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# HISTORY OF DEVELOPMENT AND RELEVANT ISSUES OF COMPUTER TOMOGRAPHY

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**Summary**

Computer tomography (CT) - one of the main methods of radiology, studying with X-ray, measurement and computer working differences in attenuation of X-ray radiation by tissues of different density.

Computer tomography lets to to conduct research in transverse planes, taking into account the anatomical features of the patient’s body, and, if necessary, to obtain three-dimensional images to accurately assess the relative position of various organs and tissues. In this article shows main centuries and stages of CT development, formation of CT as diagnostic method which constantly uses in different medical institutes all over the world. CT constantly develops and improves. Authors of this article hope that information outlined in this work will be interesting for students and doctors.

***Keywords:*** *Computer tomography, three-dimensional reconstruction, perfusion CT.*

**Резюме**

# ИСТОРИЯ РАЗВИТИЯ И АКТУАЛЬНЫЕ ВОПРОСЫ КОМПЬЮТЕРНОЙ ТОМОГРАФИИ

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Компьютерная томография - один из основных методов лучевой диагностики исследования с использованием рентгеновского излучения, с измерением и компьютерной обработке разности ослабления рентгеновского излучения различными по плотности тканями. Компьютерная томография позволяет проводить исследование в поперечных плоскостях с учетом анатомических особенностей тела пациента, а при необходимости – получать трехмерные изображения для точной оценки взаиморасположения различных органов и тканей. В данной статье показаны основные вехи и этапы развития компьютерной томографии, становления компьютерной томографии как диагностического метода, который используется постоянно в различных медицинских учреждениях по всему миру. Компьютерная томография постоянно развивается и совершенствуется. Авторы данной статьи надеются, что информация, изложенная в данной работе, будет интересна как студентам, так и практикующим врачам.

***Ключевые слова:*** *компьютерная томография, трехмерная реконструкция, перфузионная компьютерная томография.*

**Түйіндеме**

## КОМПЬЮТЕРЛІК ТОМОГРАФИЯНЫҢ ДАМУ ТАРИХЫ МЕН ӨЗЕКТІ МӘСЕЛЕРІ

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Компьтерлік томография – сәулелі диагностиканың рентген сәулелерін қолданып зерттеу әдістерінің ең негізгісі, ол жуандығы әр-түрлі тіндердегі рентген сәулесінің әлсіреуін зерттеу және өңдеуге қолданылады. Компьютерлік томография - пациент денесінің анатомиялық ерекшеліктерін ескере отырып көлденең жазықтықтарды зерттеуге және қажет болған жағдайда мүшелер мен тіндердің орналасуының үшөлшемді кескінің алуға көмектеседі. Берілген мақалада компьютерлік томографияның дамуының басты кезеңдері, компьютерлік томографияның бүкіләлемдік медицина орталықтарында диагностикалық әдіс ретінде қалыптасуы көрсетілген. Компьютерлік томография үздіксіз дамып, жетілуде. Берілген мақала авторлары келтірілген мәліметтер студенттермен қатар, тәжірибеден өтуші дәрігерлерді де қызықтыратындығына үміт артады.

***Негізгі сөздер**: компьютерлік томография, үшөлшемді қайта құру, перфузионды компьютерлік томография.*

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**Introduction**

Over the past decades, the level of medical equipment used for diagnostic purposes has changed significantly. Different modern diagnostic devices are able to display pathological changes based on various principles of action.

The most informative diagnostic methods in our time are different types of tomographs that can provide information about each structural element in the investigated object.

Currently, various types of tomography are actively developing: X-ray computed tomography (CT), magnetic resonance (MRI), positron emission (PET), ultrasound, etc. Although they are different in structure, they have one point, which is to get an image from a certain layer (section) of the investigated object among the total information. [3]

At the present stage of development of medicine, for a doctor of any specialty (surgeons, therapists, gynecologists, etc.) as well as for students and interns, it is necessary to know the basic principles of tomographic devices.

The Department of Radiation Diagnostics and Nuclear Medicine has previously published an article about the history and current issues of magnetic resonance imaging. [2] In this research, current issues of computer tomography and development of history will be highlighted.

**History of origin and development**

Among all existing tomographic methods, X-ray computed tomography (CT) has been particularly successful. The reason for its appearance was the dissatisfaction with conventional radiography.

The advantages of CT compared with traditional radiography are:

- lack of shadow overlays on the image;
- higher accuracy of measuring geometric ratios;

- sensitivity is a lot higher than with regular radiography.

The first attempt to reconstruct the image was considered in 1917 by the Austrian mathematician Johann Radon, who established the dependence of the absorption of X-ray radiation on the density of the substance.

The method of computed tomography in 1961 was proposed by the American neuroradiologist William Oldendorf, and in 1963, mathematician Alan Kormak (USA) conducted laboratory experiments on X-ray tomography and showed the feasibility of image reconstruction. The first high-quality tomogram of the human brain was obtained in 1972 [5]

In 1973, Godfrey Hounsfield (Great Britain) developed the first commercial system in the West - the brain scanner of the English company EMI. This scanner allows you to receive images with a resolution of 80x80 pixels (pixel size 3 mm). Obtaining one image required 4.5 min for data collection and 1.5 min for reconstruction. The high duration of the study imposed a limitation on the study area and the first tomographs were used only for brain research. The first Soviet medical X-ray tomograph SRT-1000 was developed in 1978 under the guidance of I. B. Rubashov, the former in 1987-1998 Director of the All-Russian Research Institute of Computed Tomography.

By 1979, computer tomographs serially produced by many Western companies, despite their impressive cost (an EMI scanner cost $ 390,000), were already working in more than 2,000 clinics in the world.

In 1979, G. Hounsfield and A. Kormak were awarded the Nobel Prize in medicine for their outstanding contribution to the development of computed tomography. Three years later, in 1982, the famous English microbiologist Aron Klug was awarded the Nobel Prize in chemistry, who made a significant contribution to the development of experimental and computational methods of three-dimensional computed tomography.

The design of a computer tomograph over the years of its existence has undergone significant changes. Five generations of CT scanners are distinguished.

In tomographs of the 1st generation, measurements were carried out at 160 positions of the tube, then the frame was rotated through an angle of 1 ° and measurements were repeated. The measurements themselves lasted about 4.5 minutes, and the processing of the data and reconstruction of the image on a special computer was 2.5 hours.

Tomographs of the 2nd generation (for example, CT-1010, EMI) already had several detectors operating simultaneously, and the tube emitted not a pointed beam, but a fan beam. The total measurement time required to obtain a single image was significantly reduced and amounted to 20 seconds.

In 3-generation tomographs, the tube emitted a wide fan beam of rays aimed at many detectors (about 700) located along an arc. The advanced design made it possible to continuously rotate the tube and detectors 360 ° clockwise through the use of a slip ring when applying voltage. This made it possible to eliminate the stage of tube movement and reduce the time required to obtain one image to 10 seconds. Such tomographs made it possible to study moving body parts (lungs and abdominal cavity) and made it possible to develop a spiral data collection algorithm. All modern medical computed tomography scans belong to the 3rd generation.

In the 4th generation tomographs, there was a continuous motionless ring of detectors and an X-ray tube emitting a fan beam of rays, rotating around the patient inside the ring. Scanning time for each projection was reduced to 0.7 s, and image quality improved.

In the early 1980s, electron beam tomographs (5th generation tomographs) appeared. In them, a stream of electrons is created by a fixed electron-beam gun located behind the tomograph. Passing through the vacuum, the flow is focused and directed by electromagnetic coils to the tungsten target in the form of an arc of a circle (about 210 degree), located under the patient's table. Targets are arranged in four rows, have a large mass and are cooled by running water, which solves the problems of heat removal. These tomographs are used in studies of the heart, as they allow you to get an image in 33 ms at a speed of 30 frames / second, and the number of slices is not limited by the heat capacity of the tube. Such images do not contain artifacts from heart pulsations, but have a lower signal to noise ratio [1].

CT scan configuration

The composition of any CT scanner includes the following main blocks:

1. gantry with a patient table and control units;
2. high voltage generator;
3. computing system;
4. operator console.

Inside the gantry there are blocks that provide data collection: an X-ray tube and collimators, detectors and a data acquisition system, a tube controller (rotor motion controller), a high-frequency generator, an integrated microcomputer (regulating the voltage and current on the tube), a computer that provides data exchange with the console.

In a computer tomograph, an X-ray tube together with a collimation system creates a narrow fan-shaped beam of rays, the divergence angle of which is 30 ° – 50 °. The attenuation of an X-ray beam when passing through an object is detected by detectors that convert the recorded X-ray radiation into electrical signals. Then these analog signals are amplified by electronic modules and converted into digital pulses.

X-ray beams are shaped with special diaphragms called collimators. They come in two forms. The source collimators are located directly in front of the radiation source (X-ray tube); they create a bundle of more parallel rays and reduce the dose to the patient.

The collimators of the detectors are located directly in front of the detectors and serve to reduce scattering radiation and reduce image artifacts. These collimators serve to determine the thickness of the slice (limiting the area considered by the sensors) and the quality of the slice profile.

The patient and gantry table control console is used to control the horizontal and vertical movement of the table, patient positioning, and the tilt of the gantry relative to the vertical axis of the scanner.

A high-voltage three-phase generator provides the entire system with the necessary electricity, allowing you to adjust the research methodology by reducing the patient's radiation dose and preserving the required power. The computer performs image reconstruction, solving more than 30,000 equations simultaneously. In modern tomographs, image processing software largely determines their clinical performance and the information content of the recorded data and accounts for 25% -30% of the total cost of the scanner.

Computer tomography scanner output is given in CT numbers or Hounsfield units (HU). With modern medical scanners, the measured CT numbers are in the range from –1024HU to +3071 HU.

Computer processing of the image allows us to distinguish between more than a hundred degrees of change in the density of the studied tissues - from zero - for water, cerebrospinal fluid to a hundred or more - for bones and metal, which makes it possible to differentiate the differences between normal and pathological tissue sections within 0.5-1%, then there are 20-30 times more than on conventional radiographs.

*Table 1.*

**Density of various tissues in Hounsfield units (HU).**

| Tissue | Density, HU | Tissue | Density, HU |
|---|---|---|---|
| bone on average | 1000 | gray matter of the brain | +20-40 |
| clotted blood | +55-75 | blood | +13-18 |
| spleen | +50-70 | cerebrospinal fluid | 15 |
| liver | +40-70 | tumor | +5-35 |
| pancreas | +40-60 | gall bladder | +5-30 |
| kidney | +40-60 | water | 0 |
| aorta | +35-50 | orbits | -25 |
| the muscles | +35-50 | fat | -100 |
| white matter of the brain | +36-46 | lungs | -150-400 |
| cerebellum | 30 | air | -1000 |

**Scan modes**

There are two ways to collect data in computed tomography: incremental and spiral scanning.

The easiest way to collect data is a step-by-step CT scan, for which there are two main stages: data accumulation and patient positioning. At the stage of data accumulation, the patient remains stationary and the X-ray tube rotates relative to the patient to accumulate a complete set of projections at a predetermined scan location. At the patient positioning stage (more than 1c), data is not accumulated, and the patient moves to the next data collection position. The image is reconstructed from the complete data set.

Patient movement during data collection at various positions of the tube causes image artifacts and limits the scope of diagnostic applications.

More complex is the spiral scan, made possible by the advent of the Gentry construction with a slip ring, allowing the tube and detectors to rotate continuously. The first idea of spiral scanning was patented by the Japanese company TOSHIBA in 1986. In 1989, a team of scientists led by T. Katakura carried out the first clinical study on a spiral computed tomography scanner.

The advantage of spiral computed tomography is the continuous accumulation of data, carried out simultaneously with the movement of the patient through the frame. The distance the patient moves per revolution of the frame corresponds to the speed of the table. Since the data is accumulated continuously, the working cycle in spiral computed tomography is close to 100%, and the displayed volume is displayed faster.

In recent decades, multislice CT scanners have been actively developed and introduced. In these tomographs, the detectors are arranged in several rows, which allows to simultaneously receive several slices with different positions. The first multilayer computed tomographs appeared in 1992 and made it possible to visually evaluate their advantages:

- higher spatial resolution;
- higher research speed;
- obtaining a larger image with specified parameters;
- rational use of the resource of the tube.

Modern multislice CT scanners have up to 512 rows of detectors and provide high resolution images, allowing you to reconstruct the obtained data in arbitrary planes and increase the information component of the study.

**Three-dimensional reconstruction**

Significantly increase the information content of the data obtained by tomography allows the use of various methods of three-dimensional reconstruction, allowing you to consider the areas of interest of the studied object from an arbitrary angle.

Three-dimensional reconstructions give a clear picture of the spatial arrangement of structures, increase recognition of diagnostic significant details, and are useful in planning operations. At the same time, structures with a high density can hide other structures of equal or lower density (for example, the bones of the skull hide the vessels of the brain). The solution of the problem is a manual or automatic procedure for removing external layers with a higher density, which allows to reconstruct the internal structures of interest with a different degree of transparency.

To obtain images of internal cavities (for example, vessels, bronchi, intestines) in perspective, and sometimes to display areas not accessible by conventional endoscopy (for example, brain cisterns), virtual endoscopy is used. In this mode, cavities and objects of interest are displayed using a volumetric representation in perspective, which gives an idea of "flight" through the displayed area.

The use of various reconstruction methods can significantly increase the information content of the obtained data, including ones due to the visibility of the spatial location of the studied tissues (for example, when examining a comminuted fracture to image the locations of bone fragments).

**Perfusion computed tomography**

One of the most promising directions in the development of computed tomography is perfusion computed tomography, which allows you to assess cerebral blood flow disorders in various pathological conditions (stroke, neoplasms, and other pathologies).

The point of the method is the quantitative measurement of cerebral blood flow by assessing changes in the X-ray density of the tissue during passage of an intravenously administered contrast medium. The theoretical foundations of the method were described by L. Axel in 1979, already 7 years after the appearance of the first CT apparatus [4], but the use of perfusion computed tomography in clinical practice became possible only in the 1990s. with the introduction of multi-helical computed tomographic scanners with high speed imaging and software improvements. Currently, the protocol of perfusion computed tomography is standard for most modern devices from leading manufacturers of imaging equipment, and the possibilities of the new technique continue to be intensively studied.

In perfusion computed tomography, the passage of contrast medium through the cerebral network of capillaries is monitored using a series of CT sections [7].

Based on the data on the change in the X-ray density of the image elements as the contrast medium passes, a graph is plotted of the density (i.e., the change in the concentration of the contrast medium in any slice element) versus time (time-density curve, TDC). Such a graph is first constructed for the projections of the large intracranial artery and vein, which allows to determine the arterial (delivery of contrast medium with blood) and venous (removal of contrast medium from the cerebral bed) mathematical functions. The latter are the basis for further calculation of the perfusion parameters in each pixel of the slice. About 40 ml of iodine-containing contrast medium is used, which is introduced at a rate of 4–8 ml / s. For the full implementation of the protocol and subsequent reconstruction of the images, it takes from 7 to 15 minutes. Due to the fact that the scanning speed of the majority of computed tomography devices used in clinical practice is insufficient to perform a study of the entire brain, with perfusion computed tomography, as a rule, 4 sections with a thickness of 0.5 to 0.8 mm are studied. Scanning is usually carried out at the level of the deep structures of the brain and the basal ganglia with the capture of supratentorial areas supplied to the anterior, middle and posterior cerebral arteries. If at the time of perfusion computed tomography there is already information about the localization of brain pathology (for example, according to other imaging methods), then the level of slices is adjusted accordingly. The equivalent dose for perfusion computed tomography is 2.0–3.4 mV, which is not much higher than the dose for conventional head CT (1.5–2.5 mSv) [6].

The main problems associated with the introduction of perfusion computed tomography are the use of X-rays and contrast agents, as well as the limited coverage of the brain. Currently, scanners with a large array of detectors are being developed, capable of performing volumetric scanning with an approximate assessment of perfusion of the whole brain. In addition, due to the presence of bone artifacts, perfusion computed tomography cannot be used to study pathology in the posterior cranial fossa. It is necessary to standardize the technique of obtaining data, as well as the study of reproducibility and the possibility of comparing data depending on the scanner and operator. The undoubted advantages of perfusion computed tomography are the ability to quantify perfusion parameters, the high availability of the method, the speed of the study and the relatively low sensitivity to patient movements, which is especially important in urgent conditions.

**Conclusion**

The main advantages of computed tomography is the short duration of the investigation (only 1–5 min) with a sufficiently high spatial resolution of the image (up to hundredths of a millimeter). The advantages can also include: the ability to build high-quality 3D reconstructions of the object; low operational costs of computed tomography (compared with other types of tomography); efficiency; the possibility of researching industrial facilities.

The main disadvantages of RCT: the presence of X-ray radiation; receiving slices only in the transverse plane; the presence of metal artifacts on tomograms; influence of temperature of the environment; the need to calibrate the device due to the drift of CT numbers.

Thus, despite the rapidly developing medical technologies and other types of tomography, computed tomography always remains as a popular tool in the diagnostic arsenal of a doctor of any specialty.

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