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Impact of the first wave of coronavirus disease 2019 (COVID-19) pandemic on the diagnosis of heart disease in the Russian Federation: results from the Russian segment of the IAEA INCAPS COVID study

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Aim. To assess the impact of the first wave of coronavirus disease 2019 (COVID-19) pandemic on the diagnosis of heart disease in the Russian Federation.

Material and methods. Fifteen Russian medical centers from 5 cities took part in an online survey organized by the Division of Human Health of the International Atomic Energy Agency (IAEA), containing questions regarding alterations in cardiovascular procedure volumes resulting from COVID-19 in March-April 2020.

Results. A number of outpatients undergoing cardiac diagnostic procedures was noted in 80% of clinics. Cardiovascular procedure volumes in the period from March 2019 to March 2020 in general decreased by 9,5%, and from March 2019 to April 2020, by 56,5%. Stress electrocardiography decreased by 38,4%, stress echocardiography by 72,5%, stress single-photon emission computed tomography by 66,9%, computed tomography angiography by 49,7%, magnetic resonance imaging by 42,7%, invasive coronary angiography by 40,7%. The decrease in diagnostic procedure volumes in selected regions (Tomsk Oblast, Kemerovo Oblast, Tatarstan) was not so pronounced compared to Moscow and St. Petersburg (-20,7%, -75,2%, -93,8% in April 2020, respectively, p<0,001).

Conclusion. The first wave of the COVID-19 pandemic caused a sharp decrease in the number of diagnostic cardiac procedures in Russia. This has potential long-term implications for patients with cardiovascular disease. Understanding these implications can help guide diagnostic strategies during the ongoing COVID-19 pandemic and minimize the future losses.

Key words: COVID-19, cardiac diagnostic procedures.

Relationships and Activities: none.

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Over the past year, the pandemic of the new coronavirus infection (COVID-19) has become one of the major global problems affecting all of humanity and having far-reaching socio-economic consequences. However, even during this period, the main cause of death in the population remains cardiovascular diseases (CVD). Between January and September 2020, 1,5 million people worldwide died from COVID-19, while 17 million died from CVD. In Russia, during the period from March to September 2020, 7317 people died from COVID-19 complications, and in another 5825 cases, various diseases in COVID-positive patients were the cause of death. At the same time, over the same period of time, 39985 people died from acute heart attack in Russia, and 220719 people died from coronary heart disease (CHD) in general [1, 2].

In domestic and foreign recommendations for the management of patients with CHD, non-invasive cardiac imaging methods play a leading role in diagnosis, evaluation of the therapy effectiveness and prognosis of patients with CHD. Timely diagnosis of CVD using methods such as echocardiography (EchoCG), computed tomography (CT), magnetic resonance imaging (MRI), single-photon emission tomography (SPECT), and coronary angiography (CA) is crucial for the patient's prognosis, while delaying or refusing to perform diagnostic procedures directly affects the long-term risk of cardiovascular complications and mortality [3]. In this regard, numerous interim recommendations for cardiac imaging during the COVID-19 pandemic have been issued [4-6].

However, the global situation with COVID-19 has led to a serious failure in the provision of many medical services, including regarding the performance of diagnostic studies in cardiology. At the same time, there was a focus shift for the entire field of radiation diagnostics — the volume of chest CT to assess lung damage in COVID-19 increased dramatically [7], while many laboratories and departments, including cardiological imaging, were

temporarily mothballed. In this regard, the Division of Human Health of the International Atomic Energy Agency (IAEA) initiated a major international study INCAPS COVID, which included data from 909 medical centers from 108 countries, to analyze the relationship between the COVID-19 pandemic and the cardiac imaging industry state [8]. This article presents the subanalysis results of the INCAPS COVID study, the purpose of which is to assess the impact of first COVID-19 wave on volume of diagnostic studies of cardiac diseases in the Russian Federation.

Table 1

The provision levels of supplies and protective equipment in institutions at the time of the peak of the first COVID-19 wave

	Available	Currently not available, supplies are planned	Not available, supplies are not planned
Protectants			
Surgical masks	14 (93%)	1 (7%)	0 (0%)
Masks N95/KN95/KF94/FFP2	8 (53%)	4 (27%)	3 (20%)
Gloves	14 (93%)	1 (7%)	0 (0%)
Protective overalls	13 (87%)	1 (7%)	1 (7%)
Glasses/screens	7 (47%)	6 (40%)	2 (13%)
Consumables (isotope laboratories only)			
^{99m}Tc Generators	9/10 (90%)	-	-
^{18}F-FDG	2/2 (100%)	-	-
^{13}N-ammonium	2/2 (100%)	-	-
Technetrile/tetrofosmin kits	10/10 (100%)	-	-

Table 2

Implementation frequency of various measures related to changing the work process in the COVID-19 conditions

	Russian Federation			Europe	
Number of centers	15			236	
	Implemented	Not implemented, planned	Not implemented, not planned	Implemented	p
Changing the work process structure					
Reduction of outpatient admissions	12 (80%)	2 (13%)	1 (7%)	201 (85%)	0,86
Cancellation of admission of all non-emergency outpatients	9 (60%)	1 (7%)	5 (33%)	189 (80%)	0,13
Cancellation of admission of all outpatients	7 (47%)	2 (13%)	6 (40%)	103 (44%)	0,97
Phased resumption of activities after the peak of the pandemic	5 (33%)	10 (67%)	0	141 (60%)	0,08
Increase in working hours after the peak of the pandemic	0	6 (40%)	9 (60%)	50 (21%)	0,10
Increase in weekend hours after the peak of the pandemic	0	3 (20%)	12 (80%)	28 (12%)	0,32
Switching to remote means for patient contact	3 (20%)	3 (20%)	9 (60%)	110 (47%)	0,08
Changing the procedure for patients admission					
Move to remote means for patient registration (questionnaires, informed consents)	3 (20%)	5 (33%)	7 (47%)	100 (42%)	0,15
Changing patient transportation (use of elevators, etc.)	5 (33%)	3 (20%)	7 (47%)	166 (70%)	<0,01
Distancing in waiting rooms	9 (60%)	5 (33%)	1 (7%)	209 (89%)	<0,01
Separate rooms for patients with COVID-19	7 (47%)	6 (40%)	2 (13%)	194 (82%)	<0,01
Reducing the time of stay of patients in waiting rooms	8 (53%)	4 (27%)	3 (20%)	198 (84%)	<0,01

Table 2. Continued

	Russian Federation			Europe	
Number of centers	15			236	
	Implemented	Not implemented, planned	Not implemented, not planned	Implemented	p
Restricting access to persons accompanying patients	8 (53%)	5 (33%)	2 (13%)	223 (94%)	<0,01
Temperature measurement for all patients and visitors	12 (80%)	2 (13%)	1 (7%)	126 (53%)	0,08
Mandatory completion of a questionnaire for COVID-19 symptoms by patients and visitors	9 (60%)	3 (20%)	3 (20%)	162 (69%)	0,68
Test for COVID-19 in all patients before enrollment	1 (7%)	4 (27%)	10 (67%)	22 (9%)	0,91
Mandatory wearing of masks for all patients and visitors	12 (80%)	2 (13%)	1 (7%)	169 (72%)	0,68
Changing the study protocol					
Use of pharmacological load tests instead of physical, if possible	4/13 (31%)	2/13 (15%)	7/13 (54%)	99 (42%)	0,37
Changing the nuclear cardiology protocols (for example, increasing the input activity to reduce the data collection time, use as a first phase with a load test)	3/10 (23%)	2/10 (15%)	5/10 (38%)	42 (18%)	0,89
Changing the heart CT protocols (for example, a decrease in the use frequency of intravenous drugs to reduce HR)	1/13 (8%)	3/13 (23%)	9/13 (69%)	24 (10%)	0,99
Additional time after each study for sanitary disposal of equipment and premises	11 (73%)	3 (20%)	1 (7%)	172 (73%)	0,79
Increasing the distance between staff and patients	10 (67%)	3 (20%)	2 (13%)	198 (84%)	0,17
Mandatory use of personal protective equipment	11 (73%)	3 (20%)	1 (7%)	210 (89%)	0,16
Changing or eliminating the protocols that require long-term contact with patient	5 (33%)	5 (33%)	5 (33%)	133 (56%)	0,14
Changing the personnel process					
Rotation of work shifts	9 (60%)	4 (27%)	2 (13%)	157 (67%)	0,81
Employment freeze/holidays without pay of part of the staff of radiologists/radiologists due to economic crisis on grounds of COVID-19	1 (7%)	0	14 (93%)	19 (8%)	0,76
— for the average staff of diagnostic laboratories	2 (13%)	0	13 (87%)	18 (8%)	0,76
Cut of radiologists'/radiologists' salary	5 (33%)	1 (7%)	9 (60%)	10 (4%)	<0,001
— for the average staff of diagnostic laboratories	5 (33%)	2 (13%)	8 (53%)	10 (4%)	<0,001
Dismissal of part of radiologists/radiologists	1 (7%)	1 (7%)	13 (87%)	4 (2%)	0,70
— for the average staff of diagnostic laboratories	0	1 (7%)	14 (93%)	5 (2%)	0,70

Abbreviations: CT — computed tomography, HR — heart rate, IV — intravenous.

Material and methods

The database for subanalysis was formed as part of the INCAPS COVID study under IAEA auspices. The online questionnaire form was developed by a group of specialists in the field of cardiology and cardiovascular system visualization [8]. The questionnaire included items related to organization of work in medical institutions, staff of diagnostic laboratories and departments, availability of personal protective equipment, and strategic plans after re-opening. Changes in volume of cardiological studies were recorded in connection with the current epidemiological situation (in April 2020) compared to March 2020 (the month preceding the epidemic onset) and the same period of the last year (March 2019), namely, the volume of performed radionuclide studies (SPECT and positron emission tomography (PET)), and CT (including for assessment of coronary calcium and CT-coronarography). Moreover, some data were obtained on the volume dynamics of such studies as EchoCG, heart MRI, heart PET for infectious diseases, as well as invasive CA. The data was collected using a questionnaire form using the IAEA's secure IRIS software plat-

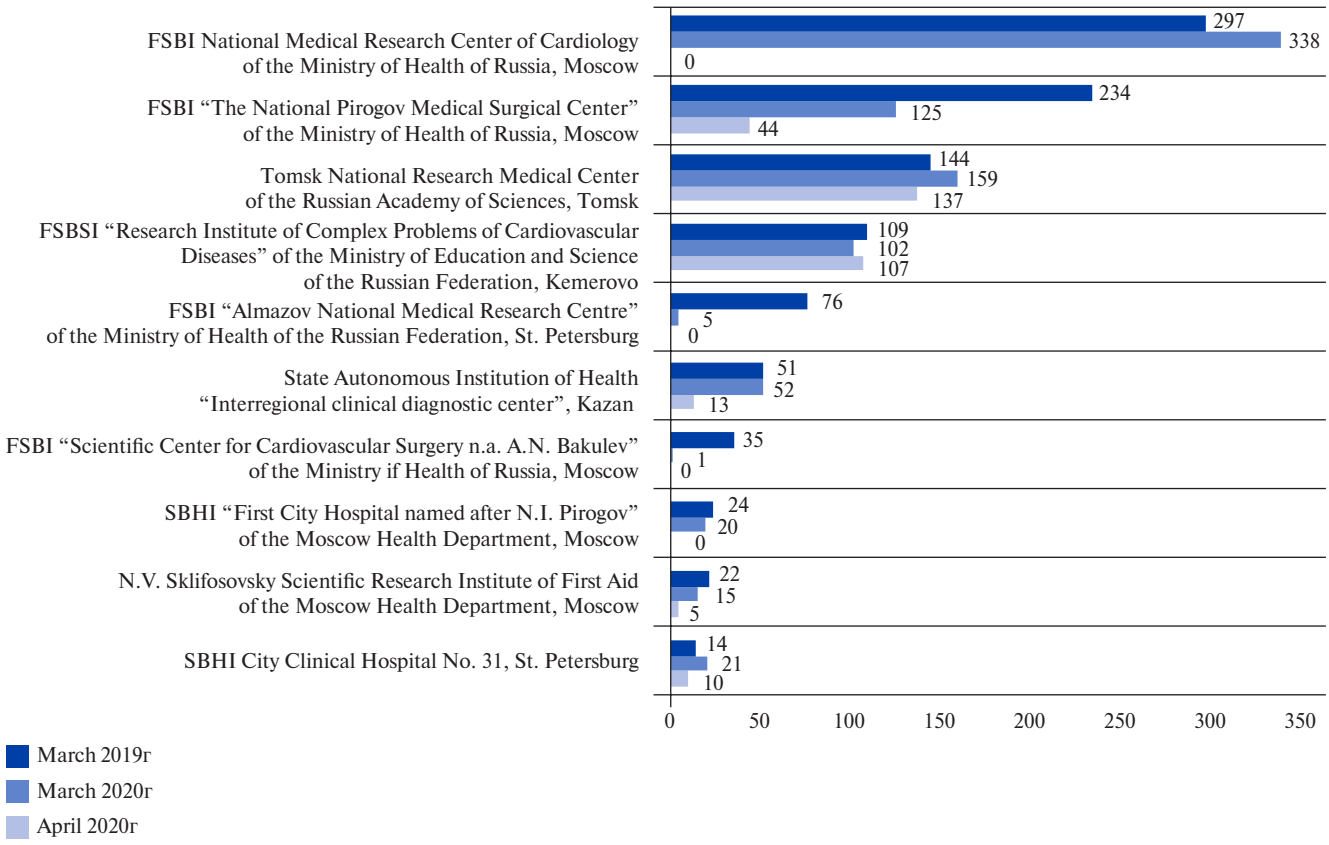

Figure 1. Volume dynamics of radionuclide myocardium studies in various centers of Russia in March and April 2020 in comparison to March 2019.

form (https://iris.iaea.org). Russian centers were invited to participate in the study through invitations from national coordinators with the participation of the Moscow Branch of the Society of Nuclear Medicine and the Russian Society of Radiologists and Radiologists. The participation of investigator sites was voluntary, no personal and confidential data was collected, so the study did not require the ethics committees' opinion.

The statistical analysis was performed using Microsoft Excel 2013 and MedCalc 15.8. The answers to the questionnaire questions are presented in the form of numerical values and percentages. The fractions were compared using the chi-square test with the Yates correction. Since official figures on hospitalizations number of patients with COVID-19 in Russia are only available from April 25, 2020, earlier values are obtained by constructing a trend line with reverse forecast.

Results

For the Russian Federation, the data are provided by questionnaires from 15 medical centers, including 8 — from Moscow, 4 — from St. Petersburg and 1 each — from Tomsk, Kazan and Kemerovo. All the enrolled centers were specialized or multidisciplinary hospitals, 13 of them — with the implementation of educational programs, including 8 federal centers and 7 city health institutions, with a capacity from 165 to 2000 (on average 500 (400-970)) beds. Of the 15 institutions, 10 had an isotope laboratory (including 2 had PET), 13 had CT (including hybrid devices of SPECT/CT or PET/CT), 13 performed exercise tolerance tests on a continuous basis.

The treatment and diagnostic units of the included centers were generally provided with individual protective gear. 90% of isotope laboratories were provided with ^{99m}Tc generators for this period, and radiopharmaceuticals ^{18}F-FDG and ^{13}N-ammonium for studies of myocardial metabolism and perfusion were available in both enrolled PET centers. The provision levels of supplies and protective equipment in institutions at the time of the peak of the first COVID-19 wave (May 2020) are shown in Table 1.

A decrease in outpatient flow of patients in Russian clinics for diagnostic cardiological examinations, as in European ones, was noted in the majority (80% vs 85%, p=0,89) of clinics. In comparison with Europe, Russian clinics less often resorted to various changes in the procedure for receiving patients. In particular, in Russia, they less often switched

Table 3

Dynamics of the cardiological examination volume in Russia in March and April 2020 compared to March 2019

	Russian Federation				Generally	Europe	p
	Moscow	Saint-Petersburg	Regions*	p			
Number of centers	8	4	3	-	15	251	-
Volume dynamics of execution of all studies							
03.2019-03.2020	-14,5%	-67,9%	3,2%	<0,001	-9,5%	-45%	<0,001
03.2019-04.2020	-75,2%	-93,8%	-20,7%	<0,001	-56,5%	-69%	<0,001
Volume dynamics of perfusion SPECT of myocardium							
03.2019-03.2020	-16,6%	-51,9%	3,0%	<0,001	-12,4%	-	-
03.2019-04.2020	-91,8%	-81,5%	-15,5%	<0,001	-66,9%	-79%	<0,001

Note: *regions — Tomsk region, Kemerovo region, Tatarstan.
Abbreviation: SPECT — single photon emission computed tomography.

Table 4

Volume dynamics of other cardiological examinations performed in April 2020 compared to March 2019

	Russian Federation	Europe	p
Stress ECG	-38,4%	-83%	<0,001
Stress EchoCG	-72,5%	-84%	<0,001
Stress PET	-100%	-42%	<0,001
Stress MRI	-14,3%	-68%	<0,001
CT-CS	-54,8%	-78%	<0,001
CTA	-49,7%	-69%	<0,001
EchoCG	-61,6%	-67%	<0,01
TE-EchoCG	-87,4%	-74%	0,002
PET (infections)	-100%	-53%	<0,001
MRI	-42,7%	-72%	<0,001
Invasive CA	-40,7%	-51%	0,006

Abbreviations: CA — coronary angiography, CS — clinical study, CT — computed tomography, CTA — computed tomographic angiography, MRI — magnetic resonance imaging, PET — positron emission tomography, TE-EchoCG — transesophageal echocardiography, ECG — electrocardiography, EchoCG — echocardiography.

to remote communication with patients, and less often modified the principles of transportation and logistics of the patients flow in the premises of diagnostic departments. Changes in work process structure and study protocols were implemented with approximately the same frequency as in European clinics. Summary data on the frequency of implementation of various measures related to changes in work process due to work in the COVID-19 conditions are given in Table 2.

In general, the volume of cardiac diagnostic procedures in the Russian centers enrolled in the period from March 2019 to March 2020 decreased by 9,5% (in European centers — by 45%, p<0,001), from March 2019 to April 2020 — by 56,5% (in Europe — by 69%, p<0,001). At the same time, the decrease in the study volume in the regions, including perfusion myocardium SPECT, was not as expressed as in Moscow and St. Petersburg (all p<0,001) (Table 3). The change in radionuclide studies in absolute values is given in Figure 1. The change in functional studies is given in Figure 2 A, while other cardiological examinations performed at rest are shown in Figure 2 B.

The scope of other cardiac studies has decreased to a lesser extent than in Europe (all p<0,01) by April 2020. At the same time, the number of PET scans in progress (incl. for myocardial blood flow assessment and for infection diagnosis), as well as transesophageal EchoCG has decreased to a greater extent than in Europe (all p<0,01). The data on change in scope of cardiac studies against European data are given in Table 4.

Empirical regularities between the nature of COVID-19 pandemic state and a decrease in scope of cardiac studies in different regions. In this connection, the number of studies in St. Petersburg decreased by 68% in March 2020 compared with March 2019, despite the relatively small number of COVID-19 cases. In April 2020, the number of cases and hospitalizations in Moscow was critical, while the number of cardiological examinations decreased by 75%, while in St. Petersburg and the regions — by 94% and 21%, respectively, with a much lower incidence of infections, hospitalizations and deaths than in Moscow, per 100 thousand populations (Table 5).

Discussion

The COVID-19 pandemic has had a major impact on the healthcare industry worldwide. The

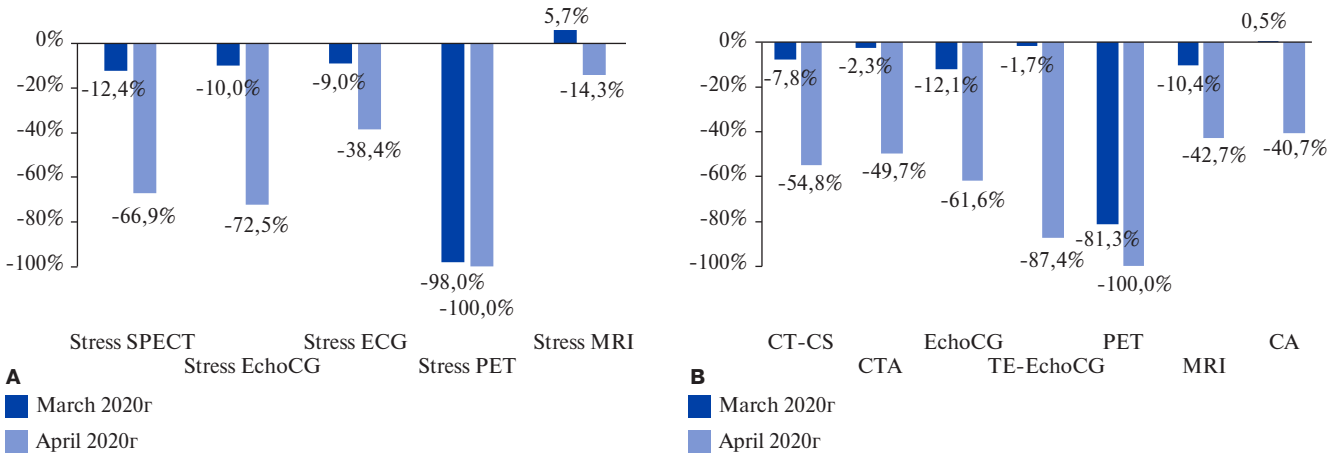

Figure 2. Changing the number of functional (**A**) and other (**B**) cardiological examinations in March and April 2020 in comparison to the same period in 2019.
Abbreviations: CA — coronary angiography, CS — clinical study, CT — computed tomography, CTA — computed tomographic angiography, MRI — magnetic resonance imaging, SPECT — single photon emission computed tomography, PET — positron emission tomography, TE-EchoCG — transesophageal echocardiography, ECG — electrocardiography, EchoCG — echocardiography.

Table 5

Dynamics of infections, hospitalizations, deaths from COVID-19 and volume of cardiac studies in the studied regions in March and April 2020

	Moscow		Saint-Petersburg		Regions	
	March 2020	April 2020	March 2020	March 2020	April 2020	March 2020
Total infections	1613	52126	98	3964	25	1015
Infections per 100 thousand	12,9	416,8	1,8	74,1	0,3	13,2
Total hospitalizations*	1452	35378	88	2656	22	680
Hospitalizations per 100 thousand*	11,6	282,9	1,6	49,6	0,3	8,9
Total deaths	11	600	2	27	0	4
Deaths per 100 thousand	0,1	4,8	0,0	0,5	0,0	0,1
Decrease in the number of cardiac examinations	-14,5%	-75,2%	-67,9%	-93,8%	3,2%	-20,7%

Note: * — the data is based on the interpolation of official reports after April 25 by constructing a trend line with reverse forecast.

results of large international INCAPS COVID study initiated by the IAEA Human Health Division, which included data from 909 medical centers from 108 countries, recorded an unprecedented decrease in the global volume of diagnostic cardiac imaging — by 42% in March 2020 and by 64% in April 2020 compared to data for March 2019 [8]. In Europe, a set of measures related to work in COVID-19 conditions varied significantly, taking into account the situation severity in different countries and regions, but the total number of cardiac examinations also decreased — by 45% in March 2020 and by 69% in April 2020. The reduction of studies and the frequency of restrictive measures from European countries were greatest in the southern regions, where the damage from the pandemic's first wave was most severe. In March 2020, location (Southern Europe) and high mortality from COVID-19 (per 100000 population) were independent predictors of reduced cardiological examinations. In April 2020, such predictors were the location and low level of the country economy (expressed in gross domestic product) [9]. These results stress the significant variability in the public health service response of different countries to the pandemic and its role in further increasing the risk for patients with CVD.

During the first wave of the COVID-19 pandemic, 7 of the 8 enrolled federal centers in Russia were redesignated as COVID-centers, which, together with other changes in the internal regulations related to COVID-19, led to many innovations in work process of diagnostic laboratories. In most centers, the volume of outpatient patients decreased, in 4 centers, the attendance of patients for radionuclide studies was completely stopped (Figure 1), and a number of limit rules were introduced within the

remaining flow. Measures were also taken to modify the protocols for recording studies, minimizing the potential for infection of patients and staff at workplaces. According to our data, the implementation frequency of these changes in Russia sufficiently differs from the European practice. Apparently, this is due to the fact that at the time of filling out the questionnaires (the end of May 2020), a large part of diagnostic laboratories was mothballed, and the new rules were implemented later, as the outpatient flow was gradually resumed. At the same time, in many centers of Russia, the flows of outpatient and hospital patients were subsequently differentiated (by organizing separate entrances, exits and partitions), which was not reflected in the form of the European Questionnaire.

According to our data, the volume of cardiological examinations in Russia in March 2020 compared to March 2019 decreased by 9,5%, and in April 2020 — by 56,5%, while in Europe the decrease was 45% and 69%, respectively ($p<0,001$). The main contribution to decrease in the study volume was made by Moscow and St. Petersburg, while in the enrolled regional centers, the decline in study volume in April was only 20,7%. This can be explained by dynamics of pandemic spread in Russia — in March, the cases in Moscow (which faced COVID-19 earlier than other Russian cities) were still only at the very beginning of an increasing trend, while in many European countries at this time, the peak of morbidity was already approaching. In turn, a sharp increase in the COVID-19 incidence in the regions occurred about another month later. Thus, the first deaths from COVID-19 in Moscow were recorded on March 25, in St. Petersburg — on March 29, in Kemerovo region — on April 18, in Tatarstan — on April 29, in Tomsk — on May 1. For this reason, in March 2020, there was not yet a massive decline in the number of cardiological examinations in the regions, and by April 2020, this decline was still less significant than in Moscow and St. Petersburg, which, in turn, was less significant than in Europe.

By autumn 2020, most of the centers that were converted into COVID centers during the first COVID-19 wave have returned to their main operation, and the diagnostic laboratories are largely disbanded and continue to see patients in the conditions of a full-fledged second wave of the pandemic. All the safety measures that were developed and implemented at the beginning of the first wave (Table 2), but not so carefully observed at that time, have now become de facto mandatory. We are talking primarily about optimizing the working hours of medical and paramedical personnel of radiological and radiological departments, switching to remote means of contact with patients (before and after studies), distancing at all stages of the study, additional sanitary measures, temperature measurement, mandatory wearing of masks, collection of COVID-anamnesis, for hospital patients — stay in observational departments.

Despite the changes in work process of diagnostic departments, special attention should now be paid to eliminating or at least reducing the consequences of the first pandemic wave. Thus, a significant decrease in the number of diagnostic cardiological examinations in the second quarter of 2020 led to the queueing formation for study among those who at that time were refused due to the closure of laboratories. In this regard, it is impossible not to mention another problem related to the state of isotopic laboratories in the country. While in Europe, the INCAPS COVID study enrolled 251 centers with isotope laboratories that are engaged in nuclear cardiology on a consistent basis (i.e., approximately 1 per 2,8 million population), according to the most optimistic estimates, there are currently no more than 15 such laboratories, of which 10 were enrolled in Russia (i.e., 1 per 14,5 million population). At the same time, given that the overwhelming volume of radionuclide cardiological studies in Russia is carried out in 6 centers — Federal State Budgetary Institution (FSBI) "National Medical Research Center of Cardiology" of the Ministry of Health of Russia (Moscow), FSBI "The National Pirogov Medical Surgical Center" of the Ministry of Health of Russia (Moscow), Cardiology Research Institute, Federal State Budgetary Scientific Institution "Tomsk National Research Medical Center of the Russian Academy of Sciences", FSBSI "Research Institute of Complex Problems of Cardiovascular Diseases" of the Ministry of Education and Science of the Russian Federation (Kemerovo), State Autonomous Institution of Health "Interregional clinical diagnostic center" (Kazan) and FSBI "Almazov National Medical Research Centre" of the Ministry of Health of the Russian Federation (St. Petersburg), in Russia, the number of performed cardiac isotope studies per head is at least 10 times less than in Europe. As a result, according to our approximate data, the waiting list for perfusion scintigraphy of myocardium in patients with suspected or established CHD at the end of 2020 (even taking into account the work resumption) in these centers is at least 500-700 people.

It should be emphasized that the heart imaging by radiation diagnostics is central to the diagnostic algorithm for many patients with both acute and chronic conditions. In particular, the imaging of transient myocardial ischemia by perfusion scintigraphy and SPECT is a key point in determining the management of patients with CHD. In particular,

the method is used to select patients for invasive CA and PCI, reducing the number of unpractical interventions. Therefore, the drop in the already low volume of cardiological radionuclide examinations performed in Russia caused by COVID-19 will have serious short-and long-term consequences for all patients with CVD in whom the diagnostic study was canceled or postponed. In addition, it is known that COVID-19 itself is associated with myocardial damage, arrhythmias, venous and arterial thrombosis [10]. These effects will exacerbate the increased risk of adverse outcomes in patients with CVD after COVID-19 infection, combined with the continued decline in the capacity of the cardiology emergency service redirected to receive patients with COVID-19 [11]. Thus, in Europe, the number of hospitalizations in March 2020 with acute myocardial infarction in emergency departments decreased by half, as a result of which there was a proportional increase in out-of-hospital cases of cardiac arrest and an increase in cardiovascular mortality in general [12-15].

According to European data, the retaliatory measures of the governments of various countries had some regularities. In particular, the most significant decrease in the cardiac diagnostics volume was typical not only for countries with highest mortality from COVID-19, but also for countries with a relatively low gross domestic product [9]. It is likely that such attempts to prevent overloading the health care system have a short-term effect, but will have dire consequences in the long term.

Conclusion

A timely solution to the problem of overloading the health system by organizers of domestic health care is extremely important, since at present the end date of the COVID-19 pandemic cannot be set. In turn, at the level of diagnostic departments, it is essential to strictly adhere to the adopted protective measures, logistics modifications and patient examination protocols. This is necessary to maintain the readiness to increase the flow of patients and their safe examination under the conditions of the ongoing COVID-19 pandemic.

Annex

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