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Technological state and prospects of production of modern X-ray diagnostic systems

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The report is devoted to the general review of technologies and prospects of development of modern X-ray diagnostic devices. In the course of progressive qualitative movement of scientific and technological progress there is a development of technologies and improvement of medical equipment, which certainly has a positive impact on the development of world medicine in general and domestic medicine in particular. Research and innovations in the field of medical equipment contribute to the development of X-ray diagnostic systems. Among the main areas of development are: achieving more accurate diagnostics, increasing resolution, improving image quality while minimising X-ray dose, automation and introduction of artificial intelligence and machine learning technologies, improving ergonomics and functionality of X-ray diagnostic systems.

Structurally, a typical X-ray diagnostic system is a single independent product developed on the basis of X-ray diagnostic apparatus with a teleoperated table-tripod for standard and special X-ray diagnostic examinations in the modes of radiography and fluoroscopy.

The basic principle of operation of a typical X-ray diagnostic system is as follows: the X-ray power supply unit (PSU) supplies power to the X-ray emitter unit with the X-ray tube, as a result of which the X-ray tube generates braking ionising X-ray radiation in the direction of the patient located on the tripod table. Thanks to the collimator, the X-ray radiation is geometrically corrected for the size of the field and is directed towards the patient's anatomical region to be examined. After the X-rays pass through the patient's body, the X-rays reach the detector inside the tripod table and are converted into electrical signals, which are then processed by a digital computer station to form a clinical image. The tripod table is rotatable, which allows the patient to be examined in various inclined positions, and is remotely controlled (i.e. teleoperated), allowing medical staff to stay in the control room to avoid exposure to ionising radiation. Clinical images are visualised on monitors. Thanks to the laboratory technician's automated workstation (AWS), the images can be edited, archived and transmitted over the network in DICOM format to the PACS system or to the hospital intranet.

Currently, there is a tendency to develop the technological side of X-ray diagnostic devices, for example, the creation of a new generation of X-ray tubes for projection radiography. Clinical practice of the past years has shown that for successful implementation of the projection radiography method the size of the focal spot of the used X-ray tubes should not exceed 0.1 mm or 100 µm. According to GOST 22091.9-86 such X-ray tubes belong to the class of microfocus tubes. Long-term studies have shown that in case of using microfocus X-ray tubes a number of peculiarities (effects) appear during X-ray image formation. The main ones are: the effects of increasing the depth of field and contrast, the effects of pseudo-volume image and phase contrast, the effect of reducing the exposure dose. However, due to the limited power supplied to the target of a microfocus X-ray tube by an electron beam of small cross-section, the intensity of the radiation generated by it is small in comparison with a "conventional" X-ray tube. This significantly limits the scope of application of microfocus radiography in such socially important areas of medical diagnostics as angiography, mammography, fluorography, tomography, etc. The intensity of radiation can be increased both by increasing the tube current and the tube voltage, so both directions were used in the development of a new generation of microfocus X-ray tubes [1].

The problem of performing X-ray diagnostic studies in non-specialised settings, such as at the patient's home, should be highlighted separately. Obviously, it is impossible to use traditional stationary X-ray devices in the home. Accordingly, the issue of ensuring radiation safety for the personnel conducting the study and for others who may also be involved in the study, for example, when laying the patient, becomes important. However, it is practically impossible to use special means of protection from unused X-ray radiation - screens, booths, etc., as well as to remove the surrounding people to a safe distance at home. Therefore, it is necessary to apply such techniques of X-ray imaging that will significantly reduce the exposure dose of radiation in comparison with imaging with stationary devices. In this case, it is extremely important to obtain image quality of the examined organ, necessary and sufficient to make a decision on the presence or absence of pathology.

The diagnostic efficiency of portable chest radiography (defined as the number of chest radiographs showing new findings or changes in known findings divided by the total number of chest radiographs) for patients admitted to the ICU is 84.5%. These conclusions were reached by Palazzetti V. et. al, (2013) in a study of the effectiveness of mobile radiography in the ICU [2]. Portable technical means in radiography are now also proposed for use in dental practice [3,4].

When using 'hand-held' X-ray machines, there is a small increase in the dose level for X-ray laboratory technicians. However, the dose remains well below the recommended levels. The position of the machine relative to the X-ray technician has a significant effect on the total absorbed dose. The availability of individual dosimeters to monitor exposure levels is recommended. In addition, guidance, training and protocols for exposure levels should be available on site and strictly adhered to; regular checks are necessary to ensure that all regulations are being followed [5].

From the prospects of development of X-ray diagnostic devices, we can separately emphasise the direction of tomography and dual energy. In general purpose radiography traditional linear tomography allows to obtain layer-by-layer images of the object, but during one pass of the radiator only one slice is imaged. As a result, in case of necessity to obtain a layer-by-layer image of all lungs the procedure is performed not less than 10 times, which leads to significant increase of radiation load on the patient and duration of the procedure. Computed tomography method allows to obtain information about the whole volume of the thorax, but significantly increases the dose load on the patient [6]. Tomosynthesis technology is at the junction of linear and computed tomography (CT), combining high informativeness (compared to linear tomography) and low dose load (compared to CT). The use of modern tomosynthesis and dual-energy technologies makes it possible to significantly increase the informativeness of the examination and improve the diagnosis of pathology at early stages. The main advantage of these technologies is that they can be used on teleoperated tripod tables with a digital flat panel dynamic detector without significant modifications of the hardware, as well as on modern devices for two workplaces [7,8].

It is expected that the introduction of dual-energy and tomosynthesis technologies into medical practice will, in a number of cases, make it possible to eliminate the need for follow-up examinations in CT rooms. This will help to relieve CT rooms of routine examinations and provide access to them for more patients.

Based on the above, it can be concluded that the development of X-ray technology at the present stage should be assessed not as the final milestone of evolution, but as the transition of X-ray technology to a qualitatively new digital level, the potential capabilities of which are enormous.

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Section

Applications of nuclear methods in science, technology, medicine and radioecology

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