Acta Simulatio - International Scientific Journal about Simulation
Volume: 3 2017 Issue: 3 Pages: 11-15 ISSN 1339-9640

Received: 09 Sep. 2017
Accepted: 23 Sep. 2017

COMPUTED TOMOGRAPHY – ITS DEVELOPMENT AND PRINCIPLE

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Keywords: Computed Tomography, principle, machine, modelling
Abstract: CT (Computed Tomography) displaying is non-invasive diagnostic method, which has begun to apply in medicine since the beginning of the 70s and it has progressively become an irrecoverable part of the complex of imaging methods used by modern medicine. CT scanning made a remarkable effect on medical practise and diagnosis. The main principle of CT is based on attenuating of X-ray radiation beam passing object as in conventional X-ray examination. This article briefly describes the development and underlying principles of this non-invasive imaging technique.

1 Development and principle of CT

1971 October 1, CT examination was carried out in 41-year-old female patient and the frontal lobe tumor was discovered. The scanning of the patient lasted 15 hours and the CT machine developed by sir Godfrey Neobold Hounsfield (Nobel Prize laureate) in EMI company (Electrical and Musical Industries) in London was used. The musical industry EMI after the success of the Beatles recordings invested in a new product. For the first time in the history of medical radiology doctors were able to obtain the high quality images of cross section of the internal parts of the body. Since then the explosive technical sophistication has dramatically developed CT scan techniques and with the new research possibilities this development is being in progress even today [1,2].

The first generation of CT scanner used by Hounsfield in his original experiment consisted of parallel beam geometry, in which numerous measuring of permeated X-ray beam were carried out with the help of single suppression narrow pencil X-ray beam and detector. The beam was moved in linear motion over patient in order to obtain the projection profile. Subsequently the source and the detector rotated around the patient by approximately 1° and so another projection profile was taken. This translational-rotational scanning motion was repeated until the source and the detector turned around by 180° (Figure 1) [3].

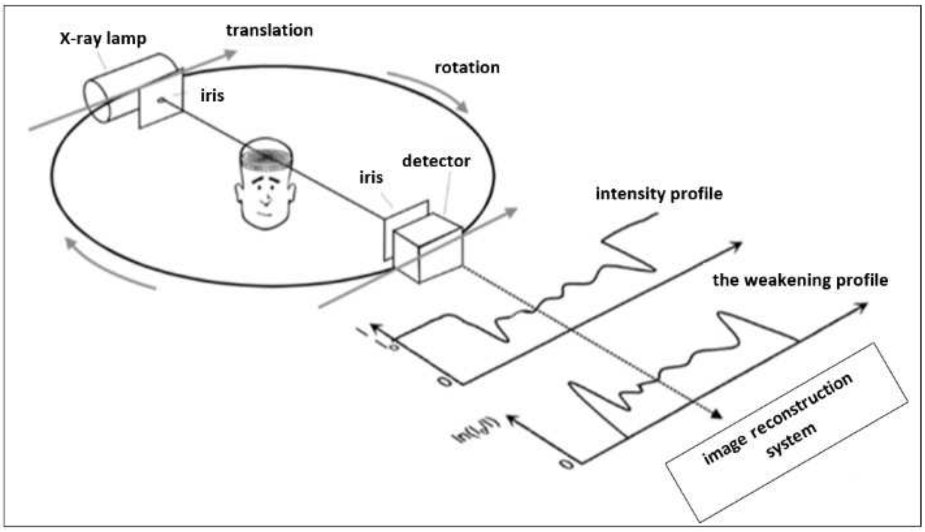

Figure 1 1st generation CT machine principle

The slow speed image data acquisition (approximately 5 min for each image) meant the restriction of scanning for moving artifacts connected with long-lasting scanning only on head. In order to overcome these time restrictions the second generation of CT scans which used a narrow fan-shaped beam and more detectors was developed. Although those scanners also used the translational-rotational moving the scanning time was reduced to 30 seconds because of the narrow fan-shaped X-ray beam and the linear series of detectors which facilitated bigger rotational acquisitions. In 1976 3rd generation of CT scanners which used fan-shaped beam configuration and rotating series of detectors was launched. In this generation fan-shaped X-ray beam together with the curved series of hundreds of detectors rotated by 360° around the patient.

The third generation of CT scanners enabled only 1-second acquisition. Consequently 4th generation of CT scanners used the rotating fan-shaped non-stationary series of detectors consisting of 600-4800 independent detectors arranged in a circular configuration around the patient (Figure 2) was developed. The scanning times of 4th generation were similar to 3rd generation scanning times.

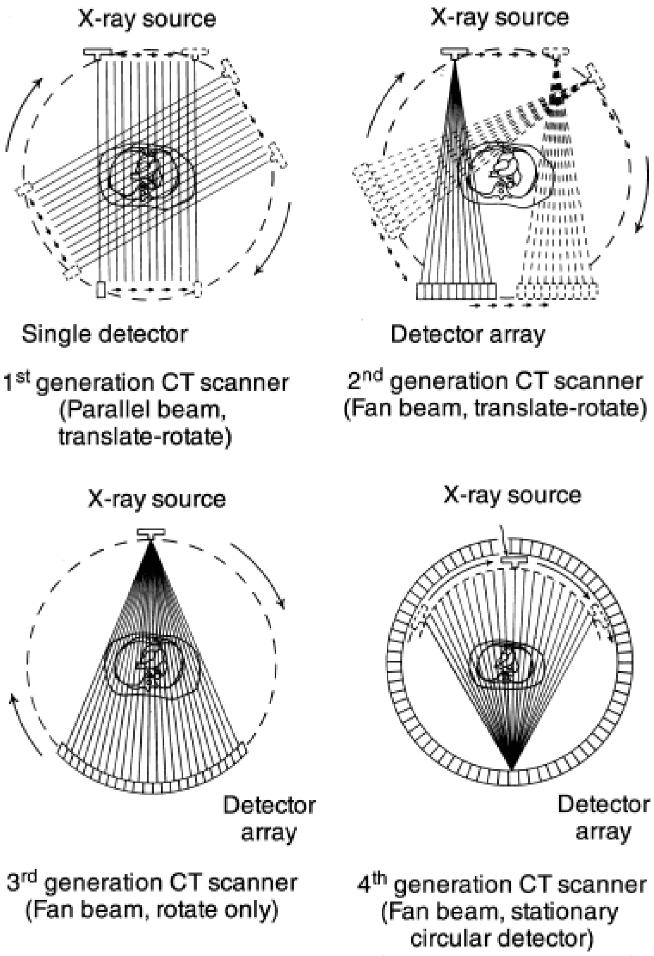

Figure 2 CT machines. The graphical representation of particular generations of CT machines [4].

The requirement for faster scanning heavily influenced the further development of CT technology in order to obtain volumetric data for 3D displaying and multiphase acquisition of images. It was enabled by the revolutionary development of slip-ring technology in 1990 which allowed X-ray source to rotate around the patient without reverse rotation (which was inevitable in conventional CT scanners) [5].

In combination with high-energy X-ray lamp, more efficient computers and more sophisticated displaying algorithm, the slip-ring technique enabled spiral CT scanning. This consists of continually activated X-ray source and continual movement of top board of the table through the gantry (a part of CT machine, a ring composed of a system of detectors and rotating X-ray) which results in volumetric acquisition. SSCT (*SpiralScan* CT) machines enabled faster and continual scan technology to obtain numerous cross cuts and volumetric data (Figure 3). The significant parameter for spiral scan characterization is pitch p. According to IEC specification in 2002 p is determined: p = movement of table in one rotation / total thickness of beam suppression [6].

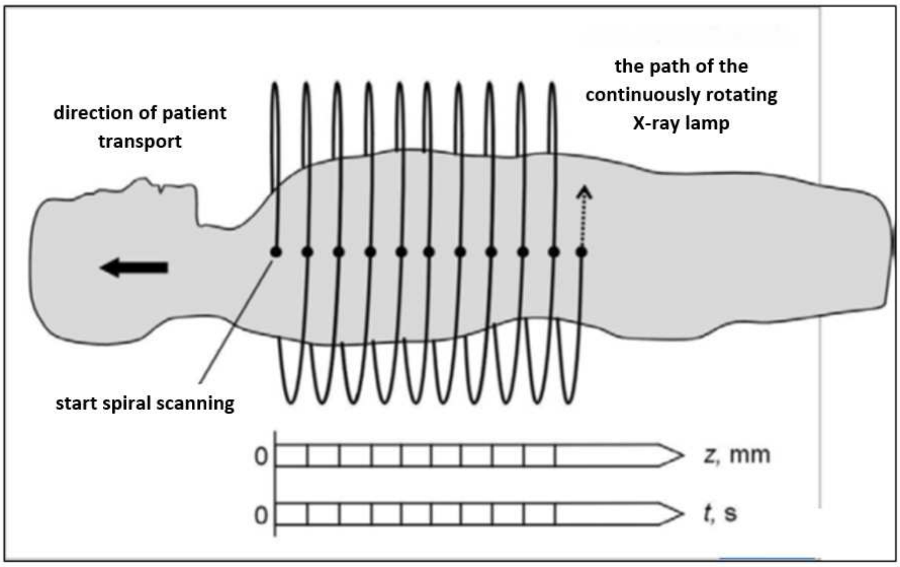

Figure 3 Schematic illustration principle of mono-slice 1st generation CT machine [5].

In 1998, the multi-slice spiral CT technology was set up which enhanced CT applications. Although MSCT (*Multi-sliceSpiralComputeTomography*) made use of the same slip-ring technology as SSCT, it provided a unique advantage in terms of increased movement of the table on rotation resulting in enlarged thickness of fan-shaped beam suppression based on width configuration of series of detectors. It is interesting that CT scanners were considered as mono-slice technique despite the fact that the first CT scanners were de facto two-slice scanners [7]. Fast development of multi-slice technology from 2000 to 2007 brought 2, 4, 8, 16, 40, 64, 256 and 320-slice CT scanners. Looking at the numbers of slices of MSCT and a year of their operation it is obvious that the number of slices exponentially increased as a time parameter roughly twice each year which is in compliance with Moore Laws of Electronics [6].

Further development was different. In 2005 the first dual-source CT scanner was launched (Figure 4). The main benefit of DSCT (*DualSourceComputedTomography*) was the scanning of the heart with improved temporal distinction. It provides the temporal distinction of one quarter of the rotation time of the gantry which is independed of the heart action and it does not need multisegmental reconstruction techniques. Except heart examination this scanner is a contribution also for general radiology. The acquisition of dual energy is the revolutionary benefit. Both X-ray lamps can operate with either various settings kV or various prior filtration. Among potential applications of CT examination with dual energy there is the tissue characterization, calcium quantification and the quantification of local blood volume in contrast images [7].

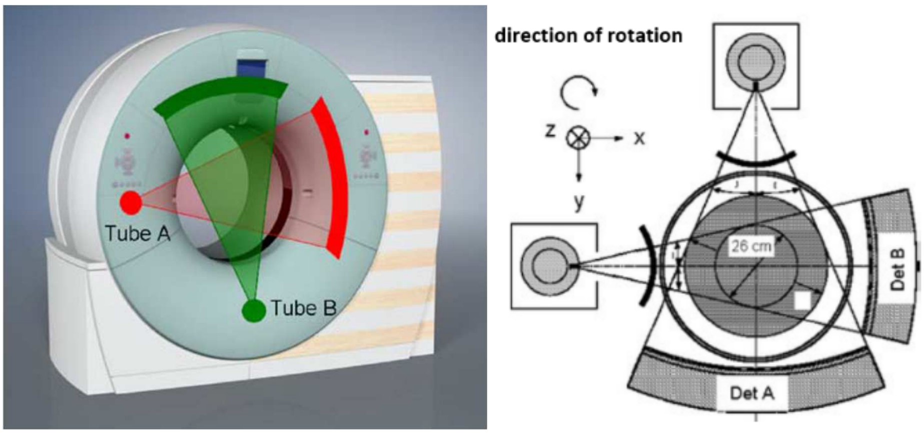

Figure 4 DSCT scanner. A schematic illustration of DSCT machine using two X-ray lamps and two series of detectors mutually placed in 90°. This type of scanner provides the temporal distinction equal to a quarter of rotating time of gantry independent of the heart action. In technical realization, the first detector (a) covers the whole scan FOV (field of view) with average 50 cm and second detector (b) has got smaller FOV [8].

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By means of modern MSCT scanners it is possible to display the whole human body during the comfortable breath holding. Improved and faster displaying algorithms, improved capacity of data storage and higher quality of 3D displaying significantly affected hardware development. Obviously usage of MSCT scanners leads to the increased productivity of CT and multi-slice examinations are carried out with more complicated protocols than CT examinations with SSCT scanners [9]. Further development of CT scanning should provide information of 4D scanning, what is the dynamic volume scanning. CT scanners with conical beam have even today the capacity for 3D displaying of larger volumes with isotropic distinction and they have a potential for 4D displaying because they are capable to obtain data from large volumes during one rotation both X-ray lamp – detector [10]. At present Toshiba and Siemens companies are imposing machines focused on this target. Toshiba launched 320-slice scanner which enables to examine all organs during one rotation. Siemens introduced 128-slice scanner with dynamic spiral shuttle mode which enables to gain 4D data from large volumes. Figure 5 demonstrates the example of perfusion scan of the whole brain. Perfusion scan has been possible only in one-slice so far.

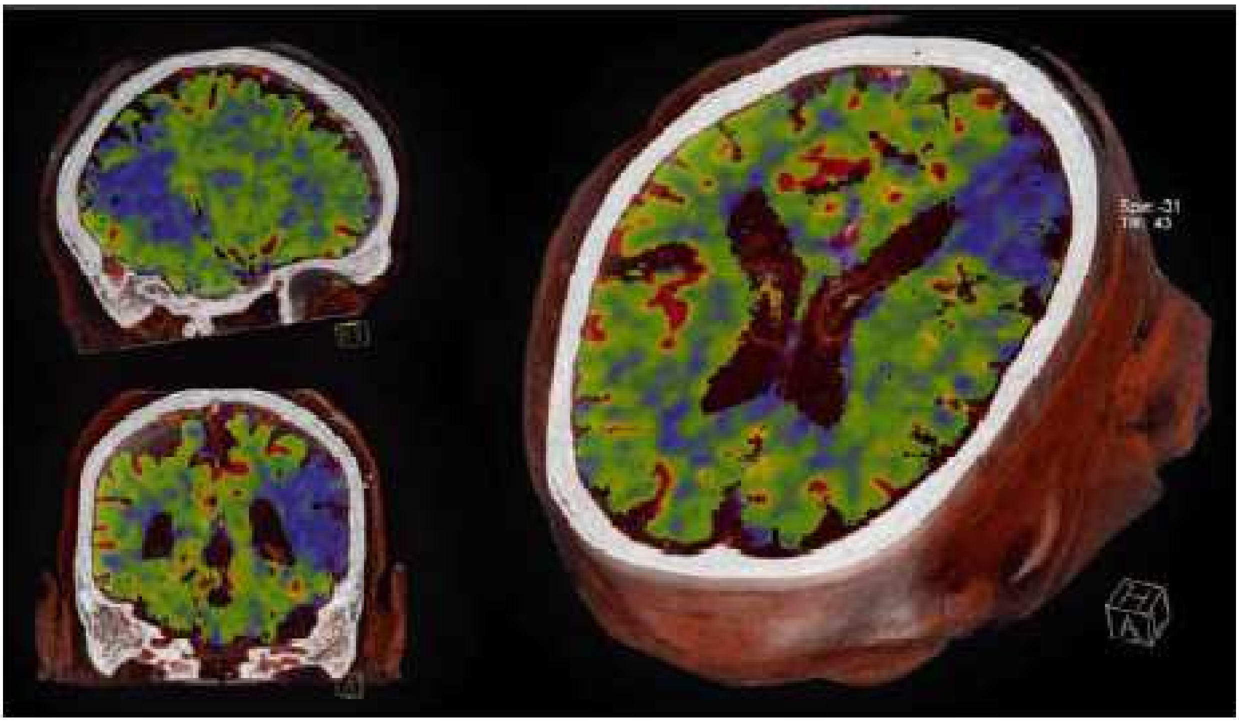

Figure 5 Perfusion scan of the whole brain on the device Siemens SOMATOM Definition AS+:

Configuration of detectors 128 x 0,6 mm and detector coverage 38,4 mm was carried out for perfusion scan of the whole brain in special spiral shuttle mode which uses sinusoidal movement of patient´s bed through the whole brain within 30sec. [6].

Prototype CT scanners use the technology of flat panel detectors originally used for conventional catheterization angiography. Their excellent spatial distinction as a consequence of small size of detector pixels predetermines them for clinical applications from ultra-high distinctive bone displaying through dynamic CT angiography study to functional examinations [11].

Conclusion

For correct interpretation of diagnostic images, it is inevitable to understand the principle of particular diagnostic methods and the principle of formation of their artifacts.

Acknowledgement

This article was supported by the state grant KEGA 069TUKE-4/2017 of the Ministry of Education of the Slovak Republic.

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Review process

Single-blind peer reviewed process by two reviewers.