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Modern development trends of the digital radiographic units

The of the digital radiographic unit modification with the linear tomography mode to units with the tomosynthesis mode are the new level of radiography. It is analyzed advantages and disadvantages of the radiography, tomography and tomosynthesis modes.

Introduction.

The modification of film photo fluorography units to digital methods of examination led to reduction the patient's dose in 5 - 15 times, and time of the diagnostic information obtaining decreased in tens of times [1]. In addition to the fluorography, the modification to the digital methods concerned the radiographic and mammographic unites. The using of the computer image post-processing in such unites made it possible to rise up of their quality to a high level [2].

Today for the Ukrainian X-ray diagnostic is character the rapid increasing of the multispiral computer tomographies in diagnostic centers. The examination results in the form of a large number of tomographic slices [2]. It greatly increases the probability of determining pathologies and the ease of the diagnostic information reading.

Such situation leads to rising of the average annual tomography working load up to 95%. In the same time the annual working load of the radiographic unites is only 28% [3]. Unfortunately, the using of the tomography examinations leads to patient's dose increasing in several times and significant financial costs for the patient [4]. For example, the average patient dose in USA due to tomography examination during 1996-2010 was about 2.3 mSv [5]. In the same time, in fluorography examination the average patient dose is less than 0,1 mSv. For these reasons, the using of tomographs for primary X-ray diagnostics raises serious objections [6].

Problem Formulation.

Now for patient care at Ukrainian medical institutions of the 1st and 2nd levels are more than 4000 of the X-ray units. These units perform the diagnostics for more than 90% of citizen's handlings. Therefore, the task of the X-ray diagnostic unit modification is relevant for Ukraine.

Such modification must be combine the presentation of diagnostic information in the large number of tomographic slices without significantly the patient's dose increasing. This is feasible by way the modernization of existing double place radiographic unites with a linear tomography mode to units with tomosynthesis mode.

Materials and methods.

The first step towards realizing of the double place X-ray diagnostic unit modernization is the some of the technical device's replacement. Such devices are memory cassettes, cassettes with X-ray film and also old X-ray image intensifier. It needs to be replaced by highly sensitive dynamic digital receivers with a field of 24x30 cm to 43x60 cm [1]. The experiments carried out with the prototype unit demonstrated the efficiency of the suggested approach [7].

The replacement to dynamic digital receiver allows to improve of the X-ray unites capabilities, to simplify their design, to abandon the expensive X-ray film using and to create the electronic archives. However, the receiver's using is not sufficient for obtaining of the X-ray unites with tomosynthesis mode.

A revolutionary technical solution for obtaining of the X-ray unit with tomosynthesis mode was the development by General Electric (USA) of a tomosynthesis method for mammography [2]. In this case, the mammary gland is scanned at angles $+ 11^\circ - + 32^\circ$ and 11 - 65 pictures are obtained during the examination. After that, 40...80 tomographic slices are reconstructed. In these slices the pathologies are diagnosed significantly better than on the mammograms [2]. The total patient's dose from such scanning corresponds to 1...3 mammograms. In this way, the patient's dose is reduced up to 3 times. Today the tomosynthesis mode in mammography is widely used in expert class devices.

For radiography, the tomosynthesis mode was initiated in the remote-controlled table during linear tomography's examination. The leader in this direction is the Shimadzu (Japan) [4]. In tomosynthesis mode the scanning angle is no more than $+ 20^\circ$ (in the standard tomographic examination the scanning angle is 360°), and the examination time is less than 10 sec.

Our researches [7] shown that the best solution is the exposition has to be adjusted depending on the projection angle to ensure the invariability of the signal/quantum noise level at the digital receptor. The 80 ... 120 slices are produced in the remote-controlled table during linear tomography's examination. According to the researches, which we made and represented in [7] the time needed for the reconstruction of 300 slices does not exceed 90 seconds for typical PC.

The reconstruction is carried out for 200...400 tomographic cross-sections, having a resolution up to 2.0 lp/mm. It's higher than the resolution of images obtained in tomographic examinations. The patient's dose is reduced to 10 times in tomosynthesis examination as compared with tomographic examination [4]. This reduction is proportionally to the scanning angle decreasing.

Our researches, represented in [7] showed, that the using the dynamic digital receptor in regime with the reduced to 1.2 lp/mm resolution and digital pre- and post-processing will lower the patient dose load into 64 times compared to radiographic image of with 4.6 lp/mm resolution. It allows ensure the patient's dose in tomosynthesis mode with digital radiographic table to be equivalent to a single radiographic examination.

There are more than 2000 remote-controlled tables with tomosynthesis mode in the world but these units unfortunately are almost haven't in Ukraine.

The low patient's dose during examination by tomosynthesis mode allowed to evaluate its effectiveness in cancer and tuberculosis screening. For oncological

diseases in chronic smokers, the probability of pathology detection increased from 0.5 (radiography) up to 0.9 (tomosynthesis) [8]. The probability was 0.97 in tomography examination. The probability of pathology detection increased from 0.56 (radiography) up to 0.75 (tomosynthesis) in tubercular screening [9, 10]. The probability was 0.93 tomography in examination.

According to the literature [3, 9, 10] the probability of the pathology detection during the years may be representation in graphically view, Fig.1.

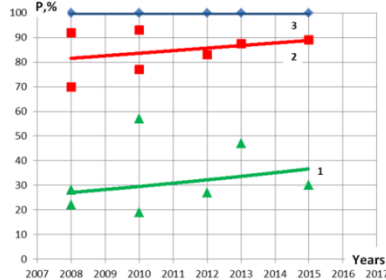


Fig. 1. The probability of pathology detection for different examinations: 1 – digital radiology, 2 – tomosynthesis, 3 – CT.

In the Fig.1 we can see why it is easier for doctors to diagnose the tomosynthesis images than the radiographic images.

New development of the tomosynthesis mode for general radiography received in 2016. The tomosynthesis mode for linear tomography was made on the basis of the double plate radiographic unit.

These units are widely used for primary X-ray diagnostics. Shimadzu (Japan), as well as Josef Batschart AG/XRAY-SWISS (Switzerland) together with Teleoptic (Ukraine) and Teleoptic (Ukraine) together with Medapparatura (Ukraine) showed such units at international exhibitions.

In the Fig. 2 are shown the images obtained traditionally to the film and by the tomosynthesis mode.

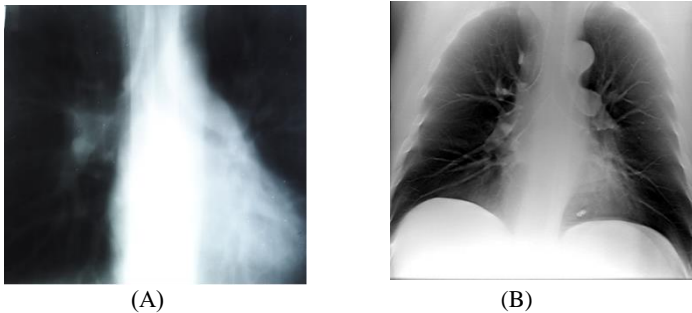


Fig. 2. Linear tomograms performed on (A) the X-ray film (average patient's dose is 1.2 mSv), and (B) the linear tomosynthesis method (B) (average patient's dose is 0.4 mSv)

The image quality advantage of the tomographic slices obtained by tomosynthesis mode does not require the explanations.

The using of the linear tomography with tomosynthesis mode allows to reduce the patient's dose due to the of the X-ray flux limitation both ways: by the collimator of the X-ray emitter and by the using of pads made of lead rubber. This is especially important for children [6].

In addition to tomosynthesis systems, the cone-beam tomographs have been developed. They are oriented for the examination of a specific interest area. Such tomographs are used the same X-ray digital dynamic receivers as unit with tomosynthesis mode, but they allow to increase the scanning angle from 40° (unit with tomosynthesis mode) to 210°...220° (the cone-beam tomographs). As a result, it becomes the possibility to reconstruct the tomographic slices in an arbitrary direction and build three-dimensional (3D) images. The most well-known and widely used among the analyzed class of units are dental tomographs [4]. They are used in dental clinics for the selection of implants and for other purposes.

Another class of cone-beam tomographs was developed by PlanMeca (Finland), Carestream (USA) and NanoFocusRay (South Korea). These tomographs are used to examinations of the head and limbs with trauma and the evolution of the pathologies.

In last years we can see the acceleration of the unit classes and diagnostic attention to the tomosynthesis mode. This is evidence this method is a successful compromise between radiography and tomography with help the multislice computer tomographs. The tomosynthesis as a whole does not replace the examinations on multislice computer tomographs. At the same time, the tomosynthesis mode significantly expands the diagnostic capabilities of the radiography without significantly the patient dose increasing. The realization of the tomosynthesis mode function in radiographic unites does not significantly increase the cost of unit in purchases, operation and repairs.

Today, the installation of the first serial domestic X-ray units with tomosynthesis mode and cone-beam tomographs in medical institutions and veterinary clinics of Ukraine has begun.

Conclusions

To summarize all the above mentioned we can describe the basic principles modification of the digital radiographic units with the linear tomography mode to units with the tomosynthesis mode as follows:

A) a new stage is developing in radiology - low-dose tomography of primary x-ray diagnostics;

B) it is realized by using of the tomosynthesis mode in x-ray units for the general purposes and specialized cone-beam tomographs;

C) these units must use the digital x-ray dynamic receivers;

D) the scanning angle in these units from 40° (the units with tomosynthesis mode), up to 210...220° (the cone-beam tomographs);

E) the small scanning angle in the units with tomosynthesis mode allows to reduce the patient dose in comparison with the multislice computer tomography examination;

F) the tomosynthesis mode as a whole does not replace the multislice computer tomography examination. At the same time, the tomosynthesis mode significantly expands the diagnostic capabilities of radiography without significantly increasing the patient dose.

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