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Methods of optimizing the radiation dose during computed tomography

Abstract. Computed tomography is the most effective method of radiation diagnosis. Starting from computed tomography, the optimization principle should be used to keep radiation doses to patients at an acceptable level. An integral part of optimization is the search for a compass between reducing the patients dose and obtaining an acceptable quality image with reliable diagnostic information. The parameters of the computed tomography are determined by the patient's radiation dose and the quality of the diagnostic image. The purpose of the article is it radiation exposure to patients. For the same reason, we considered tube current modulation. This method reduces radiation without changing the quality of the image and noise.

Keywords: computed tomography, image quality, automatic current modulation, phantom, diagnostic, radiation.

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Introduction

Currently the use of Computed Tomography is growing from year to year. But at the same time, the disadvantage of the study has not reduced. This is the due to the fact that the use of CT increases, the ability to find optimal ways of treatment and the principle of operation of the technique. As a result, the use not only increases, but also leads to an increase in the effective dose of radiation. In this regard, ways to the reduce the radiation obtained the influence of CT were considered. According to the principle of operation, based on the protocol of the attending physician, we have considered three ways to reduce the radiation dose:

- considering the requirements of the doctor depending on the treatment conditions;
- optimization of the research protocol parameters during tomography;
- using the features of the Computed tomography software process [1].

The first method, the appointment of CT scan by the attending physician to the patient, is the simplest one. We know that CT is indeed the most informative at the moment. However, in addition to CT, it is also necessary to consider methods that are not associated with ionizing radiation. For example, with physical tests or laboratory diagnostics, like MRI or ultrasound diagnostic. , a minimal area sufficient for examination must be selected by the radiologist and the attending physician so that there is no injury to the patient. By choosing it, we can reduce the effect of ionizing radiation [2]. The necessary information can be obtained by the doctor from all sides, analyzed and replaced with another CT scan.. Since our main goal is to reduce the dose load, we have obtained the principle that affects it:

- considering the possibility of conducting research that is not related to ionizing radiation;
- conducting tomography only according to indications;
- saving previously performed DICOM research data, which would prevents repeated unreasonable studies;
- preparing the patient preliminarily before the study, including: removal of metal or foreign objects; creation of ways to immobilize the patient, and sedation of small children or anxious patients;
- without extending the area of unreasonable research, but rather bringing it to the minimum area [3].

The second direction is changing the radiologist's research protocol, to obtain the necessary information. For example, we can reduce the radiation dose by lowering the voltage in the tube, but it can thereby worsen the contrast of the image. For this reason, we can only use this method to identify high contrast structures.

The third factor considered is dose reduction through the use of the features of the CT machine and software. CT manufactures determine the rational geometry of the dosage in the tomography, the design of detectors and other properties of the distance to the tube. For example, when detecting metastases, increasing the speed of movement of the table reduces the dose, but does not give a complete picture. For this reason, it is necessary to pay attention not only to software properties/ but also pathology. Radiologist, physicists need to make efforts to obtain optimal images with the lowest dose for patients when taking Computed Tomography. This process is called optimization [4, 5].

Factors that directly affect the dose:

1. Parameters of the research protocol:
- Current strength in the X-ray tube;
- Rotation time;
- Number of scans;
- High;
2. Features of CT scanner:
- Current modulation;
- Distance between the focal point of the X-ray tube and the isocenter of the scanner;
- Collimation and filtering of X-rays.
3. Patient description:
- Weight;
- Age;
- Ability to study [6].

Modern manufactures offer a number of different methods and parameters for optimizing radiation doses during CT research. The most insignificant in the CT parameters is noise. The dose is proportional to the tube current and exposure time. An excessive increase in the tube current causes an increase in the radiation dose to the patient and if it is low it may have a negative effect and fail not to be able to get a full image. For this reason, when the radiologist selects the tube current parameter, it is also necessary to determine the patient size, as it will be difficult to quickly and correctly set the tube current during the study. In addition, when changing the tube current, it will is be necessary to optimize the patient to the largest size or attenuated part, which will prevent the patient from receiving excessive radiation [7, 8]. Automatic exposure control is relized implemented by the modulation of the tube current of the CT to adapt the tube current while obtaining the image we see that it is effective for us to optimize the beam dose. The concept of dose modulation was first developed by J.R. Haaga in 1981 and introduced into practice by General Electric Medical Systems in 1994. This will reduce radiation by 20% [9].

Dose modulation is can be divided into the following types:

1. Angular (xy)
2. Length (z)
3. Length angular (xyz)
4. Based on the body
5. Based on ECG.

When irradiated at different angels or from one area of the study to another, there is a significant change in the degree of X-rays absorption in the patient's body. Since the CT noise level of images is determined by the projection where the radiation absorption is high, in other projections where the degree of absorption is less important the radiation intensity can be reduced without losing image quality. Large dose reduction capabilities provide automatic exposure control methods, including: automatic selection of whether fixed depending on the degree of attenuation of radiation in the patient's

body; modulation of whether depending on the respiratory phase or heart cycle another. Automatic exposure control methods have reduced patient radiation dose by 10-30% in CT studies over past years without worsening quality [10].

The dose of radiation received by the patient and the image quality are determined by the following parameters of computed tomography protocols: scan length (mm), number of study stages, tube voltage (kv), product of the current strength during tube rotation (by exposure, mass), parallelism of radiation emission and CT conductivity. In order to choose the best parameters of the study taking into account the patients physical features, our modern computerized tomographs are equipped with programs for automatic current modulation. During the study the intensity of the current is determined by the thickness and density of the scanned body structures, which allows the dose reducing to a significant extently while maintaining the desired image quality [11]. This is why there is currently no universal way to find optimal protocols for CT.

Methods

We conducted the research on three modern CT scanners, the most common of them are Optima 64, General electric (USA); Definition AS, Siemens (Germany); Ingenuity Core, Philips (Netherlands). The tomographs were equipped with the following automatic force modulation programs [12]:

Table 1. Investigated CT, tube current modulation, parameters

Tomograph, manufacturer, year of production	**Tube current modulation**	**Parameter**	**Operating principle**
Optima 64, GE, 2015	Auto mA	Noise index (NI)	Protocol based NI-noise if image and values of tube current (mA) range
Definition AS, Siemens, 2015	Care Dose 4D	mAs, mAc	The reference mAs and corresponding image quality for reference patient and determined in protocol
Ingenuity Core, Philips	Dose Right	Dose right index, DRI	The value of DRI corresponding to the reference mAs value for the homogenous image quality

To study the operation of automatic current modulation programs from three different manufactures, CT phantom scanned using different protocols with automatic current modulation, and the values of different voltage in the range 80-120 kv were changed. To simulate the patient's body, we used anthropomorphic phantom (height 174 cm, weight 75 kg) the chest of healthy man (Lungman multipurpose chest phantom, Japan) [13].

Table 2: Automatic tube current modulation parameters for the different values of tube voltage

	Optima 64			**Definition AS**			**Ingenuity core**		
Tube voltage, kv	NI, mAmin-Amax	Pitch	Collimation, mm	Ref. mAs	Pitch	Collimation, mm	DRI	Pitch	Collimation, mm
80	15.23 (10-400)	0.984	32×1.25	100	1	32×1.2	3	1.448	32×1.25

100	15.23 (10-480)	0.984	32×1.25	100	1	32×1.2	3	1.448	32×1.25
120	15.23 (10-560)	0.984	32×1.25	100	1	32×1.2	3	1.448	32×1.25

Observations

We used the following standard settings for all protocols: the rotation time of the tube was 1 sec; the scanning area – 300 mm from the tops of the lungs; reconstruction of all images was performed with 2 mm thick slice.

The effective dose was used as the dose value:

E= DLP×Edlp

Where,

DLP (Data Length Product, product of dose by length) is the absorbed dose for the entire CT study in mGr*sm.

Edlp is the dose coefficient for the corresponding anatomical region mSv/(mGr*cm).

The dose coefficient for CT scanning of the chest is 0.017 mSv / (mGr * cm).

On Optima tomograph, using the Auto mA program, a decrease in the NI parameter entails stricter requirements for the quality of the CT image- noise reduction. To achieve this, the Auto mA program increases the current strength, which leads to an increase in the effective dose.

Care Dose program is aimed at selecting the current strength for individual patients in order to achieve image quality comparable to the image quality for the reference patient.

On Ingenuity Core tomograph, when using the Dose Right program an increase in the DRI parameter leads to an increase in the effective dose.

Table 3. Effective dose for body organs

Effective dose value for common diagnostic imaging	Effective dose(mSv)
Head CT	1-2
Chest CT	5-7
Abdomen CT	5-7
Abdomen and pelvis CT	8-14
Coronary CT angiography	5-15

Conclusion

In the article we examined the methods to improve (reduce) the radiation dose provided during the computed tomography. We have identified three main principles that affect it. That is, we considered everything from the attending physician to the manufacturers parameters.

The modulation of the tube current affects the reduction of the radiation dose. The automatic current modulation programs are specific for each manufacturer of diagnostic equipment. It was found that for the Auto mA program, the image noise was directly proportional to the NI parameter, and the effective dose of the patient decreased with increasing NI. For the Dose Right program, it was found that voltage had little effect on the effective dose, while in the Care Dose program, its value significantly increased with increasing voltage. With the implementation of the principle of increasing radiation protection of patients and the corresponding revision of the examination protocols it is necessary to find parameters that ensure the quality of the computed tomography image sufficient for the patient to solve the clinical problem with a minimum dose of radiation.

To keep radiation dose as low as reasonably achievable, two guiding principles must be followed:

- CT exams must be appropriately justified for clinical need;
- All technical aspects of each examination must be optimized.

Strategies for reducing the dose of Computed Tomography

- Determine the appropriate target image quality for each diagnostic task;
- Use the most effective method to achieve the target image quality;
- Optimize the dose performance of detector, collimator and beam- shaping filter; and
- Improve data processing.

Future perspectives:

The individualization of scanning methods according to the attenuation level, anatomical structure and clinical characteristics of each patient can be further improved with advanced automatic exposure adjustment techniques that select the appropriate tube potential and then modulate the current in the tube.

With steadily increasing computing power, iterative reconstruction is being introduced into every day clinical practice, which can lead to a significant improvement in image quality and reduction in radiation dose compared to conventional reconstruction algorithms based on filtered back projection.

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Компьютерлік томография өту барысында пациенттердің сәулелену дозасын оңтайландыру әдістері

Аңдатпа. Компьютерлік томография – сәулелік диагностиканың ең тиімді әдісі. Компьютерлік томографиядан бастап пациенттердің сәулелену дозаларын қолайлы деңгейде ұстау үшін оңтайландыру принципін ұстану қажет. Оңтайландырудың ажырамас бөлігі пациенттер үшін дозаны төмендету мен сенімді диагностикалық кескіннің сапасы компьютерлік томография параметрлерімен анықталады. Мақаланың мақсаты – пациенттерге радиациялық әсерді төмендету болып саналады. Сол себепті біз ток модуляциясын қарастырдық. Бұл әдіс кескін сапасы мен шуды өзгертпестен сәулеленуді азайтады.

Түйін сөздер: компьютерлік томография, сурет сапасы, токтың автоматты модуляиясы, фантом, диагностика, сәулелену.

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Основные направления снижения дозы облучения пациентов при компьютерной томографии

Аннотация. Компьютерная томография – самый эффективный метод лучевой диагностики. Для поддержания доз облучения пациентов на приемлемом уровне, необходимо следовать принципу оптимизации, начиная с этапа компьютерной томографии. Неотъемлемой частью оптимизации является снижение дозы и качество достоверного диагностического изображения пациента, определяемое параметрами компьютерной томографии. Целью статьи является снижение радиационного воздействия на пациентов. По этой причине мы рассмотрели метод модуляции тока. Данный метод уменьшает степень излучения, не меняя качество изображения и шум.

Ключевые слова: компьютерная томография, качество изображения, автоматическая модуляция тока, фантом, диагностика излучения.

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