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ASSESSMENT OF THE CHANGES IN STRUCTURE OF X-RAY DIAGNOSTICS AND COLLECTIVE DOSE FROM CT EXAMINATIONS RELATED TO COVID-19 IN THE RUSSIAN FEDERATION IN 2020

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***Abstract*:** The pandemic of COVID-19 and the corresponding transformation of the Russian healthcare system had a significant impact on X-ray and nuclear medicine diagnostics in 2020. A reduction of 10-30% could be observed for all imaging modalities, both in the number of examinations and corresponding collective dose. Computed tomography is an exception, increasing by 60% in number and by 81% in collective dose. The previous estimates of the changes in the collective dose from CT examinations correlate well with the results.

Keywords: COVID-19, medical exposure, X-ray diagnostics, collective dose, computed tomography

1. Introduction

The novel coronavirus infection (COVID-19) is an infectious disease caused by the SARS-CoV-2 virus [1]. At the current moment, the virus has spread to almost all countries of the world. As of August 22, 2021, in the Russian Federation, the coronavirus infection has been detected in more than 6.7 million people, more than 176 thousand people have died already [1].

The use of computed tomography (CT) for the diagnostics of COVID-19 has been widely discussed within the medical community. Initially, there were several points of view on the applicability of diagnostic imaging modalities, ranging from the use of CT scan for screening of the disease to the use of CT only for confirmed cases of COVID-19 [2]. However, due to the availability, high diagnostic informativity, non-invasiveness, ad fast speed, CT scan became the indispensable diagnostic method for the early and initial diagnosis of COVID-19 in the Russian Federation.

The widespread application of CT for COVID-19 diagnostics was associated with various issues connected to radiation protection and risk communication. Rapidly increasing number of CT examinations in hospitals and even in outpatient facilities, lack of general opinion on the frequency of CT scans during the treatment period, referral of CT scans of the chest even for the representatives of risk groups (i.e. pregnant women) lead to the increased public anxiety. Unfortunately, no data on patient doses was available from the hospitals, leading to the overestimation of the radiation risks from CT by the public.

The patient dose data collection in the Russian Federation is performed on an annual basis using state statistical data collection systems, using statistical form №3-DOZ [3] (a part of Joint governmental system of control and accounting of the individual doses of the citizens) and radiation-hygienic passports [4]. However, these forms are filled in and collected on an annual basis, hence not allowing operative patient dose data acquisition. Additionally, doses are averaged per medical facility, and the data on typical patient doses is unavailable.

Considering the lack of reliable information on the changes in the structure of X-ray diagnostics and collective doses from medical exposure, in the summer of 2020, the Institute of Radiation Hygiene in collaboration with local radiation protection and healthcare authorities as well as with several major hospitals. The results were published as a preprint [5].

At the current time, all the statistics on the structure and collective doses from medical exposure for 2020 have been collected. Hence it is important to assess the changes between these indicators between 2019 and

2020, considering the overall trends of the development of radiology in the Russian Federation.

The aim of the current study was to perform the assessment of changes in the structure of the X-ray diagnostics and collective dose from medical exposure in the Russian Federation in 2019-2020 (during the COVID pandemic).

2. Materials and methods

The study was based on the data from state statistical dose data collection form: №3-DOZ "Data on the patient doses from X-ray examinations. Form №3-DOZ contains the data on the collective doses from medical exposure and number of the examinations for the following imaging modalities: fluorography (chest screening), radiography, fluoroscopy, computed tomography, interventional examinations, diagnostic nuclear medicine examinations and "other" (everything that did not fit into other categories, i.e. bone densitometry). Data was taken from the federal dose databank of the Joint system of the control and accounting of the individual doses of the citizens hosted by the Institute of Radiation Hygiene for the 2015-2020 period for all 85 regions of the Russian Federation [3,4]. For the simplicity of the data processing, digital and analogue fluorography and radiography examinations were merged.

To assess the changes in the structure of the X-ray diagnostics and collective dose from medical exposure in each of the regions of the Russian Federation, data from Form #3-DOZ was processed using the following steps:

- Estimation of the number of X-ray and nuclear medicine examinations in each of 85 regions of the Russian Federation for each year for each imaging modality:
- Estimation of the collective dose from X-ray and nuclear medicine examinations in each of 85 regions of the Russian Federation for each year for each imaging modality:
- Calculation of the increment rates for the number and collective dose from X-ray and nuclear medicine examinations for each region of the Russian Federation for each year for each imaging modality using Equations 1 and 2 respectively:

$$\Delta_{N,i,k} = \frac{N_{i,k} - N_{i,k-1}}{N_{i,k-1}} \times 100\% \quad (1)$$

$$\Delta_{E,i,k} = \frac{E_{i,k} - E_{i,k-1}}{E_{i,k-1}} \times 100\% \quad (2)$$

where:

N – total number of X-ray or nuclear medicine examinations from the imaging modality I for the year k (2016, 2017, 2018, 2019 and 2020), examinations;

E – total collective dose from X-ray or nuclear medicine examinations from the imaging modality I for the year k (2016, 2017, 2018, 2019 and 2020), man -Sv;

$\Delta_{N,i,k}$ – increment rate of the number of examinations for imaging modality I for the year k (2016, 2017, 2018, 2019 and 2020), %;

$\Delta_{E,i,k}$ – increment rate of the collective dose for imaging modality I for the year k (2016, 2017, 2018, 2019 and 2020), %.

- Calculation of the average increment rate for the number and collective dose from X-ray and nuclear medicine examinations for each region of the Russian Federation for 2015-2019 for each imaging modality using Equations 3 and 4 respectively:

$$\Delta_{Navg,i} = \frac{\sum_{2016}^{2019} \Delta_{N,i,k}}{4} \quad (3)$$

$$\Delta_{Eavg,i} = \frac{\sum_{2016}^{2019} \Delta_{E,i,k}}{4} \quad (4)$$

where:

$\Delta_{Navg,i}$ – average increment rate of the number of examinations for imaging modality I for the four time intervals (2015/2016, 2016/2017, 2017/2018 and 2018/2019), %

$\Delta_{Eavg,i}$ – average increment rate of the collective dose for imaging modality I for the four time intervals (2015/2016, 2016/2017, 2017/2018 and 2018/2019), %

- Correction of the changes in the number and collective doses from X-ray and nuclear medicine examinations for each imaging modality for each of 85 regions of the Russian Federation for the 2019/2020 period considering average increment rate for the last four years using Equations 5 and 6 respectively:

$$\Delta_{N,i}{}_{adj}^{2020} = \Delta_{N,i\ 2020} - \Delta_{Navg,i} \quad (5)$$

$$\Delta_{E,i}{}_{adj}^{2020} = \Delta_{E,i\ 2020} - \Delta_{Eavg,i} \quad (6)$$

where:

$\Delta_{N,i}{}_{adj}^{2020}$ – change in the number of the examinations from imaging modality I in 2020 compared to 2019, adjusted considering the average increment rate in 2015-2019, %;

$\Delta_{E,i}{}_{adj}^{2020}$ – change in the collective dose from imaging modality I in 2020 compared to 2019, adjusted considering the average increment rate in 2015-2019, %;

All results were processed to exclude missing or biased data. The following exclusion criteria for the biased data were established:

- Lack of data on the number of examinations or collective dose for the selected imaging modality for one of the surveyed years;
- Increase or decrease in the number of examinations or collective dose from the selected imaging modalities exceeding 500% for one of the surveyed years;

Changes in the number of examinations and collective dose from the selected imaging modalities for the Russian Federation were calculated as mean values for the sample of 85 regions for each parameter.

Descriptive statistics were generated using Statistica 10 software. Comparison between samples was performed using the Mann-Whitney test. Relations between the assessed parameters were estimated using regression analysis. Results were considered significant with $p<0.05$.

3. Results and discussion

Data on the changes in the number of the X-ray and nuclear medicine examinations and collective dose from medical exposure as well as the increment rates for the selected imaging modalities are presented in tables 1-2 and 3-4, respectively.

Table 1. Changes in the number of X-ray and nuclear medicine examinations in the 2019/2020 period

Imaging modality	Number of X-ray and nuclear medicine examinations, thousands	
	2020	2019
Fluorography	72367	85706
Radiography	161861	190752
Fluoroscopy	999	1548
Computed tomography	2929	1724
Interventional examinations	1327	2291
Nuclear medicine	549	583
Other	247	183
Total	240280	282787

Table 2. Increment rates for X-ray and nuclear medicine examinations in the 2019/2020 period

Imaging modality	Increment rate, %	Increment rate adjusted by the 2015-2019 trends, %
Fluorography	-17.2	-18.0
Radiography	-15.5	-18.5
Fluoroscopy	-32.4	-28.5
Computed tomography	+60.5	+43.0
Interventional examinations	-23.9	-34.5
Nuclear medicine	-9.5	-16.3
Other	-2.5	+11.3
Total	-12.9	-15.4

Table 3. Changes in the collective dose from medical exposure in the 2019/2020 period

Imaging modality	Collective dose, man - Sv	
	2020	2019
Fluorography	4298	5318
Radiography	12106	16677
Fluoroscopy	2690	4069
Computed tomography	85075	49766
Interventional examinations	6847	8584
Nuclear medicine	3666	288
Other	183	3083
Total	114865	87785

Table 4. Increment rates for collective dose from medical exposure for the 2019/2020 period

Imaging modality	Increment rate, %	Increment rate adjusted by the 2015-2019 trends, %
Fluorography	-18.7	-15.6
Radiography	-28.1	-25.8
Fluoroscopy	-31.7	-28,4
Computed tomography	+81.0	+63.5
Interventional examinations	-18.3	-35.4
Nuclear medicine	11.4	-10.4
Other	-32.8	-27.6
Total	+37.1	+31.0

It is visible from tables 1-4 that during the pandemic of COVID-19 both structure of X-ray diagnostics and collective dose from medical exposure has undergone significant changes. The number of all X-ray examinations has decreased by 20% on average, varying from 10% for nuclear medicine, to almost 30% for fluoroscopy. Only computed tomography has undergone a significant boost, increasing up to 60%. That can be explained by several factors:

- Transformation of general practice hospitals into COVID hospitals;
- Reduction of diagnostics, including radiology, during the lockdown periods;
- Increase in the number of operating CT units and departments.

First two factors were deciding for the first wave (March-July) of coronavirus, when the healthcare system was 'mobilized' for the COVID epidemics, with the subsequent negative impact on the provision of healthcare for non-infected patients. The majority of the hospitals were closed down for the quarantine, accepting only emergency patients, or transformed into COVID treatment centers. All planned treatment was postponed. Later, during the second wave, a more balanced approach was applied, with the establishment of dedicated COVID treatment centers and/or departments. Hence, major hospitals returned to normal functioning, but the number of X-ray examinations nevertheless has decreased.

It should be noted that the lowest reduction in number was observed for nuclear medicine examinations. That can be explained by the fact that in the Russian Federation they are mainly performed for oncology patients. Diagnostics and treatment of such patients received the least impact from COVID pandemics.

Correction of the changes in the number of X-ray examinations by the 2015-2019 trends does not significantly change the results, except for CT. Increase in the number of CT examinations becomes less pronounced (43% compared to 60%). The changes in the total number of X-ray and nuclear medicine examinations are equal to -15% (from 283 million

examinations in 2019 to 240 million examinations in 2020).

The similar situation can be observed for the collective dose from medical exposure. However, the increase of the collective dose from CT examinations is more significant (81% unadjusted, 64% adjusted by the 2015-2019 trends). It should be noted that the decrease in the number of nuclear medicine examinations is accompanied by the increase in the collective dose (11%), indicating the increasing contribution of high dose procedures, mainly PET/CT. Total increase of the collective dose from medical exposure is equal to 37%, mainly due to the increased contribution of CT examinations.

It is interesting to compare the actual changes in the collective dose from CT examinations with the estimates, calculated by the Institute of Radiation Hygiene in August 2020, based on the data collection in several representative hospitals and regions [5]. These estimates considered three basic scenarios for the Russian hospitals:

Scenario 1. "Covid-19 hospital". It corresponds to the transformation of general practice regional hospitals into hospitals for COVID-19 patients and emergency patients with various pathologies. In this scenario, it was assumed that the total number of CT examinations in the region has not been changed; the number of CT exams of all other anatomical areas (except for the chest) decreased by 80%. The released capacities were used for chest CT scans.

Scenario 2. "Intense activity". Corresponds to the medical facilities operating after the peak of COVID-19: the number of examinations remains the same as in 2019, except for chest CT scans. It was assumed that prior to each admission to the hospital or planned X-ray examination, a patient undergoes chest CT examination. The number of CT studies increases by the sum of all other CT exams.

Scenario 3. "Combined". A combination of scenario "Covid-19 hospital" for three quarters of the time with the scenario "Intensive activity" for one quarter.

Comparison between these scenarios and the real data for the collective dose from CT examinations is presented on figure 1.

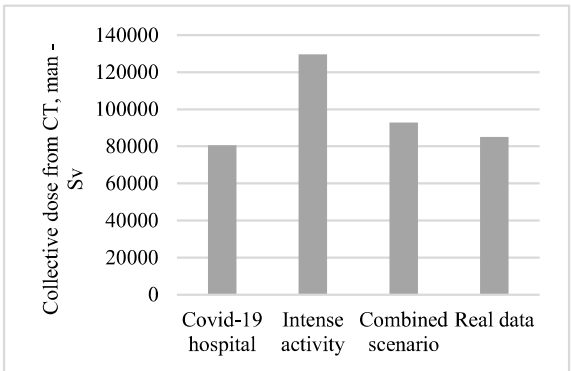

Fig. 1. Comparison between the estimated collective dose from CT examinations for three scenarios and real data.

It is visible from Figure 1 that the real collective dose from CT examinations is comparable with scenarios 1 and 3. Scenario 2, as it was mentioned before, is ultra-conservative and differs from the real data by 20%.

4. Conclusions

The pandemic of COVID-19 and the corresponding transformation of the Russian healthcare system had a significant impact onX-ray and nuclear medicine diagnostics in 2020. A reduction of 10-30% can be observed for all imaging modalities, both in the number of examinations and corresponding collective dose. Computed tomography is an exception, increasing by 60% in number and by 81% in collective dose. The changes in the structure of X-ray and nuclear medicine diagnostics follow the trends for the last four years, however, these trends become more pronounced in the year of the pandemic. The results of the study indicate that the previous rough estimates of the changes in the collective dose from CT examinations were mostly accurate, allowing using the methods for such estimates in the future. The limitation of the current study is that it presents only general data, without a detailed evaluation of the changes in the structure of each imaging modality or dosimetry data. Such data will be processed and presented in future studies.

5. References

1. Stopcoronavirus.RF. [On-line resource]: - Available from: https: //xn80aesfpebagmfblc0a.xn-p1ai/ Last accessed: 07.09.2021
2. Interim guidelines for the prevention, diagnosis, and treatment of a new coronavirus infection (covid-19) Version 11 (07/05/2021) Ministry of Health of the Russian Federation https://spbmiac.ru/wp-content/uploads/2021/05/B%D0%9C%D0%A0_COVID-19.pdf Last accessed: 07.09.2021
3. Methodical guidelines “Completition of the federal statistical surveillance form 3-DOZ ”. M., Rospotrebnadzor, 2014. 34 p.
4. Order of the Ministry of healthcare of the Russian Federation №298 “On the establishment of the Provision on the joint state system of the control and accounting of the individual doses of citizens”. https://docs.cntd.ru/document/901766853 Last accessed 07.09.2021
5. A.V. Vodovatov et.al. Preliminary assessment of structure and collective dose from CT examinations related to COVID-19 diagnostics in the Russian Federation in March - June 2020. medRxiv 2020.08.25.20181396; doi: https://doi.org/10.1101/2020.08.25.20181396