ОРИГИНАЛЬНАЯ СТАТЬЯ

RADIATION SAFETY OF PATIENTS: REDUCING THE RADIATION DOSE IN ABDOMINAL MULTISLICE COMPUTED TOMOGRAPHY

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Purpose. This article describes an approach for reducing the radiation exposure in patients based on excluding the non-enhanced phase (NECT) while performing the abdomen multislice computed tomography (MSCT) with intravenous bolus contrast enhancement. The main purpose of the study was to show how an exception of NECT in the abdominal MSCT study affected the diagnostic results, and to determine how it reduced the radiation dose to the patient.

Materials and Methods: During a two-year period since the commissioning of the MSCT in radiologic department of central medical-sanitary unit No.71 where more than 5,000 MSCT studies were performed to the nuclear workers. About 10 % of these studies were intravenous contrast-enhanced abdominal MSCT. These abdominal MSCT studies with and without NECT were the material for analysis.

Results: An average effective dose per study was around 10 mSv depending on the study matter. The analysis showed that the exclusion of NECT allowed reducing the radiation dose to the patient up to 30%. Exclusion of the NECT was inappropriate just in 0.6% of cases.

Conclusions: A MSCT of the abdomen with intravenous enhancement without NECT does not cause quality loss of the diagnostic information. The method allows reducing the time of the study, the radiation dose to the patient as well as extending the life resource of the MSCT equipment. To assess the risk of stochastic effects due to MSCT exposure it is necessary to create a prospective epidemiological registry of MSCT patients.

Keywords: MSCT, abdominal MSCT, non-enhanced CT, NECT, effective dose, medical radiation dose, radiation safety.

РАДИАЦИОННАЯ ЗАЩИТА ПАЦИЕНТОВ: СНИЖЕНИЕ ЛУЧЕВОЙ НАГРУЗКИ НА ПАЦИЕНТА ПРИ ПРОВЕДЕНИИ МСКТ БРЮШНОЙ ПОЛОСТИ

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Цель. В статье описан способ снижения лучевой нагрузки на пациента при проведении мультиспиральной компьютерной томографии (МСКТ) брюшной полости с внутривенным болюсным контрастным усилением, основанный на исключении нативной (бесконтрастной) фазы. Главной целью исследования было показать, влияет ли исключение нативной фазы на полноту диагностической информации, и определить, насколько количественно данный метод позволяет снизить дозу облучения пациента.

Материалы и методы. С момента пуска в эксплуатацию мультиспирального компьютерного томографа в отделении лучевой диагностики Центральной медико-санитарной части №71 г. Озёрск, где проходят обследование работники предприятия ядерно-промышленного комплекса, было проведено более 5000 МСКТ, около 10% из которых составили исследования брюшной полости с внутривенным болюсным контрастированием, что являлось материалом для исследования.

Результаты. Средняя эффективная доза за исследование одного пациента составляла порядка 10 мЗв в зависимости от характера исследования. Проведённый анализ показал, что исключение нативной фазы позволяет до 30% снизить лучевую нагрузку на пациента. Исключение нативной фазы представляло трудности лишь в 0,6% случаев.

Выводы. Предложенный метод не приводит к потере диагностической информации, а также позволяет сократить время исследования пациента и продлить срок

эксплуатации оборудования МСКТ. Для оценки риска возможных стохастических эффектов действия медицинского ионизирующего излучения целесообразно создание проспективного регистра пациентов, проходивших процедуру МСКТ.

Ключевые слова: МСКТ, МСКТ брюшной полости, без контрастирования, нативная фаза, эффективная доза, доза медицинского облучения, радиационная безопасность.

Introduction.

Medical radiation exposure is of a global importance in modern reality. A multislice computed tomography (MSCT), a new method of X-ray imaging, is one of the perspective radiological methods with high diagnostic value. Despite that fact, the impact of X-rays on the human organism, as well as any sources of ionizing radiation, is a risk factor of human radiation pathology. According to the materials of the IAEA, radiation dose due to X-ray examinations is increasing since last years [1]. This is largely due to wide spread of MSCT, which is currently the most dose-abused X-ray diagnostic procedure [2]. The manufacturers of medical equipment attempts to improve the technology, however, the dose received by the patient during the MSCT study is still high.

Regulation of medical exposure is an important question and a complicated problem in radiation protection today. According to existing radiation safety standards, an exposure level of man-made sources of ionizing radiation on workplaces does not include medical exposure [3]. Also, in accordance with 5.4.1 paragraph of Methodical Recommendations No. 2.6.1.962-00 "Control of effective patient's dose in medical X-ray studies", "... the principles of control and limitation of radiation effects in medicine based on the necessity and usefulness of diagnostic information or therapeutic effect at the lowest possible levels of exposure. It does not set the dose limits, but uses the principles of justification the radiological procedures and optimization measures for protect patients".

Assessment of permissible levels (dose limits) of medical exposure of patients on the basis of radiation risk estimates can be reached in epidemiological studies, such as the study on radiation risk assessment of digestive tract cancer deaths in the cohort of nuclear workers [4]. However, it is obvious, that when medical radiation dose approaching the level of external dose on the workplaces of nuclear facilities it may cause similar effects as a professional radiation exposure. Understanding the complexity of the problem and the lack of accumulated knowledge to adequately assess the harm of medical exposure leads to the formation of the principle of preventive policies in radiation protection of patients [5]. Therefore, along with measures to reduce the professional exposure levels on workplaces of nuclear facilities, the radiation exposure of the patient during medical X-ray examinations must also be reduced in all possible ways. Thus, reducing radiation dose from MSCT is one of the priorities of modern radiology and radiation protection together [6].

This is of great importance in closed administrative-territorial units such as Ozyorsk, where the most of population is occupationally exposed to ionizing radiation as a result of working at the nuclear complex. It should be noted that the proposed levels of cumulative dose of medical exposure of 0.5 Sv, and the annual level of 0.2 Sv are 10 times higher than the corresponding occupational exposure levels. Since the whole responsibility for the X-ray procedures belongs to radiologist, one must have information about how to reduce radiation exposure to the patient [7]. A complex of radiation protection measures of the patient has now been implemented in the Radiological Department of Central Medical Sanitary Unit No.71 of Ozyorsk by practical implementation of the latest international experience gained by radiologists and researchers [8].

Purpose of the study.

The purpose of the study was to show whether an exception of NECT in the abdominal MSCT study affects the diagnostic information and how much it reduces the radiation dose to the patient.

Material and methods.

The study was conducted on the basis of radiological department of central medical sanitary unit No.71 of Ozyorsk. Information on patients who were examined on a 16-slice CT scanner «Bright Speed Elite» was retrospectively collected. Since the commissioning of new multislice computed tomograph in 02/07/2012 over 5103 MSCT-studies were performed and 4933 patients were examined to the end of 01/23/2014. All received diagnostic information was stored in electronic storage, integrated with the hardware of the user's interface of MSCT. Dosimetric and other special information related

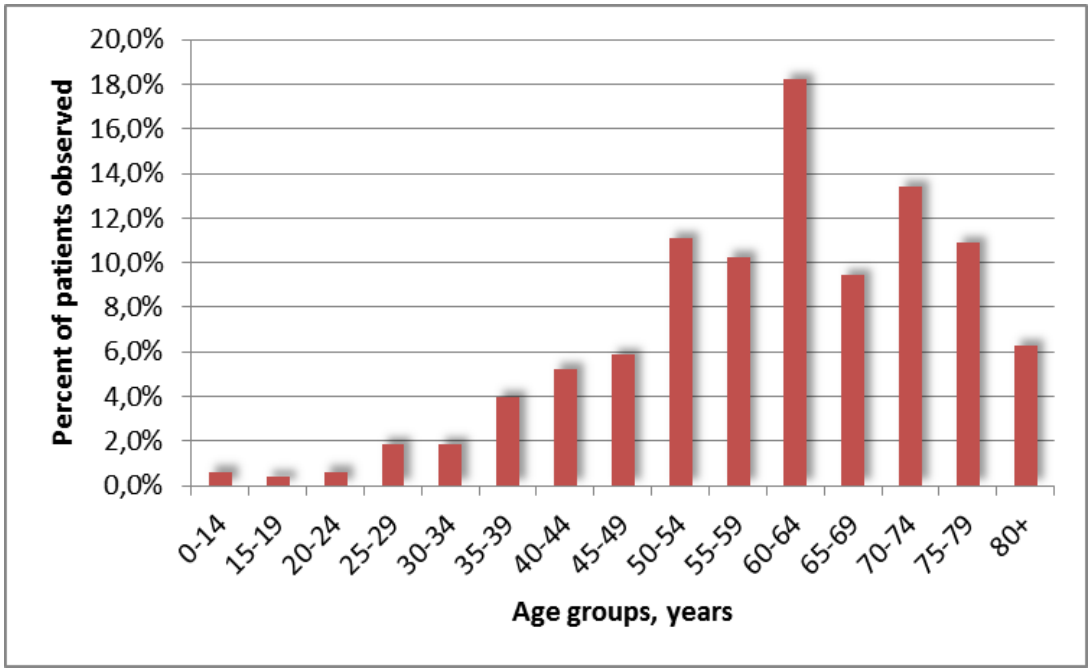

Fig. 1. Age distribution of patients examined on MSCT, as a percentage of the total number of abdominal MSCT-patients surveyed.

to each study was included in a special log of MSCT-studies. Electronic database of MSCT-studies based on this information was created. All abdominal MSCT with or without bolus contrasting were selected from database for the present analyses. The effective dose was calculated by taking into account the DLP-value according to methodological guideline [9].

All the necessary diagnostic information could be obtained during one or more phases of bolus contrasting [10]. Non-enhanced phase (NECT) is an MSCT-study without injection of contrast. As our clinical practice shows, the majority of abdominal MSCT studies with bolus contrast enhancement could be performed without using NECT. Reducing the radiation dose to the patient by eliminating the non-enhanced phase in abdominal MSCT is a well-established practice in radiology [11,12]. Unfortunately this practice is not common in our country. This could be explained by the suggestion that marking the zone of interest must be performed first, and the question about how the contrast will be accumulated by the examined area is interesting as well. However, there are strong arguments against the mandatory use of native phase in all abdominal MSCT. Excluding NECT enables radiologists to limit the patient's exposure by only necessary MSCT-scans. This is especially important in pediatrics radiology, because the child's organism, in comparison with adult, is more sensitive to ionizing radiation [11].

In most of MSCT-studies up to 120 ml at speed 2.5 - 4 ml per second (depending on the patient's vein condition) of nonionic water-soluble iodine-containing intravenous bolus contrast “Omnipaque-300” applied automatically using Dual Syringe CT Injection System «Stellant». As usual, only two phases of contrast enhancement were performed during one MSCT-study of the abdomen: the late arterial (38-40 seconds after the start of bolus injection) and portal-venous (60-70 seconds), except the cases of kidney MSCT-study (i.e. CT – urography), when the excretory phase were required.

Results.

The average age of patients with abdominal pathology examined on MSCT was 60. The age distribution of patients is shown on Figure 1.

As the figure shows, the bulk of surveyed patients presented by the adult persons, more than 50% of them are over 60, and the largest age group from 60 to 65 years, which corresponds to the age of gastrointestinal cancer incidence in population. Young age is not a contraindication to MSCT-study, but this is of special attention the limitation of radiation exposure to pediatric patients [12].

Male / female ratio in MSCT-study was roughly 1/1. The results obtained in the study in terms of average age and dose is shown in Table 1.

The radiation dose in any MSCT-study (with bolus contrast enhancement and without it) considerably varies. This variation (from 0.5 to 29 mSv) is typical for MSCT-study because it depends on many individual parameters of the patient (i.e. weight, height, examined area) as well as

Table №1. Dose-age characteristics of surveyed group.

Procedure	Male (%)	Female (%)	Average Dose, mSv*	Median dose, mSv	Average Age, years*
All abdominal MSCT	224 (46,9)	254 (53,1)	10,7 (0,5-29,0)	10,0	60,0 (8-89)
Without contrasting (NECT only)	12 (37,5)	20 (62,5)	4,1 (0,5-9,2)	4,7	53,0 (11-87)
Bolus contrasting	212 (47,5)	234 (52,5)	11,2 (1,8-29,0)	10,3	60,3 (8-89)
- with non-enhanced phase	39 (46,4)	45 (53,6)	14,2 (1,9-29,0)	14,0	61,0 (26-89)
- without non-enhanced phase	175 (48,3)	187 (51,7)	10,4 (1,8-25,0)	9,9	60,0 (8-89)

*** in parentheses: minimum and maximum values of dose and age are shown**

the matter and purpose of study, in particular,

the number of contrasting phases during the MSCT. Median of the dose has slight deviation from mean value; this indicates that the distribution might be close to normal.

Only NECT without further contrasting study was performed in 32 cases. Based on the obtained data, the maximum patient's dose in a study without contrast enhancing reached 9.2 mSv. The average dose for that kind of MSCT-study 4.1 mSv.

In case of MSCT-study with non-enhanced phase and subsequent bolus contrast enhancement average dose per study reached 14.2 mSv (from 1.9 to 29 mSv).

With the exception of NECT the average dose estimate was lower than in case of MSCT-study with non-enhanced phase: the average dose reduced to 10.4 mSv (from 1.8 to 25.0 mSv). Thus, in the study without native phase the dose decreased by 3.8 mSv in average.

It should be noted that the excluding of NECT was not resulted in any appreciable loss in diagnostic information of the obtained images. In two cases of renal pathology with high density (up to 38 H) a problem with differential diagnostics has occurred (0.6% of MSCT-study with bolus contrast enhancement without NECT). The problems were solved by the administration of additional NECT of the kidney area, then all necessary diagnostic information was obtained and the diagnosis was clarified.

Discussion.

The study showed that the abdominal MSCT with bolus contrast enhancement without NECT does not degrade the quality of diagnostic information and reduces the radiation dose in one MSCT-study by 26.8% in average. Reduction of radiation exposure to the patient by excluding, for example, the late arterial phase, does not seems as an effective solution, because in this case the diagnosis of some pathological entities, particularly hemangiomas and hypervascular formations, is difficult. Nevertheless, in many cases a single portal-venous phase could be quite enough for diagnostics (particularly in cases of repeated control studies of patients treated from cancer) to obtain a good result. This can be a question for further investigation in terms of reducing medical radiation exposure to the patient.

Unfortunately, this study does not allow us to evaluate the benefit of reducing the radiation dose to the patient in terms of risk minimization. To calculate the risk of long-term (stochastic) effects of medical radiation exposure (for example, risk of cancer), we need to perform a long-term prospective study which should cover the period of latency of stochastic effects. The prospective register of MSCT patients must contain the data on effective and (if it possible) organ dose calculated using the information about patient and technical characteristics of the X-ray equipment. In the other hand, the calculation of radiation risk using the effective dose calculated to the whole body does not allow us to get a correct estimate of certain organ effects: for example, in case of abdominal CT when we investigate liver pathology we irradiate the abdominal area while the other parts of the patient's body are not irradiated. Thus, after the possible latency period expecting the stochastic effects such as liver cancer is more probably than other cancers so the liver dose used to assess the risk seems to be more correct. But the calculation of organ dose is not provided by MSCT software.

In this study we didn't calculate the time that this method allows to save as well as the saved resource of the MSCT equipment. Although, it is evident that with decreasing amount of phases the time of the study should decrease, as well as the number of images to process.

Conclusions.

The results of analyzes showed that performing an abdominal MSCT without non-enhanced phase could reduce the radiation dose to the patient without loss of diagnostic information. However, native phase (NECT) should be applied when it is necessary.

The proposed method of MSCT-study could both reduce the radiation dose to the patient and

the time of the MSCT-study, as well as extends the life of X-ray equipment.

Any of MSCT-studies should be carefully justified due to high dose to the patient. Regardless the way how medical exposure was obtained, the patient's dose from X-ray examination should be always stored in the individual medical documentation and be available to epidemiological analysis.

To investigate the stochastic effects of medical diagnostic exposure it is necessary to create the prospective register of X-ray examinations, in which all information on each X-ray study (including MSCT) for epidemiological analyses to assess the radiation risk from medical exposure will be collected.

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Список литературы:

1. *IAEA Publication 1532. Justification of Medical Exposure in Diagnostic Imaging. – Vienna: International Atomic Energy Agency, 2011.*

2. *Brenner D. J., Hall E. J. Computed tomography – an increasing source of radiation exposure. N Engl J Med. 2007; 357: 2277–84.*

3. *Radiation Safety Standards NRB-99/2009. SanPiN 2.6.1.2523 – 09.*

4. *Osipov M.V., Sokolnikov M.E. Digestive Tract Cancer Risk Assessment among "Mayak" PA Workers. Questions of Radiation Safety. 2014; 1: 76–83.*

5. *Slovis T.L. The ALARA (as low as reasonably achievable) concept in pediatric CT intelligent dose reduction. ALARA conference proceedings. Pediatr Radiol. 32: 219–22 S0.*

6. *ICRP Publication 103. Recommendations of the International Commission on Radiological Protection. Ann. ICRP. 2007; 37 (2): 4.*

7. *Narkevich B. Ya., Dolgushin B. I. Radiation safety assurance in computed tomography and interventional radiology. REJR. 2013; 3 (2): 7–19.*

8. *Lebedev N.I, Osipov M.V., Fomin E.P. An Approach to Reduce the Radiation Dose Resulted from Multislice CT of the Abdomen. Medical radiology and Radiation Safety. 2014; 59 (4): 48–52.*

9. *Control of effective patient's dose in medical X-ray studies. Methodical instructions 2.6.1.2944 – 11.*

10. *Прокоп М., Галански М. Спиральная и многослойная компьютерная томография. Том 2. Москва, Медпресс-информ, 2009. 712 с.*

11. *McHugh K., Disini L. Commentary: for the children's sake, avoid non-contrast CT. Cancer Imaging. 2011; 1 (11): 16–18. DOI: 10.1102/1470–7330.2011.0003*

12. *Taylor C., Bose S., Lim A. K., McHugh K. Unenhanced CT of the pediatric abdomen: radiation exposure versus diagnostic benefit. ECR, Vienna, 2000.*

References:

1. *IAEA Publication 1532. Justification of Medical Exposure in Diagnostic Imaging. – Vienna: International Atomic Energy Agency, 2011.*

2. *Brenner D. J., Hall E. J. Computed tomography – an increasing source of radiation exposure. N Engl J Med. 2007; 357: 2277–84.*

3. *Radiation Safety Standards NRB-99/2009. SanPiN 2.6.1.2523 – 09.*

4. *Osipov M.V., Sokolnikov M.E. Digestive Tract Cancer Risk Assessment among "Mayak" PA Workers. Questions of Radiation Safety. 2014; 1: 76–83.*

5. *Slovis T.L. The ALARA (as low as reasonably achievable) concept in pediatric CT intelligent dose reduction. ALARA conference proceedings. Pediatr Radiol. 32: 219–22 S0.*

6. *ICRP Publication 103. Recommendations of the International Commission on Radiological Protection. Ann. ICRP. 2007; 37 (2): 4.*

7. *Narkevich B. Ya., Dolgushin B. I. Radiation safety assurance in computed tomography and interventional radiology. REJR. 2013; 3 (2): 7–19.*

8. *Lebedev N.I, Osipov M.V., Fomin E.P. An Approach to Reduce the Radiation Dose Resulted from Multislice CT of the Abdomen. Medical radiology and Radiation Safety. 2014; 59 (4): 48–52.*

9. *Control of effective patient's dose in medical X-ray studies. Methodical instructions 2.6.1.2944 – 11.*

10. *Prokop M., Galanski M. The spiral and multislice computed tomography. 2 vol. 2nd ed. New York, 2003. 712 p. (in Russian).*

11. *McHugh K., Disini L. Commentary: for the children's sake, avoid non-contrast CT. Cancer Imaging. 2011; 1 (11): 16–18. DOI: 10.1102/1470–7330.2011.0003*

12. *Taylor C., Bose S., Lim A. K., McHugh K. Unenhanced CT of the pediatric abdomen: radiation exposure versus diagnostic benefit. ECR, Vienna, 2000.*