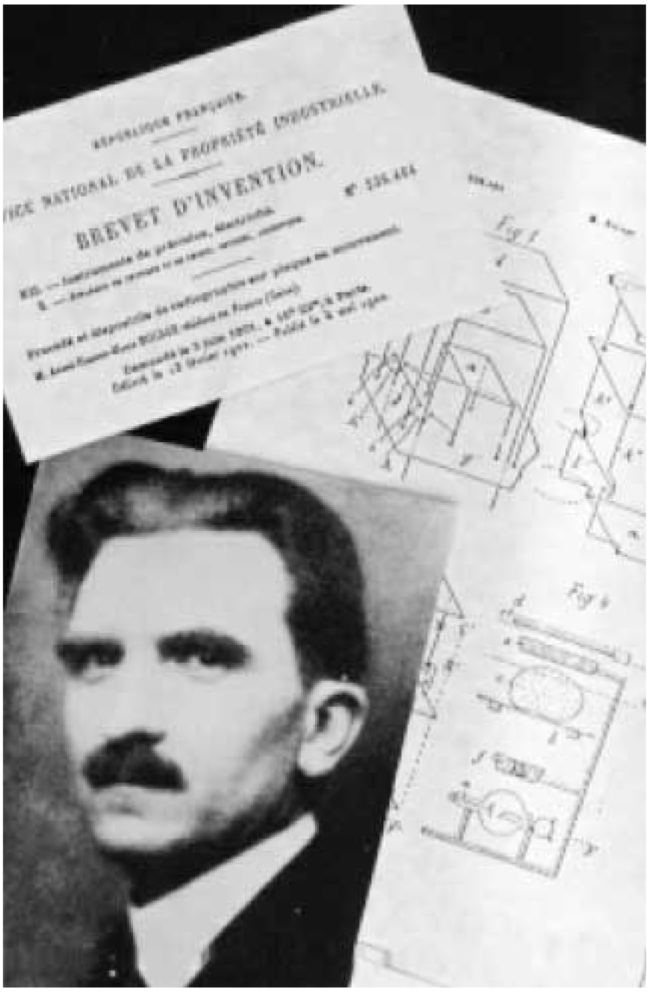

Fig. 2

able to “erase” the projected shadows most unwelcome during radiography (7).

At that time, only the national literature was consulted by researchers, this is why, ignoring the study already performed, the Parisian A. Bocage (1892-1953) developed the same concept which principles he applied to radiography (fig. 2).

During the Great War, he determined by a radiographic stereoscopic procedure and savvy trigonometrics the localization of the depth of a metal foreign body in the body of a patient. In 1917, to avoid slow and elaborate computing, he developed a radiographic and photographic technique which allowed «cutting» the human body in longitudinal slices and, at the end, to select the level needed. The technique had been discovered during the war and Bocage perfected the procedure during his internship in Paris in 1920 and introduced a patent in 1921, to be subsequently registered in 1922 (8).

Unfortunately, the circumstances didn’t allow him to produce his device, the Biotome but it became available in 1937, thanks to the company of M. G. Massiot (1875-1962) (9, 10). Once he became a dermatologist, Dr Bocage no longer possessed the genius of the do-it-yourselfer to realize, himself, the production of the apparatus. Furthermore, from 1924 on, he was no longer able to continue to pay the annuities of his patent which fdell in the public domain. However Dr Bocage merits the invention of the radiography in slices.

After Bocage, two other Frenchmen, E. Portes (?) and M. Chaussé (1900- ?) took, in 1921, a patent founded on the identical concept with a less performant equipment. Their method was never used in radiology but found application in radiation therapy (11).

Also ignoring the work of his forebears, a Dutch engineer who became a medical student, B.G. Ziedses Des Plantes (1902-1993), conceived in 1922, by analogy to the histologic slices on the microscope the same invention ! Due to a medical incident happening during a duty in neurology in 1928, he picked up his work again and developed not only tomography but also stereoscopic techniques and subtraction techniques which became the subject of his thesis publicized in 1934. With fortunate means and grand dexterity, in August 1931, he finalized an ingenious prototype of tomography which he called planigraphy (fig. 3) (linear, circular, and spiral sweeping) (12, 13). The same year, he publicized the first clinical results obteined on the skull and the spine. It is again the French company Massiot that built the first commercial apparatus in 1936; an improved version appeared in 1938 (10).

At the same time, and also ignoring the work of the others, another Dutchman of Nijmegen, D.L. Bartelink (1894-1985) built a radiotomographic apparatus with which he

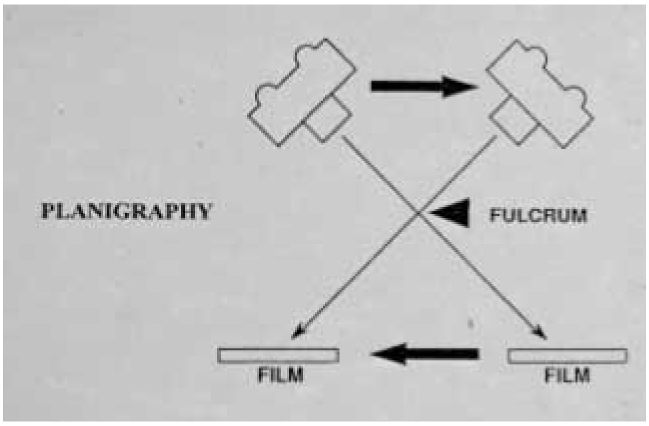

Fig. 3

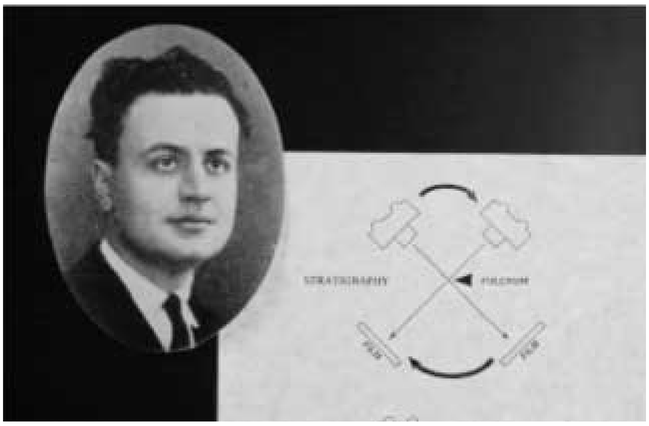

Fig. 4

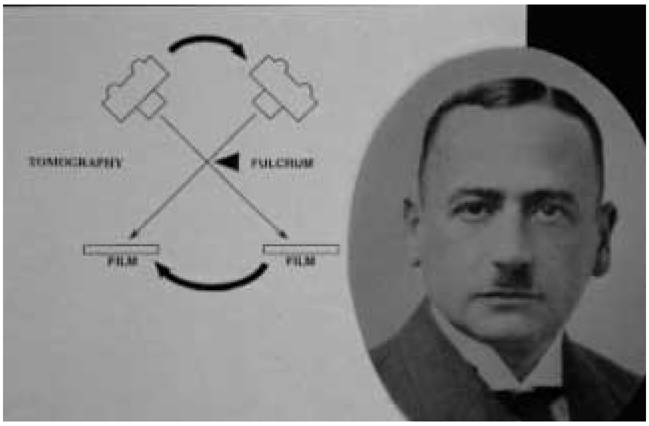

Fig. 5

Fig. 6

made the first pictures in 1930 (14). On November 22 1931, at a radiology meeting in Amsterdam, Ziedse Des Plantes presented his equipment and Bartelink showed results obtained with his technique. He publicized these results in 1932 (15, 16) and completed his work in 1933 (17).

In Italy, A. Vallebona (1899-1987) from Genoa obtained his first radiotomographic image in 1930. He described two techniques. In the first one, the subject remains immobile and the system (Xray tube–plate) pivots around an axis situated at the level of the slices (18); this procedure was called stratigraphy (fig. 4). In the second technique, it is the system (tube-film) which remains immobile and the patient rotates around an axis situated in the level of which one wants to obtain the image. This technique also is not a true tomograph.

In 1934, during the 4th Congress of Radiology in Zurich, H. Chaoul (1883-1964) (19) and G. Grossmann (1878-1957) (20-23) from Berlin presented the results obtained with a new tomograph which was commercialized in 1935 by the Berlin Company Sanitas. The technique was very different from planigraphy developed by Bocage and Ziedse Des Plantes as, in the latter equipment, the movement of the tube and the film takes place at a parallel level and describes a circular, sinusoïdal or spiral trajectory. The apparatus of Chaoul and Grossmann reproduces the linear movement of the focus and the film on an arc of a circle: the focus and the film carrier are fixed at the two extremities of a swing which pivots around a horizontal axis, corresponding to the recumbent patient. Characterizing this movement, the apparatus was called tomograph (fig. 5) by Grossmann himself.

Finally, the studies by the Franco-American technologist J. Kieffer (1897-1972) who, again independently from works of other researchers, also investigated the principle of planigraphy in 1928 during a stay as a patient in a sanitorium in Connecticut also deserve to be quoted. His objective was to produce radiographic images to visualize his own pulmonary lesions. His method was patented in 1934 (24) and, in 1938, the American company “Keleket X-ray Company” commercialized an apparatus which was called laminagraph (25). It is thanks to Kieffer that planigraphy came into general use in the USA.

By the eve of the second global conflict, the use of tomography was widely generalized. After the war and inspired by the principles of Bocage and of Ziedses Des Plantes, two Parisian engineers, R. Sans (1902- ?) and J. Porcher (1910- ?) appealed to the firm Massiot for the construction, in 1947, of an exceptional multidirectional tomograph: the polytome (26).

After presentation of a prototype in Paris in 1949, the first device built was showcased in Brussels in 1951 during the 1st Convention of French-speaking Radiologists (fig. 6). This novel tomograph permitted linear, circular, elliptical, and hypocycloidal

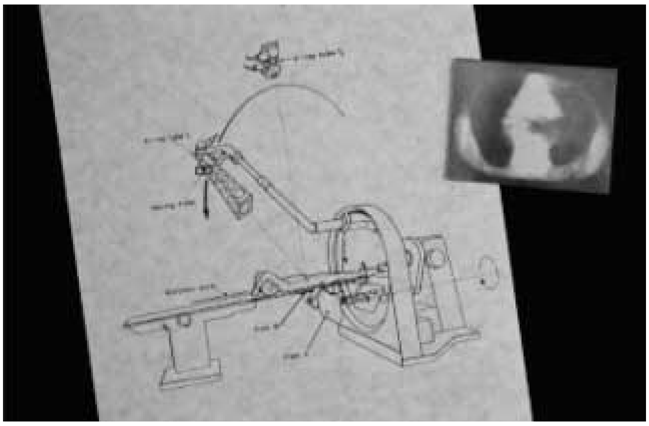

Fig. 7

Fig. 8

sweeping with the best erasure of superimposing structures ever obtained.

In 1968, the Antwerp company De Man developed a dangerous challenge to the polytome: the stratomatic. This tomograph -also multidirectional- was based on the original principle of planigraphy studied by Bocage and Ziedses Des Plantes by using spiral movement thus avoiding every crossing in its trajectory.

The family company De Man was taken over by the Compagnie Générale de Radiologie, which commercialized this famous Belgian tomograph which may be considered as the most performing one.

Transverse axial tomography

Based on the second tomographic method developed by Vallebona, G. Bozzeti, in 1935, conceived an outline of the axial transverse tomograph by rotating the photographic plate synchronically with the patient (27).

On his side, Keiffer in the USA also proposed a method to obtain images by transverse section in the horizontal plane.

All these outlines of axial transverse tomography reached full development when the rotational movement became complete.

The fatherhood of the axial transverse tomography is attributed to the English W. Watson (1895- ?) who obtained the first radiographic images in 1936 (28, 29).

A patent was introduced in Great Britain in 1936 and in the USA in 1939, but remained very confidential.

After the second world war, Vallebona resumed his work and performed his first images of axial transverse tomography in 1947 (30). In his configuration, the Xray tube, inclined at 10%, remained immobile and the patient rotated, perfectly synchronized with the film.

Among other investigations on the same topic made by different teams, the study by S. Takahashi which had raised interest since 1945 but remained no very well known until 1957 when he published his results in English (31) (fig. 7), should also be quoted.

All this had to be overrun by the emergence of computed tomography in 1972.

Three-dimensional medical imaging

The real revolution coincided with the use of digital computers for image reconstruction and the commercial launch of X-ray CT.

Frustrated by the limitations inherent in conventional X-ray images Sir Godfrey Hounsfield (1919-), an engineer in the British firm EMI (Electro-Musical-Instruments), devised a method for creating an image in great detail of narrow cross-section of a portion of the body (fig. 8). This method directs hundreds of narrow x-ray beams at various angles through a specific part of the anatomy. When the information is collected and analyzed by a computer a very detailed image of the slice can be created. Called computerized assisted (later axial) tomography or CAT scan for short and introduced in 1972, this technique marked the first time that computers were integrated into the process of constructing a medical image (32). CAT scan images can be arranged in sequence to approximate a three-dimensional structure.

Three-dimensional ultrasound also comes of age. Vizualization in 3-D has been on the mind of many investigators, including Brown Th. G. (1933-) (33) in Glasgow, who had developed an elaborate probably the world's first multiplanar scanner in 1973, under the Sonicaid Ltd. With improvements in ultrasonic and computer technology, work on three-dimensional vizualization began to appear in the early 1980's. Contribution came from the work of cardiologists in their effort to ascertaining the volume of cardiac chambers. Real-time scanner probes mounted on articulated arms with which the position of the probe could be accurately determined were often used.

The first MRI scanner sponsored by Fonar (34) was introduced to the world at the April 1980 annual meeting of the American Roentgen Ray Society and later that year at the annual meeting of the Radiological Society of North America (RSNA). In the late 1970s magnetic resonance imaging (MRI) was introduced. MRI is able to produce two- or three-dimensional images of great quality showing cross-sections through body parts at regular intervals. The images are so precise that radiologists are often able to get as much information from a scan as from looking at the tissue directly. MRI is the state-of-the-art radiological imaging method that has far superior soft tissue contrast to any other radiological methods. Not surprisingly, its applications have grown rapidly in recent years.

Conclusion

Over the seventy years following the discovery of X-rays, many attempts have been made to develop imaging techniques producing 3-dimensional images of the human body. CT, ultrasound and MRI revolutionized diagnostic radiology, as for the first time, 3D information was recorded. However, this information was presented as 2D images, requiring advances in computer technology before 3D vizualization came into wide-spread use.

Computer technology and software advanced sufficiently to allow real-time reconstruction of 3D images and their vizualization and manipulation on desktop computers. Only now, can we begin to explore the full potential of true 3D imaging and its usefulness for both diagnostic (and therapeutic) applications.

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