Влияние COVID-19 на динамику изменений дозовой нагрузки на пациентов при проведении компьютерной томографии в медицинских организациях Москвы

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АННОТАЦИЯ

Обоснование. Распространение новой коронавирусной инфекции (COVID-19) в Москве привело к значительному увеличению числа компьютерных томографий органов грудной клетки, выполняемых пациентам в рамках диагностики и оценки эффективности проводимой терапии. Связанное с COVID-19 изменение структуры лучевой диагностики в Москве ведёт к изменениям в величине и структуре коллективной дозы облучения населения столицы, при этом сам процесс выглядит разнонаправленным. Отсутствие на текущий момент достоверной информации по изменению структуры лучевой диагностики и уровней облучения населения Москвы в связи с эпидемией COVID-19 и обусловило проведение данной работы.

Цель — оценить влияние эпидемиологической обстановки на динамику изменений уровня дозовых нагрузок на пациентов при проведении компьютерно-томографических исследований в медицинских организациях Москвы за период 2017–2020 гг.

Материалы и методы. Собраны и проанализированы заполненные формы № 3-ДОЗ за 2017–2020 гг., полученные от медицинских организаций города Москвы различных форм собственности; данные формы № 30 за 2017–2020 гг. и данные единого радиологического информационного сервиса (ЕРИС) за 2020 г. Проведён анализ годовых коллективных и средних индивидуальных доз облучения пациентов по анатомическим областям тела.

Результаты. Анализ данных учётных форм продемонстрировал существенный рост компьютерно-томографических исследований в Москве: реальное количество исследований оказалось на 31% больше ожидаемых. Количество исследований органов грудной клетки в 2020 г. увеличилось почти в 2 раза по сравнению с другими временными периодами. В совокупности всё это повиляло на рост значений средней эффективной дозы, которая в 2020 г. также выросла более чем в 2 раза.

Заключение. Эпидемиологическая обстановка в 2020 г. оказала существенное влияния как на динамику изменений дозовой нагрузки на пациентов при проведении компьютерной томографии, так и на вклад определённых видов компьютерно-томографических исследований в зависимости от анатомической области. Анализ помог выявить ряд преимуществ и недостатков различных форм сбора данных.

Ключевые слова: радиационная безопасность; дозовая нагрузка; пациент; компьютерная томография; лучевая диагностика; 3-ДОЗ; форма № 30; ЕРИС; аналитика.

Coronavirus disease–2019: Changes in computed tomography radiation burden across Moscow medical facilities

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ABSTRACT

BACKGROUND: The spread of coronavirus disease-2019 (COVID-19) in Moscow has significantly increased the number of chest computed tomography examinations to establish a diagnosis and assess the treatment efficacy. In Moscow, the new approach to diagnostic imaging associated with COVID-19 caused divergent shifts in the volume and structure of the population radiation burden. This study aimed to bridge the gap in data, as no reliable information about the changes in the structure of diagnostic imaging and the current radiation burden due to COVID-19 in the Moscow population has been reported.

AIMS: To evaluate the impact of the pandemic on the computed tomography radiation doses in Moscow medical facilities between 2017 and 2020.

MATERIALS AND METHODS: We collected and analyzed the following data: forms No. 3-DOZ completed by the public and private Moscow medical facilities in 2017–2020; forms No. 30 completed in 2017–2020; data from the Unified Radiological Information Service for 2020. The study provides details about the annual population radiation exposure and the average individual radiation doses, with a breakdown by anatomic region.

RESULTS: The statistical form evaluation elucidated the boost of computed tomography imaging in Moscow, accounting for 31% higher than anticipated. In 2020, the number of chest imaging studies increased almost two-fold compared to the previous periods. Thereby, causing a corresponding increase in the mean effective dose by over two times.

CONCLUSION: The results show that the epidemiological situation of 2020 had a profound effect on the changes in the computed tomography-related radiation exposure, which helped us get insight into the diagnostic effect of certain types of computed tomography studies applied to various anatomic regions. The analysis contributed to a better understanding of the strengths and weaknesses of various statistical forms.

Keywords: radiation safety; radiation dose; patient; computed tomography; diagnostic imaging; 3-DOZ; form 30; ERIS; analytics.

COVID-19对莫斯科医疗机构计算机断层扫描期间患者剂量负荷变化动态的影响

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简评

论证。新型冠状病毒感染（COVID-19）在莫斯科的传播导致对患者进行的胸部计算机断层扫描数量大幅增加，这是诊断和评估治疗效果的一部分。莫斯科与COVID-19相关的放射诊断结构的变化导致首都人口集体辐射剂量的范围和结构发生变化，而该过程本身似乎是多向的。由于COVID-19流行病，目前缺乏关于莫斯科人口放射诊断结构和暴露水平变化的可靠信息，促使这项工作开展。

目标是评估疫情对2017-2020年期间莫斯科医疗机构计算机断层扫描研究期间患者剂量负担水平变化动态的影响。

材料与方法。收集并分析了从莫斯科市各种所有权形式的医疗机构得到的2017-2020年填好的第3-DOZ号表格； 2017-2020年第30表格数据和统一放射信息服务(ERIS)的2020年数据.对患者的年度集体和平均个人暴露剂量按身体解剖区域进行了分析。

结果。对这些登记表的分析表明，莫斯科的计算机断层扫描检查显着增加：实际检查数量比预期高31%。与其他时间段相比，2020年的胸部检查次数几乎翻了一番。总起来看，所有这些都影响了平均有效剂量的增长，在2020年也增加了一倍多。

结论。2020年疫情对计算机断层扫描期间患者剂量负担变化的动态以及某些类型的计算机断层扫描研究的贡献（取决于解剖区域）产生了重要影响。该分析有助于确定不同形式的数据收集的一些优势和劣势。

关键词：辐射安全； 剂量负担； 患者； CT扫描； 放射诊断； 3-DOZ； 第30号表格； 统一放射信息服务(ERIS)，分析。

BACKGROUND

The use of computed tomography (CT) in diagnosing coronavirus disease-2019 (COVID-19) has been widely discussed among physicians. Initially, multiple perspectives on the applicability of diagnostic radiology existed worldwide, ranging from the use of CT as disease screening [1] to CT scans only in confirmed COVID-19 cases [2]. The reliability of polymerase chain reaction diagnostics did not exceed 70%; thus many countries, including Russia, particularly Moscow, decided to introduce the term "clinically confirmed COVID-19 case" that combines symptoms, respiratory disorders, and CT or X-ray findings (regardless of results from a single laboratory test for SARS-CoV-2 ribonucleic acid by a polymerase chain reaction and epidemiological history) [3]. Additionally, diagnostic radiology detects COVID-19 pneumonia, complications, and differential diagnosis with other lung diseases, as well as determines the status and change dynamics and assesses the therapy effectiveness [4]. The common manifestation of COVID-19 includes viral lung damage (viral pneumonia), thus radiological methods are one of the main tools to assess disease severity and decide the hospitalization needs for patients [5, 6].

Chest CT is not a classical method for diagnosing acute respiratory viral infection but is highly sensitive to pulmonary thickening, a typical COVID-19 symptom [7]. The spread of COVID-19 in Moscow significantly increased the number of chest CT scans performed on patients as part of COVID-19 diagnosis and therapy effectiveness assessment. The increased number of chest CT scans is probably related both to the increased demand for this type of examination and the increased availability of medical care for patients with COVID-19 signs due to the organization of outpatient CT centers within the city; however, this issue was not included in the goals and objectives of the study.

The rapid growth in the number of CT scans was associated with an increased radiation dose of medical exposure in the Moscow population, hence additional cases of radiation-induced cancers and hereditary effects [8, 9]. Additionally, the scope of radiological techniques to detect pathological conditions had rapidly increased, along with the increased radiological burden on patients, accompanying persons, and medical facility staff [10]. COVID-19-related changes in the structure of diagnostic radiology in Moscow changed the value and structure of the radiation dose to the city's population, with the multidirectional process. On the one hand, the number of chest CT scans dramatically increased; on the other hand, the transfer of some exclusive medical organizations for COVID-19 treatment and the closure of medical facilities or individual departments for quarantine due to COVID-19 decreased the number of performed CT scans on elective patients, primarily multiphase procedures with X-ray contrast agents associated with high (up to 50–80 mSv) individual radiation doses [11, 12]. The structure of radiological examinations was affected by the suspension of the All-Russian Medical Examination of the Adult Population of the Russian Federation, stipulated by a decree of the Government of the Russian Federation[1] and other regulatory documents of the executive authorities. Unfortunately, reliable information on the changes in the diagnostic radiology structure and exposure levels of the Moscow population is currently unavailable due to the COVID-19 epidemic.

The study aimed to assess the radiation dose changes in the Moscow population from CT scans in 2020 compared to 2017–2019 as affected by the epidemiological situation associated with COVID-19.

MATERIALS AND METHODS

Data from Forms No. 3-DOZ and No. 30 for 2017–2020 and the Unified Radiological Information Service (ERIS) for 2020 was analyzed.

Research and Practical Clinical Center for Diagnostics and Telemedicine Technologies of the Moscow Health Care Department systematically collect and records data according to Form No. 3-DOZ "Information on Patient Radiation Doses during Medical X-Ray Radiological Examinations,"[2] approved by the order of the Federal State Statistics Service[3].

In Moscow, as elsewhere in the country, data are collected using Form No. 30,[4] approved by the order of the Federal State Statistics Service. The study only analyzed the sections related to diagnostic radiology.

Additionally, ERIS[5] data were analyzed.

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[1] Decree of the Government of the Russian Federation dated March 21, 2020, No. 710-r "On the Temporary Suspension of the All-Russian Medical Examination of the Adult Population of the Russian Federation." Available at https://www.garant.ru/products/ipo/prime/doc/73681079/. Accessed on 01/15/2022.

[2] Information on Patient Radiation Doses during Medical X-Ray Radiological Examinations (form No. 3-DOZ). Available at http://www.consultant.ru/document/cons_doc_LAW_52009/c262c55885294afd998489c7f7ef8fe17e14da38/. Accessed on 01/15/2022.

[3] Federal State Statistics Service Order No. 411 dated October 16, 2013, (revised on December 22, 2021) "On Approval of Statistical Tools for Federal Statistical Monitoring of Sanitary Status of Territories, Occupational Diseases (Poisonings), and Radiation Doses by Federal Service for Surveillance on Consumer Rights Protection and Human Wellbeing." Available at http://www.consultant.ru/document/cons_doc_LAW_153534/2ff7a8c72de3994f30496a0ccbb1ddafdaddf518/. Accessed on 01/15/2022.

[4] Federal State Statistics Service Order No. 863 dated December 30, 2020, (revised on December 20, 2021) "On Approval of Federal Statistical Monitoring Forms with Instructions for their Completion for the Organization of Federal Statistical Health Protection Monitoring by the Ministry of Health of the Russian Federation." Available at http://www.consultant.ru/document/cons_doc_LAW_373430/. Accessed on 01/15/2022.

[5] Research and Practical Clinical Center for Diagnostics and Telemedicine Technologies of Moscow Health Care Department: Unified Radiological Information Service (ERIS). Available at https://zdrav.expert/index.php/Продукт:НПКЦ_ДиТ_ДЗМ:_Единый_радиологический_информационный_сервис_(ЕРИС). Accessed on 01/15/2022.

This retrospective study did not contain personalized information about the patients. The data presented in Forms No. 3-DOZ and No. 30 was anonymized and contained information only about the number of examinations by modality and anatomical regions. Data from the ERIS were also anonymized and extracted only by the number of performed CT scans.

Both annual population and average individual radiation patient doses depending on anatomical body regions during CT scans were analyzed. Moreover, the specific contribution of CT concerning other types of examinations, particularly fluorography, radiography, fluoroscopy, and special (angiographic and interventional) and radionuclide (functional tests and scintigraphy) instrumental methods was estimated.

Data from Forms No. 3-DOH and No. 30 were analyzed for 2017–2020, whereas ERIS data were considered only for 2020, which is due to the completion of connecting all CT scanners operated in Moscow public medical facilities to the Unified Radiological Information Service only by 2020.

Each of the three options for data collection (ERIS and Forms No. 30 and No. 3-DOZ) has both advantages and disadvantages. For example, ERIS, which is the most complete and user-friendly database, has a significant limitation on the operating time and modalities of the currently connected equipment used in diagnostic radiology. Form No. 30 has excellent data details but a significant limitation on the organizations that fill it out. Additionally, most of this is manual work, in which the quality and completeness of the provided information are significantly affected by the human factor. Significant disadvantages of Form No. 3-DOZ, which provides the most complete

information on the number of examinations, the population and effective dose per examination, and the distribution of the demand for examinations depending on the anatomical region, includes the limited range of organizations that fill it out and the human factor resulting from incorrect information due to the manual data entry.

Statistical analysis

The statistical analysis used the specialized options of Microsoft Excel software, where data on the number of examinations presented in Forms No. 3-DOH and No. 30 for 2017–2019 were entered. The estimated number of examinations in 2020 was calculated based on the "Forecast" function of the same software.

RESULTS

Annually, an increased number is observed in medical organizations that submit data according to the federal state statistical monitoring form, which is used by the Federal Service for the Oversight of Consumer Protection and Welfare to collect information on patient radiation doses during medical X-ray radiological examinations to protect the well-being of citizens of the Russian Federation (Form No. 3-DOZ),. Hence, the number of X-ray radiological examinations and, therefore, the population radiation dose (manSv) consistently increased (Table 1).

The specific share of the use of different types of examinations (Table 2) and the specific population dose contribution from different types of examinations (Table 3) in 2017–2020 was estimated to assess the current

Table 1. Summary data on radiological examinations and dose burdens in Moscow medical facilities according to Form No. 3-DOZ

Parameters	2017 г.	2018 г.	2019 г.	2020 г.
Number of medical facilities	1233	1330	1394	1453
Number of examinations, units	27 128 339	28 882 702	29 705 881	23 626 477
Population dose, manSv	10 946	11 593	12 582	16 662
Average effective dose, mSv	0,404	0,401	0,424	0,705

Table 2. Specific share of the use of different types of examinations according to Form No. 3-DOZ

Year	FG, %	RG, %	FS, %	CT, %	Other procedures, %	RN, %
2017	28.4	63.9	1.1	5.5	0.7	0.4
2018	27.8	63.7	0.8	6.4	0.9	0.4
2019	26.1	62.9	0.8	6.8	3.0	0.4
2020	22.7	62.0	0.6	13.1	1.0	0.5

Note. Here and in Table 3: FG, fluorography; RG, radiography; FS, fluoroscopy; CT, computed tomography; RN, radionuclide examinations.

Table 3. Specific population dose contribution from different types of examinations according to Form No. 3-DOZ

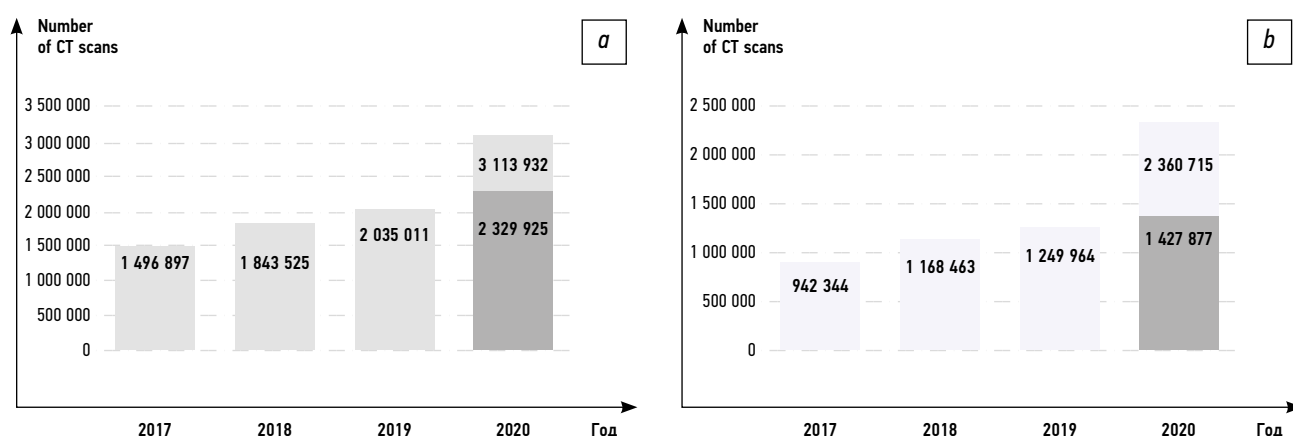| Year	FG, %	RG, %	FS, %	CT, %	Other procedures, %	RN, %
2017	2.8	13.2	6.8	60.7	11.3	5.2
2018	3.3	11.0	5.5	64.2	9.1	6.9
2019	2.8	9.4	5.2	65.0	10.1	7.5
2020	1.5	5.2	2.4	75.9	7.2	7.8

Fig. 1. Number of CT scans according to Forms No. 3-DOZ (*a*) and No. 30 (*b*). The yellow color marks the predicted number of examinations.

situation with the average effective dose per procedure in 2020.

The results presented in Tables 2 and 3 show a significantly increased number of CT scans performed in 2020 (almost twofold) and a uniformly increased population radiation dose contribution (manSv). Additionally, CT scans in all analyzed years (2017–2020) contribute to the maximum radiation patient doses (manSv).

The predicted number of 2,329,925 examinations for 2020 was calculated using the Microsoft Excel "Forecast" function, based on the number of given CT scans in the reporting Form No. 3-DOZ for 2017–2019. A linear one with an approximation coefficient of 0.989 was used when making a forecast of five different types of trend lines. According to Form No. 3-DOZ, the actual number of examinations was 3,113,932, which is 31% higher compared with the expected number of CT scans. A similar analysis was conducted according to Form No. 30 (Fig. 1): the expected number of examinations in 2020 was 1,427,877, whereas 2,360,715 examinations were conducted in reality, which is 65% higher than that of the predicted number (see Fig. 1). The linear type of trend lines with the approximation coefficient of 0.9714 was also used when making the forecast.

Based on three sources (Forms No. 30, ERIS, and No. 3-DOZ), Table 4 was generated, which presents data on the number of CT scanners and CT scans depending on the data source.

Table 5 shows the effective radiation doses per CT scan depending on the anatomical region.

The dynamics of the demand share for CT scans were analyzed according to Form No. 3-DOZ based on the anatomical region (Table 6). Based on Tables 5 and 6, the

specific contribution to the total effective dose was estimated depending on the number of CT scans of certain anatomical regions (Table 7).

DISCUSSION

Data analysis results demonstrated a significant impact on the distribution structure of the use of different types of X-ray radiological examinations and the dynamics of changes in the effective radiation doses of patients. The analysis results of Form No. 3-DOZ, presented in Table 1, shows that the average effective dose per X-ray radiological examination in 2017–2019 differed by 5%, whereas the average effective dose (mSv) per examination increased by 66% and 74% in 2020 compared with 2019 and 2017–2018, respectively.

The number of examinations, such as fluorography, radiography, and fluoroscopy, evenly decreased from 2017 to 2020 (Table 2). Relatedly, the population dose contribution from these examinations also decreased (Table 3). However, a sharp increase in CT scans (more than twofold in 2020 compared with 2017) was observed (Table 2). The population dose contribution from CT scans grew more evenly, with a maximum increase in all years, reaching approximately 76% in 2020 (Table 3). The number of radionuclide examinations was approximately the same from 2017 to 2019, with a slight increase in 2020 (Table 2). Additionally, the population dose contribution from radionuclide examinations, due to their variety conducted using an increasingly broad spectrum of radiopharmaceuticals and the expansion of examination protocols, grew slowly, which resulted in an increased effective dose of patient exposure per examination (Table 3). The number of other examinations, which include

Table 4. Data on the number of CT scanners and CT scans for 2020 from three sources

Data source	Scanners	Scans	Number of scans per scanner
ERIS	183	1 931 908	10 557
Form No. 30	305	2 360 715	7740
Form No. 3-DOZ	595	3 113 932	5233

Table 5. Average effective dose per CT scan depending on the anatomical region for 2017–2019 compared to data for 2020 according to Form No. 3-DOZ

Anatomical region	Average effective radiation doses, mSv			
	2017 г.	2018 г.	2019 г.	2020 г.
Thoracic organs	5.609	4.933	4.818	4.545
Extremities	0.718	0.781	0.702	0.674
Cervical vertebrae	3.142	2.288	2.134	1.710
Thoracic vertebrae	5.228	5.708	4.331	4.563
Lumbar vertebrae	6.139	6.795	6.438	5.884
Pelvis and femur	6.368	6.468	6.573	6.858
Ribs and sternum	3.712	3.953	2.566	3.811
Abdominal organs	8.886	8.246	8.005	7.413
Upper gastrointestinal tract	5.348	3.721	4.118	6.894
Lower gastrointestinal tract	5.810	5.832	5.951	12.304
Skull, maxillofacial area	1.681	1.448	1.476	1.225
Teeth	0.080	0.100	0.104	0.042
Kidneys, urinary system	7.269	7.210	6.651	6.103
Other	4.396	4.556	4.104	3.023
The average radiation dose for CT scan, mSv	4.442	4.040	4.019	4.061

Table 6. Dynamics of the demand share for CT scan based on the anatomical region

Anatomical localization (according to Form No. 3-DOZ)	The share of one examination of the anatomical region relative to the total number of examinations per year, %			
	2017 г.	2018 г.	2019 г.	2020 г.
Thoracic organs	24.36	24.09	25.55	55.6
Extremities	2.88	2.37	2.98	1.98
Cervical vertebrae	1.71	1.99	2.39	1.4
Thoracic vertebrae	0.97	1.09	1.05	0.62
Lumbar vertebrae	2.56	2.28	2.37	1.27
Pelvis and femur	3.04	3.64	3.3	2.11
Ribs and sternum	0.03	0.02	0.22	0.03
Abdominal organs	16.31	15.2	15.44	9.11
Upper gastrointestinal tract	0.48	0.29	0.25	0.02
Lower gastrointestinal tract	0.65	0.48	0.12	0.43
Skull, maxillofacial area	38.52	40.41	38.28	22.41
Teeth	1.54	0.69	0.25	0.72
Kidneys, urinary system	4.58	4.39	6.14	3.67
Other	2.37	3.06	1.66	0.63

Table 7. Specific contribution to the total effective dose based on the number of CT scans of certain anatomical regions

Specific contribution (%) to the total effective dose depending on the number of CT scans of certain anatomical regions, mSV		2017 г.	2018 г.	2019 г.	2020 г.
Thoracic organs	%	24.36	24.09	25.55	55.6
	mSv	1.37	1.19	1.23	2.53
High-dose examinations (lumbar vertebrae, pelvis and femur, upper and lower gastrointestinal tract, kidneys, and urinary system)	%	27.62	26.28	27.62	16.61
	mSv	2.2	2.0	2.03	1.17
Other CT scans (extremities, cervical vertebrae, ribs and sternum, skull, and teeth)	%	48.02	49.63	46.83	27.79
	mSv	0.87	0.85	0.76	0.36
Average effective radiation doses	mSv	4.442	4.040	4.019	4.061

procedures, such as radiosurgery and angiography, slightly and irregularly varied from year to year, along with the population dose contribution, which was most probably due to incorrect recording of examinations in different columns for one or another year (Tables 2, 3).

According to Forms No. 30 and No. 3-DOZ, the actual number of CT scans performed in 2020 was significantly higher than that predicted from the 2017–2019 data. Thus, according to Forms No. 3-DOH and No. 30, the increased number of examinations conducted in 2020 compared with those expected was 31% and 65%, respectively. According to ERIS, which records only examinations conducted in medical facilities belonging to the Moscow City Health Department, 1,931,908 CT scans were performed, which was 81% and 62% of the total number of examinations recorded in Forms No. 30 and No. 3-DOZ, respectively. This means that most of the registered CT scans were performed in medical facilities of the Moscow City Health Department. The results indicate a significant impact on the dynamics of the population dose to the organizational and methodological measures taken due to the epidemiological situation and the transfer of the outpatient departments to the operation mode of the outpatient CT centers.

Further analysis of the impact of the epidemiological situation on the dynamics of changes in the patient dose burden during CT was conducted according to the data presented in Form No. 3-DOZ for 2017–2020.

The study showed that average effective radiation patient doses during CT scan in all anatomical regions, except for doses from lower gastrointestinal tract examinations, uniformly decreased from year to year, which is directly associated with equipment renewal and examination protocol quality improvement (Table 5). The reasons for such a significant (over twofold) increase in the average effective dose for lower gastrointestinal tract examinations (Table 5) have not yet been found an explanation, which requires detailed analysis, consideration, and possible correction of the examination protocols to reduce the effective dose while maintaining the quality of the obtained diagnostic information.

The analysis found that skull and maxillofacial examinations contributed the most in 2017–2019, presumably, because this line also included dental CT scanners examinations. In 2020, the largest number of examinations was conducted on thoracic organs (over twice as many as in 2017), while the number of the skull and maxillofacial area examinations sharply decreased (approximately twofold), and insignificantly on almost all anatomical regions except for ribs and sternum, whose specific contribution to the number of examinations increased and gradually decreased (Table 6).

Based on Tables 5 and 6, the specific contribution to the total effective dose from chest CT scans and high-dose examinations (lumbar vertebrae, pelvis and femur, upper and lower gastrointestinal tract, kidneys, and urinary system) and other CT scans (extremities, cervical vertebrae, ribs

and sternum, skull, and teeth) was estimated and presented in Table 7. The results suggest that the main population radiation dose contribution was from chest CT scans.

Study limitations

This study was limited to 1 year of data on CT radiation burden in the ERIS, inadequate information on patient doses recorded in Form No. 30, and the restricted range of organizations that fill out Forms No. 3-DOZ and No. 30.

CONCLUSIONS

The epidemiological situation in 2020 had a significant impact both on the dynamics of changes in CT dose burden on patients and on the number of certain types of CT scans depending on the anatomical region. The largest share (55.6%) of all CT scans in 2020 was that of thoracic organs, with an overall almost twofold increased share of CT in the total number of all X-ray radiological procedures. The analysis of the dynamics of changes in the number and population dose in X-ray radiological examinations confirms that the population dose in medical exposure was formed mainly due to CT scans. Therefore, special attention should be paid to the control of existing CT examination protocols and to the development and implementation of new protocols that would reduce the radiation burden while maintaining the quality of diagnostic information. Moreover, particular attention should be paid to the possibility of conducting a low-dose CT instead of the traditional one for COVID-19 analysis, which would significantly reduce the radiation burden on patients.

The analysis revealed several advantages and disadvantages of different forms of data collection. Generally, the existing reporting forms are representative enough; however, the specifics of their completion may significantly reduce their value and the available data quality. Thus, the use of specialized dose-monitoring software is recommended to avoid errors and simplify the work of medical professionals who are responsible for collecting data on X-ray radiological examinations.

ADDITIONAL INFORMATION

Z.A. Lantukh — expert evaluation of literature review, systematization and final editing of the review; A.N. Mukhortova — determination of research methods determination of research methods and materials; Y.N. Lubentsova — literature analysis, determination of research materials. All authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the

version to be published and agree to be accountable for all aspects of the work.

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