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Оценка поглощённых доз в плоде у беременных при компьютерной томографии: систематический обзор

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АННОТАЦИЯ

Обоснование. Отсутствие в отечественной практике утверждённых методик расчёта и систематизированных данных в отношении доз облучения плода при рентгенорадиологических исследованиях у беременных затрудняет их практическое применение. Данная проблема особенно актуальна для компьютерной томографии как широко распространённого высокоинформативного метода лучевой диагностики, ассоциированного со значительными уровнями облучения пациентов.

Цель — систематизировать существующие данные о поглощённых дозах в плоде при проведении компьютерной томографии.

Материалы и методы. Проведены поиск и анализ публикаций на русском и английском языках. Поиск осуществлялся в системах PubMed/Medline, Google Scholar и eLibrary. В окончательный анализ включено 12 публикаций, в том числе 8 исследований с использованием антропоморфных фантомов, 3 ретроспективных и 1 проспективное клиническое исследование.

Результаты. Наиболее высокие значения поглощённых доз в плоде получены при проведении компьютерных сканирований брюшной полости и малого таза, а также сканировании всего тела. Во включённых в обзор публикациях не зафиксировано превышения предельно допустимой дозы облучения плода.

Заключение. При проведении однократных однофазных компьютерных сканирований у беременных превышение допустимого порога поглощённой дозы 100 мГр в плоде маловероятно независимо от зоны сканирования, что позволяет назначать исследование при наличии клинических показаний. Однако этот порог может быть превышен при многократных или многофазных исследованиях методом компьютерной томографии брюшной полости и малого таза, а также всего тела при травме. В таких случаях мультидисциплинарной командой специалистов по радиационной безопасности (врачи-рентгенологи и клинические специалисты) должна быть проведена дополнительная оценка рисков.

Ключевые слова: беременность; радиационный риск; доза облучения органов; диагностическая визуализация; риск для плода во время беременности; облучение; компьютерная томография; поглощённые дозы в плоде.

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Evaluation of fetal absorbed doses from computed tomography examinations of pregnant patients: A systematic review

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ABSTRACT

BACKGROUND: Currently, no systematic data are available on fetal radiation exposure as a result of radiographic studies during pregnancy. Consequently, there are no approved methods of its calculation that can be used in clinical practice. It is especially relevant for computed tomography scans as it is a widely used and highly informative method of diagnostic imaging associated with high exposure levels.

AIM: to systematize currently available data on radiation dose absorbed by the fetus from computed tomography scans in pregnant women.

MATERIALS AND METHODS: The search for publications in Russian and English was conducted in PubMed/Medline, Google Scholar and eLibrary. The final analysis included 12 papers including 8 studies using human body phantoms, 3 retrospective studies and one prospective clinical study.

RESULTS: Abdominal and pelvic computed tomography scans as well as whole-body scans were found to be associated with the highest fetal radiation exposure. However, in none of the publications the fetal exposure limit was exceeded.

CONCLUSION: Clinically indicated non-contrast-enhanced computed tomography scans in pregnant women are not likely to be associated with the fetal absorbed doses that exceed the limit of 100 mGy regardless of the scanned area. However, this limit might be exceeded in case of performing multiple studies or if multiphase abdominal or pelvic computed tomography scans, or whole-body computed tomography scans are performed in patients with multiple trauma. In these cases, a decision regarding the need for these investigations should be made by a multi-disciplinary team (including radiation safety specialists, diagnostic radiologists and clinicians) based on the results of additional risk assessment.

Keywords: computed tomography scans; pregnancy; radiation risk; organ dose; diagnostic imaging; fetal absorbed dose; fetal risks pregnancy radiation.

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当对孕妇进行电子计算机断层扫描时胎儿吸收剂量的评估：系统综述

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简评

论证。由于在国内实践中缺乏经批准的计算方法和关于当对孕妇进行X线放射检查时胎儿辐射剂量的系统化数据，因此在实践中很难应用这些检查方法。该问题对于电子计算机断层扫描来说尤其重要，因为虽然该这个问题对于电子计算机断层扫描是一种被广泛使用的、信息量大的放射诊断技术，但是与较高病人辐射剂量有关的。

该研究的目的是使现有的关于进行电子计算机断层扫描时胎儿吸收剂量的数据系统化。

材料和方法。对俄文和英文出版物进行了搜索和分析。在PubMed/Medline、Google Scholar和eLibrary系统中进行了搜索。最后的分析包括12份出版物，其中有8项使用拟人模型的研究、3项回顾性研究和1个前瞻性临床研究。

结果。当进行腹部、盆腔和全身电子计算机断层扫描时胎儿吸收的剂量最高。在审查所包括的出版物中，没有关于超过胎儿剂量限制的报告。

结论。无论扫描区域如何，对孕妇进行一次性单相电子计算机断层扫描的时候，超过胎儿吸收剂量限制（100 mGy）是不太可能的，因此，有需要的话，可以对孕妇进行这样的检查。然而，在进行腹部、盆腔或受伤全身的多次或多相电子计算机断层扫描的情况下，会超过这个阈值。在这种情况下，多科目辐射安全小组（放射科医生和临床专家）应该进行额外的风险评估。

关键词：怀孕；辐射风险；器官剂量；诊断成像；怀孕期间的胎儿风险；辐射剂量；电子计算机断层扫描；胎儿吸收的剂量。

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BACKGROUND

During pregnancy, the safety of diagnostic radiology is a priority for radiologists and other specialists. Until the middle of the 20th century, medical imaging methods using ionizing radiation sources were widely used in obstetrics for diagnostic and therapeutic purposes. However, later experimental and epidemiological data on the effects of ionizing radiation on fetal development were obtained. The International Commission on Radiation Protection established limitations for the use of ionizing radiation during pregnancy [1].

The negative effects of ionizing radiation are usually classified into deterministic and stochastic effects. Deterministic effects are associated with direct cell damage or death resulting from radiation exposure above the threshold level. The probability of these effects depends on the radiation dose and gestational age of the fetus. The main fetal risks include congenital malformations of the internal organs and central nervous system (such as neurological disorders and developmental delays). The severity of the deterministic effects is proportional to the dose and frequency of examinations.

Fetal sensitivity to radiation depends on the gestational age of the fetus. Organogenesis (pregnancy weeks 5–17 or post-conception weeks 3–15) is the most dangerous period for radiation exposure. In the second and third trimesters, fetal resistance to radiation increases; however, in this period, exposure to >500 mGy can still lead to adverse effects, including growth retardation and malformations [2].

Currently, the no-effect threshold value of the fetal absorbed dose is 100 mGy [3,4]. International professional societies (International Commission on Radiation Protection, U.S. National Council on Radiation Protection, American College of Radiology, and American College of Obstetricians and Gynecologists) consider the risk of spontaneous abortion and serious malformations to be negligible in fetuses exposed to radiation doses <50 mGy [3-6].

Stochastic effects are radiation-induced changes in cells that can lead to malignant neoplasms. Stochastic effects do not have a threshold, and data on the corresponding risk are inconsistent [7]. According to the clinical practical guidelines of the American College of Radiology, an absorbed fetal dose of 20 mGy corresponds to a cancer risk of 1/125 in addition to background incidence [6]. According to the International Commission on Radiation Protection, the fetal cancer risk is lower and is 1/500 at the fetal absorbed dose of 30 mGy. In Russian research practice, the risk of radiation-induced cancers and genetic fetal effects following medical radiation exposure have not been examined [8].

Improvements in medical imaging techniques have led to their widespread application and use in the differential diagnosis of some life-threatening conditions, which requires an assessment of their safety in pregnancy. A quantitative evaluation of fetal radiation exposure level is the most reliable assessment of the safety profile of medical imaging techniques in pregnancy. Moreover, pathological conditions that most often require various imaging studies in pregnant patients must be assessed, such as pulmonary embolism (PE), aortic dissection, polytrauma, urolithiasis, acute appendicitis, and lung damage in COVID-19 [9–12].

Fetal safety is the main parameter for imaging technique selection in pregnant women [6]. To reduce potential risks of negative effects, pregnant patients should be protected from radiation using recommended means. Unfortunately, in Russian practice, no such recommendations have been established, and no Russian data on fetal exposure doses when using certain medical imaging techniques are available [8]. Thus, the authors conducted this systematic review to summarize and analyze current data on fetal radiation exposure levels when using computed tomography (CT), the highest-dose imaging technique.

MATERIALS AND METHODS

Study design

The systematic review was based on PRISMA guidelines (2009).

Literature search

Study materials included scientific publications searched from PubMed/Medline, Google Scholar, and eLibrary databases. Existing foreign and national guidelines for imaging studies in pregnancy were also reviewed. The following keywords were used: CT, pregnancy, radiation risk, organ dose, diagnostic imaging, fetal risks pregnancy radiation, computed tomography, and fetal absorbed doses.

Following the database search query, duplicate results were excluded. The content of the selected studies, including parameters such as the year of publication, study design, purpose, methodology, and results were analyzed, and publications on non-ionizing techniques of diagnostic radiology were excluded. The systematic review excluded studies that did not measure fetal and uterus absorbed doses and studies measuring dose loads during radiation therapy and fluoroscopy. Finally, the systematic review included 12 studies. The study design is presented in Fig. 1.

Estimated parameters

The systematic review evaluated selected publications using the following parameters: doses absorbed by the fetus/embryo, gestational age, pathological condition, anatomical area of interest, method of absorbed dose estimation, and number of studied cases using CT in pregnant women. The systematic review included clinical and experimental studies using anthropomorphic phantoms.

RESULTS

In total, 837 studies were found in PubMed/Medline, Google Scholar, and eLibrary databases for the following search queries: “CT radiation risk in pregnancy,” “fetal absorbed doses from diagnostic imaging," "CT fetal dosimetry," and "assessment of fetal doses in CT" from 2007 to 2022. After a preliminary analysis and removal of duplicate results, 12 studies in English and Russian were included in the review, including 8 studies using anthropomorphic phantoms, 3 retrospective studies, and 1 prospective clinical study. Each study was evaluated by the study type and design, measurement method, and calculation method of absorbed doses. Information on studies is summarized in Tables 1–7.

Measurement and calculation of absorbed doses

Absorbed doses were measured using a thermoluminescent dosimeter (TLD) or metal oxide semiconductor field-effect transistor (MOSFET). In 2 of 8 studies, a virtual phantom technology was used, which involves mathematical modeling of the absorbed doses.

Absorbed doses were estimated based on measurement results or using special software for assessing absorbed doses in radiosensitive organs and tissues (ImPACT MC, CT EXPO, NCICT 3.0, and virtual dose CT).

In 2 of 4 clinical studies, absorbed doses were calculated using the special calculation program ImPACT. Two other studies did not provide information on calculation methods.

The gestational age modeled in anthropomorphic phantoms ranged from 5 to 40 weeks. In 5 of 8 studies, the scan length was 32 cm, which corresponds to the length of a standard phantom. In four studies, programs with decreased

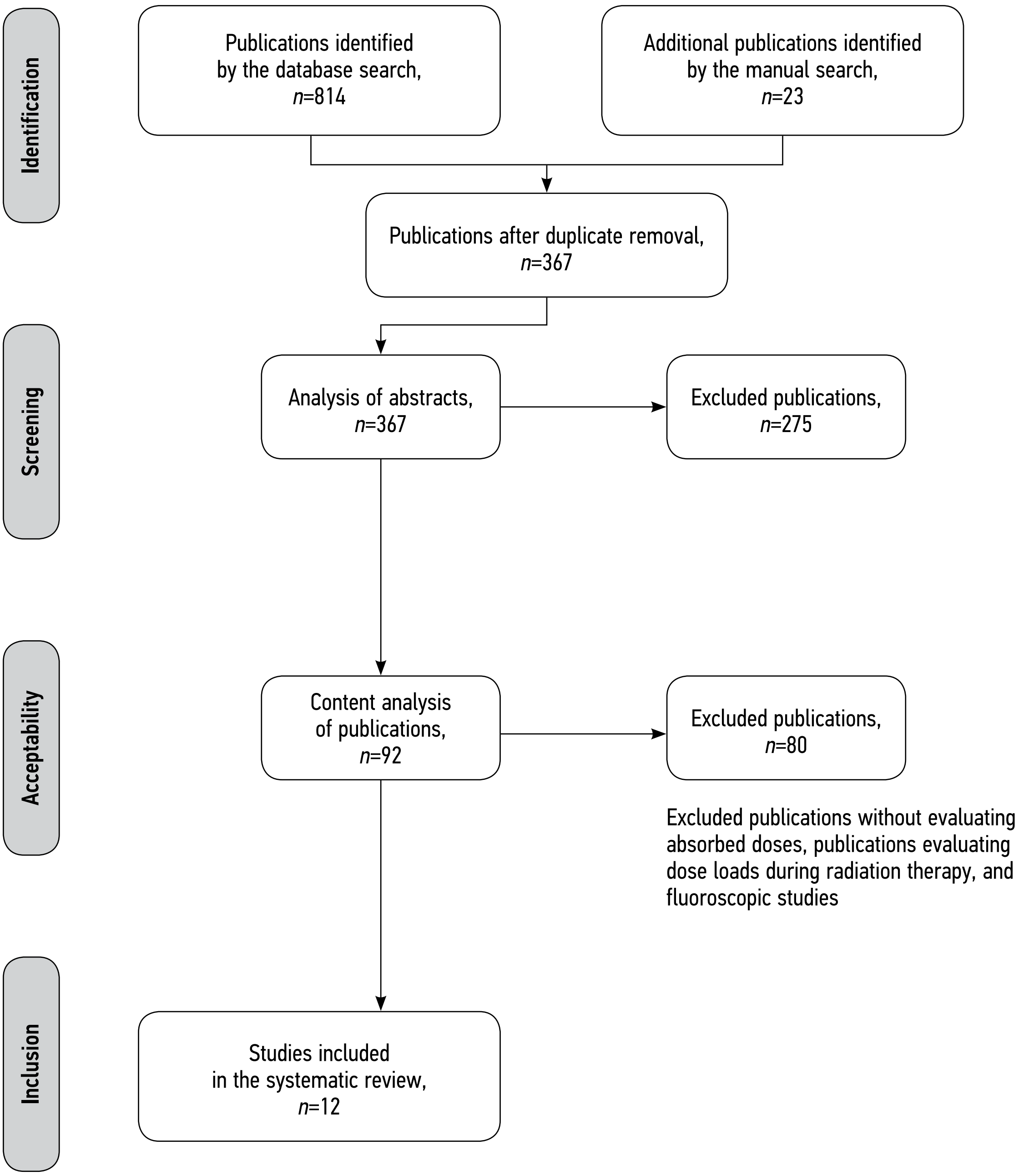

Fig. 1. Study design in the PRISMA scheme.

scan length were also used, and three studies used programs with increased scan length.

Comparative analysis

The fetal absorbed doses were compared in several groups by anatomical scan regions including chest, abdomen, pelvis, and whole body in trauma (Tables 5–7).

Considering the presented data of phantom studies, two pairs of studies were combined (Vodovatova et al. [8] and Gu et al. [13], and Kelaranta et al. [14] and Angel et al. [15]) to determine general patterns in absorbed dose change depending on the gestational age and scan region. In these studies, the gestational age and scan regions were comparable (chest in studies by Vodovatova and Gu, and abdomen or pelvis in studies by Kelaranta and Angel), and similar technical scan parameters (exposure, pitch factor, and voltage) were reported. The comparable nature of the above data made it possible to compare pooled data. The results of the comparative analysis are presented in Fig. 2. Chest scan showed a significantly lower fetal absorbed dose than the abdominal scan. In addition, in chest CT, the fetal absorbed dose tends to decrease slightly with increases in gestational age. To confirm these findings, more powerful studies are needed.

Finally, evidence suggests that the fetal absorbed dose threshold of 100 mGy [3,5] indicated in regulatory and methodological documents significantly exceeds the observed levels of fetal exposure during phantom studies. Moreover, exposure levels of 20 and 30 mGy [5,6], potentially leading to stochastic effects, are not achieved in single-phase CT on a once-only basis.

In all clinical studies included in the systematic review (except for the study by Goldberg-Stein et al. [16]), the fetal absorbed doses also did not exceed the above range of 20–100 mGy. In the study by Goldberg-Stein et al. [16], scan parameters were overestimated (up to 140 kV and 815 mAs), which led to a high fetal absorbed dose. Moreover, multiphase CT and multiple examinations were considered (highlighted in the text of the publication).

This comparison allows radiologists to conduct one single-phase CT in eligible pregnant women without undue concerns. If repeated scans are necessary, additional risk assessment shall be performed.

DISCUSSION

The main approaches to radiation safety in pregnant women are similar to those in other populations. In general, if ultrasound and magnetic resonance imaging are impossible to use as diagnostic techniques, ionizing radiation techniques should be used only in life-threatening situations with minimized radiation doses [17]. Life-threatening complications requiring diagnosis of pathological conditions should exceed the potential negative effect of diagnostic techniques. The choice of imaging techniques should be regulated in clinical standards of care with recommendations for their use in established or suspected diseases.

For the safe use of ionizing diagnostic techniques, the level of fetal absorbed doses must be monitored during the examination, and duplicate studies should not be conducted whenever appropriate [18].

Table 1. Characteristics of studies using anthropomorphic phantoms

Source	Method for measuring doses	Estimated absorbed doses
Angel et al. 2008 [15]	Not reported	ImPACT; MC; CT Expo
Begano et al. 2020 [33]	TLD	VirtualDose CT
Doshi et al. 2008 [36]	TLD	According to TLD measurements
Kelaranta et al. 2017 [14]	MOSFET	ImPACT MC
Vodovatov et al. 2021 [8]	Not reported	NCICT3.0
Gilet et al. 2011 [37]	TLD	According to TLD measurements
Gu et al. 2009 [13]	MOSFET	MCNPX According to MOSFET measurements
Jaffe et al. 2008 [26]	MOSFET	According to MOSFET measurements

Note. MOSFET, metal oxide semiconductor field-effect transistor; TLD, thermoluminescent dosimeter.

Table 2. Characteristics of clinical studies

Paper	Type of study	Estimated absorbed doses
Lazarus et al. 2009 [29]	Retrospective clinical study	Not reported
Goldberg-Stein et al. 2011 [16]	Retrospective clinical study	ImPACT
Litmanovich et al. 2009 [32]	Prospective clinical study	ImPACT
Lazarus et al. 2007 [30]	Retrospective clinical study	Not reported

Table 3. Protocols of CT for anthropomorphic phantoms

Source	CT machine model	Voltage, kV	Exposure, mAs	Pitch factor	Gestational age, weeks	Scan length, cm
Angel et al. 2008 [15]	LightSpeed 16, GE	120	100–300	1,375	5–36	46,2
Begano et al. 2020 [33]	Definition Flash CT (Siemens Healthineers,Germany)	120	85	1,5	28–38	32 cm, standard program; 22 cm, short program
Doshi et al. 2008 [36]	Siemens Sensation 16 Siemens Somatom Emotion / Marconi MX8000	100–130	125–250	1,25	35–40	32 cm, standard program; 27 cm, short program
Gilet et al. 2011 [37]	LightSpeed 4 LightSpeed 16 LightSpeed 64 VCT, GE Healthcare	120	100–500	1,375–1,5	5, 10, 18, 32	32
Gu et al. 2013 [13]	LightSpeed 16 GE-MDCT	80–140	100	1,375	15,20,31	22 cm, ches; 36 cm, abdomen
Kelaranta et al. 2017 [14]	LightSpeed 64-MDCT GE	100–120	100–300	1,375	12, 20, 28, 38	27 cm, chest; 32 cm, abdomen; 94 cm, trauma
Vodovatov et al. 2021 [8]	Ingenuity 128, Philips Somatom Definition AS, Siemens Somatom Scope, Siemens Emotion 16, Siemens	100–130	60–142	1,048–1,5	8, 10, 12, 15, 20, 25, 30, 35, 38	33
Jaffe et al. 2008 [26]	GE LightSpeed 16-MDCT	140	300–380	0,9–1,75	5	32

Table 4. Protocols of CT for pregnant women

Source	CT machine model	Voltage, kV	Exposure, mAs	Pitch factor	Gestational age, weeks	Scan region (anatomical landmarks)
Lazarus et al. 2007 [30]	Either single-detector row scanner (CTI GE Healthcare, Waukesha, WI), 4 MDCT Lightspeed; GE Healthcare) 16-MDCT Somatom; Siemens, Malvern	140	-	-	5–40	Abdomen
Lazarus et al. 2009 [29]	-	-	-	-	-	Head Chest Abdomen and pelvis
Litmanovich et al. 2009 [32]	64-MDCT LightSpeed VCT	100	200	0,984	5–36	Chest Aortic arch to the diaphragmatic cupula 19.846 ± 2.98 cm
Goldberg-Stein et al. 2011 [16]	LightSpeed Plus, LightSpeed 16 Pro, LightSpeed Qx/I, High-Speed RP,HighSpeed CT/GE Healthcare)	120–140	180–716	0,9–1,5	5–36	Abdomen and pelvis

Table 5. Systematized data on the assessment of fetal absorbed doses in chest CT

Source	Volume CT dose index (CTDI vol), mGy	DLP, mGy×cm	Gestational age, weeks	Fetal absorbed dose, mean, mGy	Uterus absorbed dose, mean, mGy
In phantom studies					
Kelaranta et al. 2017 [14]	1,34–1,97	476,63–582,22	12 20 28 38	0,03 0,08 0,14 0,22	0,04 0,09 0,29 1,13
Doshi et al. 2008 [36]	-	-	35–40	0,23	-
Begano et al. 2020 [33]	1,5–4,0	44–137	28–38	0,02–0,12	-
Gilet et al. 2011 [37]	-	-	5–32	0,33–0,77	-
Gu et al. 2013 [13]	8,1–14,7	-	15 20 31	0,13 0,21 0,26	0,17 0,33 0,37
Vodovatov et al. 2021 [8]	5,6–9,3	185–306	8 10 15 20 25 30 35 38	0,09 0,10 0,08 0,13 0,12 0,16 0,39 0,52	0,09 0,10 0,07 0,09 0,11 0,15 0,33 0,64
In clinical studies					
Litmanovich et al. 2009 [32]	5,21	105,65	5–38	0,02	-
Lazarus et al. 2009 [29]	-	-	1st, 2nd, and 3rd trimesters	0,22	-

Note. CTDI, computed tomography dose index; DLP, dose–length product.

Table 6. Systematized data on the assessment of fetal absorbed doses in abdominal and pelvic CT

Source	Volume CT dose index (CTDI vol), mGy	DLP, mGy×cm	Gestational age, weeks	Fetal absorbed dose, mean, mGy	Uterus absorbed dose, mean, mGy
In phantom studies					
Kelaranta et al. 2017 [14]	2,63–3,91	102,34–151,86	12 20 28 38	4,7 5,5 4,8 4,8	5,1 5,8 4,9 5,1
Angel et al. 2008 [15]	-	-	5 12 15 20 25 30 35	- 14,2 11,2 8,5 12,3 9,7 10,4	11,8
Gu et al. 2013 [13]	-	-	15	6,9	-
Gilet et al. 2011 [37]	-	-	5, 10, 18, 32	15–20,5	-
In clinical studies					
Lazarus et al. 2009 [29]	-	-	1st, 2nd, and 3rd trimesters	17,1	-
Lazarus et al. 2007 [30]	-	-	5–40	16	-
Goldberg-Stein et al. 2011 [16]	-	-	5–36	24,8	-

Note. CTDI, computed tomography dose index; DLP, dose–length product.

Table 7. Systematized data on the assessment of fetal absorbed doses in CT for trauma in phantom studies

Source	CTDI, mGy	DLP, mGy×cm	Gestational age, weeks	Fetal absorbed dose, mean, mGy	Uterus absorbed dose, mean, mGy
Kelaranta et al. 2017 [14]	4,74–5,79	45,18–66,52	12 20 28 38	10,6 11,2 10,1 9,9	11,3 12,6 10,3 10,7
Jaffe et al. 2008 [26]	6,55–26,02	-	5	18,0	-

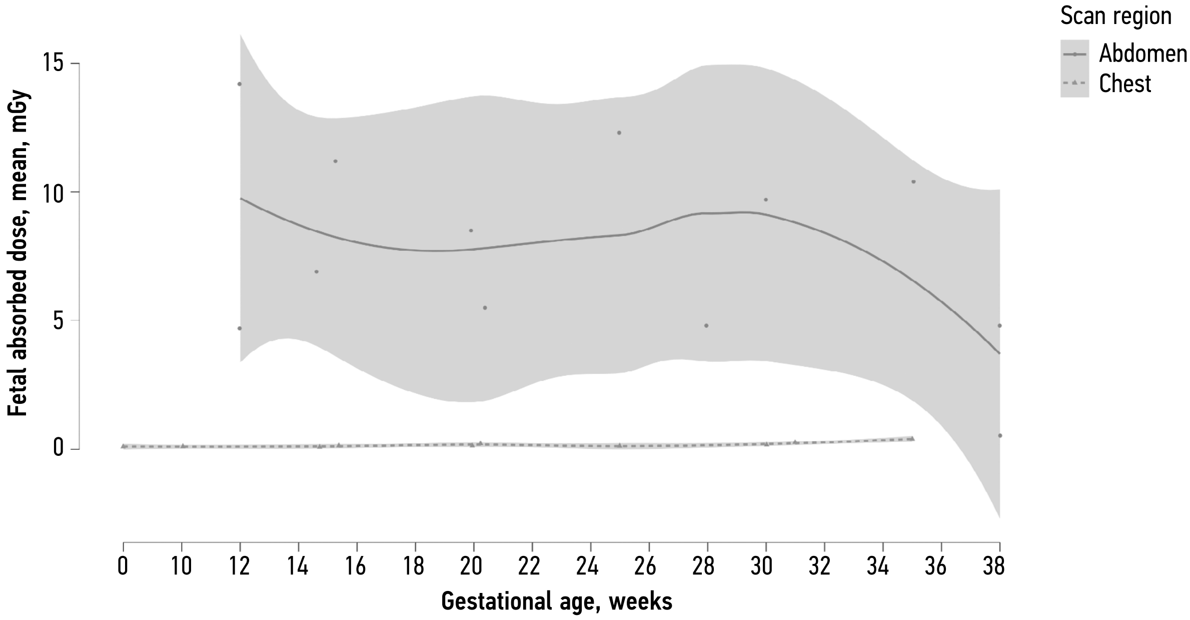

Fig. 2. Summary results of fetal dosimetry in chest CT (led by Vodovatov [8] and Gu [13]) and abdominal CT (led by Kelaranta [14] and Angel [15]) with LOESS regression line modeling and 95% confidence interval.

CT is the most conclusive ionizing technique of diagnostic radiology. CT has an undeniable advantage such as short examination time combined with high informative value, making CT an optimal method for diagnosing life-threatening conditions that require immediate treatment [19,20]. Depending on the indication and diagnostic goals, CT may be performed either as a native or a contrast-enhanced examination. Native examinations can be used in pregnant women to diagnose inflammatory lung diseases, urolithiasis, various traumatic injuries, etc. [21,22]. Contrast-enhanced examination is necessary for differential diagnosis of neoplasms, inflammatory changes, and CT angiography for diagnosing thrombosis and vascular wall damage and assessing blood supply to certain structures [19,23]. In pregnant patients, only one of these options must be selected. If contrast-enhanced CT is necessary, a native examination must be excluded to reduce the procedure time and radiation dose.

In diagnostic imaging of pregnant patients, the fetal absorbed dose must be assessed [24]. Owing to the limited capabilities of cohort studies on this issue, physical (anthropomorphic) or digital phantoms are currently widely used [25]. However, phantom studies using human body simulators have some limitations. They are mainly related to differences in phantom sizes and real patients. If real body parameters exceed the parameters of the phantom used, the absorbed dose will be overestimated, and vice versa, the dose may be underestimated if the patient's dimensions are smaller than the dimensions of the phantom [25]. However, phantom studies are reasonable for use as experimental guidance because they provide more information on absorbed doses to be calculated for each week of pregnancy, in contrast to cohort studies, which provide calculation results as averaged doses. In addition, fetal absorbed doses in cohort and phantom studies were not significantly different (Tables 5–7).

Radiation doses directly depend on the scan region. When the fetus is outside the radiation field (CT region), it is exposed to scattered radiation. Therefore, the farther the scan region is located from the fetus, the lower the absorbed dose and the likelihood of negative effects [14].

The literature review showed that fetal absorbed doses directly correlated with the anatomical scan region. As shown in Tables 5–7, the maximum fetal absorbed doses are observed during CT of the whole body, abdomen, and pelvis. The lowest fetal absorbed doses are observed in chest CT.

The estimated absorbed doses for phantoms are comparable with those obtained in cohort studies.

None of the foreign studies included in the review reported a fetal absorbed dose threshold exceeding 100 mGy. In Russia, no studies were conducted to evaluate indications for CT and the number of absorbed doses in pregnant women and fetuses during abdominal and pelvic CT.

In early gestation, the fetal absorbed dose assessment is difficult because of the small size of the embryo. Some studies [8,26,27] have shown insignificant differences in doses absorbed by the uterus and fetus. Therefore, the uterus absorbed dose can be used as an equivalent of the fetal absorbed dose [28]. Experimental studies have shown a relationship between the absorbed dose and gestational age.

Since the reviewed cohort studies presented data as average fetal absorbed doses for different gestational ages, determining the correlation between the gestational age and the level of absorbed dose is impossible for these studies [29–31].

In addition to the gestational age and anatomical scan regions, the absorbed dose depends on technical parameters such as the length of the scan region, algorithm for automatic modulation of the current strength, if any, pitch factor, and voltage.

The radiation dose can be decreased by changing the parameters of the scanning protocol and reducing the length of the scan region. In the study by Litmanovich et al. [32], 26 pregnant women with suspected PE underwent CT angiography of the pulmonary artery with decreased voltage and current and decreased scan length compared with the standard protocol. The effective dose was significantly lower than that in the control group (1.8 and 9.8 mSv, respectively) without a decrease in the diagnostic quality of the examination.

The decreased length of the scan region has also shown its effectiveness in phantom studies [33]. The authors reported a significant decrease in the mean fetal absorbed dose compared with doses for the standard scan length (0.03 and 0.1 mSv, respectively). However, some risks are associated with excluding part of anatomical structures from the scan region, and this should be considered when reducing the scan length.

Some studies have also considered the need to use screens (personal protective equipment) when conducting radiological examinations during pregnancy [33,34]. The reviewed publications did not use additional protective measures when examining organs located at some distance from the uterus, since the fetus is mainly exposed to scattered radiation rather than direct radiation. In this case, shielding does not reduce fetal exposure to scattered radiation but provides psychological protection. When compared with shielding, the decreased scan length is the most effective means of reducing fetal absorbed doses [34-36]. In addition, when the shielding material is introduced into the scan region, the image optimization system of the CT scanner is forced to dramatically increase the radiation power of the tube, which ultimately increased the exposure dose to pregnant women and their fetuses [37].

CONCLUSION

Diagnostic radiology in pregnancy should be performed in accordance with radiological safety principles because of the likelihood of negative effects, and completely avoiding diagnostic techniques using ionizing radiation is a mistake.

Examinations using ionizing radiation may be necessary for various life-threatening conditions, and they are also preferred in the diagnosis of some diseases. Note that the risk of complications, arising from delayed diagnosis, many times exceeds the risk of negative effects from exposure to ionizing radiation.

These studies confirm that doses absorbed by the fetus during CT do not reach the threshold values. In chest CT, the doses absorbed by the fetus are insignificant and cannot lead to deterministic effects. More significant fetal radiation exposure occurs during abdominal and pelvic CT and whole-body scans; however, even in these studies, exceeding the permissible exposure threshold is unlikely if a single-phase examination is performed only once. Moreover, multiple abdominal or whole-body CT or multiphase CT with an intravenous contrast enhancement may lead to exceeding the permissible threshold for the absorbed dose of ionizing radiation. This information should be considered when referring a pregnant woman to CT in these areas. Other undesirable effects on fetal development when using contrast enhancement must be also considered.

ADDITIONAL INFORMATION

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