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Impact of Access to Specialized, Including High-Tech Medical Care for Patients With the Coronary Artery Disease on Coronary Artery Disease Mortality in the Russian Federation

Aim	To assess the effect of the availability of specialized, including high-tech, medical care for patients with ischemic heart disease (IHD) on mortality from IHD in the Russian Federation.
Material and methods	To achieve the predetermined goal, we used cointegration of time series characterizing the mortality from IHD and the availability of specialized, including high-tech, medical care for patients with IHD in the Russian Federation for the period from 2015 to 2021: availability of cardiac beds; availability of cardiac surgery beds; availability of beds in regional vascular centers (RVC); availability of beds in primary vascular departments (PVD); availability of cardiologists in polyclinics; availability of cardiologists in hospitals; availability of cardiovascular surgeons (CVS) in hospitals; availability of interventional radiologists for endovascular diagnosis and treatment (EVDT) in hospitals; availability of therapeutic procedures of percutaneous coronary intervention (PCI) in acute coronary syndrome (ACS); availability of elective PCI procedures; availability of coronary artery bypass grafting (CABG).
Results	Cointegration tests showed a relationship between IHD mortality and the availability of beds at RVCs and PVDs and of CABG operations. Furthermore, an increase in the availability of RVC beds by 1 unit in each period results in a decrease in IHD mortality by 22.8 per 100,000 population during the year; an increase in the availability of PVD beds by 1 unit in each period results in a decrease in IHD mortality by 64.4 per 100,000 population during 2 years; and an increase in the availability of CABG by 1 unit in each period of time results in a decrease in IHD mortality by 34.8 per 100,000 population during 2 years.
Conclusion	Thus, the most promising directions for concentrating healthcare resources to quickly reduce IHD mortality are the further deployment of a network of RVCs and PVDs, as well as increasing the number of CABG operations.

Keywords	Ischemic heart disease; resource provision; specialized medical care; high-tech medical care
For citations	Oleinik B.A., Starodubov V.I., Evdakov V.A., Abzalilova L.R. Impact of Access to Specialized, Including High-Tech Medical Care for Patients With the Coronary Artery Disease on Coronary Artery Disease Mortality in the Russian Federation. Kardiologiia. 2024;64(6):58–64. [Russian: Олейник Б.А., Стародубов В.И., Евдаков В.А., Абзалилова Л.Р. Персонализированный подход к анализу доступности специализированной, в том числе высокотехнологичной, медицинской помощи пациентам с ишемической болезнью сердца в Российской Федерации. Кардиология. 2024;64(6):58–64].

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Introduction

One of the most significant challenges to public health, both in Russia and globally, is the prevalence of circulatory system diseases (CSD) [1]. Over the past decade, atherosclerosis-related CSDs have remained the primary cause of mortality worldwide, accounting for approximately 47% of all cases in both economically developed and developing countries. This is attributed to the aging of the population, the increasing prevalence of type 2 diabetes mellitus and obesity [2, 3].

Coronary artery disease (CAD) represents the primary cause of death from CSDs. It is of particular significance that 42% of all deaths resulting from CAD occur among individuals of working age [4]. However, due to the direct impact of Covid 19 and epidemiologic limitations, experts have predicted an additional increase in mortality from CAD. The forecast for countries with relatively high levels of economic prosperity indicates an epidemic of CSDs with an increase in the global prevalence of CAD by 9.3% by 2030 and a concomitant increase in direct medical costs of 98% compared to the figures recorded in 2010 [5].

In order to enhance the accessibility and quality of medical care, the Government of the Russian Federation endorsed the national project «Health Care», which encompasses eight federal projects, including the project

ISSN 0022-9040. Kardiologiia. 2024;64(6). DOI: 10.18087/cardio.2024.6.n2490

«Combating Cardiovascular Diseases». This project has identified the reduction of mortality from CSDs to 450 cases per 100,000 of the population by 2024 as a primary objective [6].

The novel coronavirus pandemic, however, has resulted in a significant reallocation of material and non-material resources in favor of endeavors aimed at curbing the spread of Covid-19. Furthermore, economic sanctions imposed by Western nations have introduced objective challenges in the construction and particularly in the provision of cutting-edge equipment for new and reconstructed medical facilities, which could impede the achievement of the targets set forth in the Federal Project.

In this context, it is of particular importance to identify the most effective Russian healthcare resources in order to achieve the planned mortality rates from CSDs under the Federal Project «Combating Cardiovascular Diseases».

Objective

Assess the impact of the accessibility of medical care, including high-tech treatments, for patients with CAD on mortality from CAD in the Russian Federation.

Material and Methods

In order to assess the impact of the accessibility of specialized medical care for patients with CAD on mortality from CAD, the following factors characterizing the availability of medical care, including high-tech treatments, for patients with CAD in the Russian Federation were used: availability of cardiology beds (x1); availability of cardiac surgery beds (x2); bed availability in regional vascular centers (RVC) (x3); bed availability in primary vascular departments (PVD) (x4); availability of cardiologists in outpatient clinics (x5); availability of cardiologists in hospitals (x6); availability of cardiovascular surgeons in hospitals (x7); availability of physicians of X-ray endovascular diagnosis and treatment in hospitals (x8); availability of percutaneous coronary intervention (PCI) procedures for acute coronary syndrome (ACS) (x9); availability of elective PCI procedures (x10); availability of coronary artery bypass grafting (CABG) interventions (x11).

In order to identify the factors influencing mortality from CAD, we investigated the cointegration of time series [7] describing the availability of medical care,

Central illustration. Impact of Access to Specialized, Including High-Tech Medical Care for Patients With the Coronary Artery Disease on Coronary Artery Disease Mortality in the Russian Federation

ASSOCIATION BETWEEN MORTALITY RATES FROM CORONARY ARTERY DISEASE AND PARAMETERS OF THE AVAILABILITY OF SPECIALIZED MEDICAL CARE, INCLUDING HIGH-TECH TREATMENTS, FOR PATIENTS WITH CORONARY ARTERY DISEASE IN THE RUSSIAN FEDERATION

Availability	Presence(+) / absence(-) of co-integration relationship	Change in the CAD mortality rate with an increase in the availability parameter by one unit (per 10,000 population)	Coefficient of determination (R2)
Cardiac beds	–	–	–
Cardiac surgical beds	–	–	–
RVC beds	+	-22.8 per 100 thousand population within 1 year	0.95
PVD beds	+	-64.4 per 100 thousand population within 2 years	0.98
Cardiologists in outpatient clinics	–	–	–
Cardiologists in hospitals	–	–	–
Cardiac surgeons in hospitals	–	–	–
Physicians of X-ray endovascular diagnosis and treatment in hospitals	–	–	–
PCI procedures for ACS	–	–	–
Elective PCI procedures	–	–	–
CABG surgeries	+	-34.8 per 100 thousand population within 2 years	0.89

Table 1. Indicators of the availability of medical care, including high-tech treatments, for patients with CAD in the Russian Federation (per 10 thousand population)

Parameter	Years						
	2015	2016	2017	2018	2019	2020	2021
Availability of cardiac beds	3.22	3.25	3.21	3.19	3.12	2.56	2.51
Availability of cardiac surgical beds	0.33	0.36	0.35	0.35	0.35	0.36	0.38
Availability of RVC beds	0.93	0.97	1.02	1.09	1.17	1.2	1.29
Availability of PVD beds	1.45	1.56	1.61	1.71	1.72	1.43	1.42
Availability of cardiologists in outpatient clinics	0.24	0.25	0.25	0.26	0.27	0.26	0.26
Availability of cardiologists in hospitals	0.42	0.44	0.47	0.46	0.47	0.46	0.47
Availability of cardiac surgeons in hospitals	0.12	0.13	0.13	0.13	0.14	0.14	0.15
Availability of physicians of X-ray endovascular diagnosis and treatment in hospitals	0.04	0.05	0.06	0.07	0.08	0.09	0.1
Availability of PCI procedures for ACS	6.62	8.56	9.78	11.4	12.74	11.5	13.05
Availability of elective PCI procedures	2.1	2.41	2.38	2.51	3.46	3.01	3.95
Availability of CABG surgeries	2.05	2.24	2.22	2.31	2.41	1.81	2.02

CAD, coronary artery disease; RVC, regional vascular center; PVD, primary vascular department; PCI, percutaneous coronary intervention; ACS, acute coronary syndrome; CABG, coronary artery bypass grafting.

including high-tech treatments, for patients with CAD, and the time series of mortality from CAD in the Russian Federation.

In order to analyze the data, we employed the indicators from the statistical monitoring forms No. 14, entitled «Information on the activities of medical facility departments providing inpatient medical care», and No. 30, entitled «Information on medical facility», and the «Monitoring of measures to reduce mortality from CAD» for the period between 2015 and 2021 in the Russian Federation.

The testing and construction of the model were performed with the statistical EViews econometric software suite.

Results

Table 1 presents the indicators of the availability of medical care, including high-tech treatments, for patients with CAD in the Russian Federation (per 10 thousand population) for the period between 2015 and 2021.

The listed indicators were co-integrated with mortality rates from CAD in the Russian Federation for the period between 2015 and 2021 (per 100 thousand population): 337.8 in 2015, 328.5 in 2016, 311.7 in 2017, 308.7 in 2018, 301.4 in 2019, 347.3 in 2020, and 332.42 in 2021.

The results revealed the existence of a co-integration correlation for the availability of RVC beds (x^3), PVD beds (x4), and CABG procedures (x11) (Figure 1).

Distributed lag models expressing the relevant relationships were constructed for these indicators of health care resource provision:

$y_t = -11.8 - 22.8 \cdot x_{3t} + 57{,}0 \cdot ds$ $R^2=0.95$ (1)

$y_t = 494.1 + 24.9 \cdot x_{4t} - 89.3 \cdot x_{4t-1} + 41.5 \cdot ds$ $R^2=0.98$ (2)

$y_t = -91.8 - 66.6 \cdot x_{11t} + 31.8 \cdot x_{11t-1} + 93.8 \cdot ds$ $R^2=0.89$ (3)

The analysis of equation (1) indicates that an increase in the availability of RVC beds by one unit in each period is associated with a reduction in mortality from CAD by 22.8 per 100,000 population per year.

As well as for RVC bed availability, there was a co-integration relationship between PVD bed availability and CAD mortality (Equation 2). For each additional unit of PVD beds available in a given period, there was a 64.4 per 100,000 decrease in CAD mortality over a two-year period.

Furthermore, a co-integration relationship was identified between the availability of CABG procedures (Equation 3) and mortality from CAD. Specifically, an increase of one unit in the availability of CABG procedures in each time period was associated with a reduction of 34.8 per 100,000 in mortality from CAD over a two-year period.

Meanwhile, no co-integration correlation was identified between mortality from CAD in the Russian Federation and the availability of cardiology and cardiac surgery beds, cardiologists in outpatient clinics and hospitals, cardiovascular surgeons, and physicians of X-ray endovascular diagnosis and treatment in hospitals, as well as the availability of PCI procedures for ACS and stable exertional angina pectoris.

Discussion

The results of the co-integration analysis indicated a correlation between the availability of RVC beds and a reduction in mortality from CAD. From a practical standpoint, the obtained data substantiate effective prioritization of resource consolidation by the Ministry of Health of the Russian Federation in achieving the objectives of the National Project «Health». This was accomplished through the deployment of the network

ISSN 0022-9040. Kardiologiia. 2024;64(6). DOI: 10.18087/cardio.2024.6.n2490

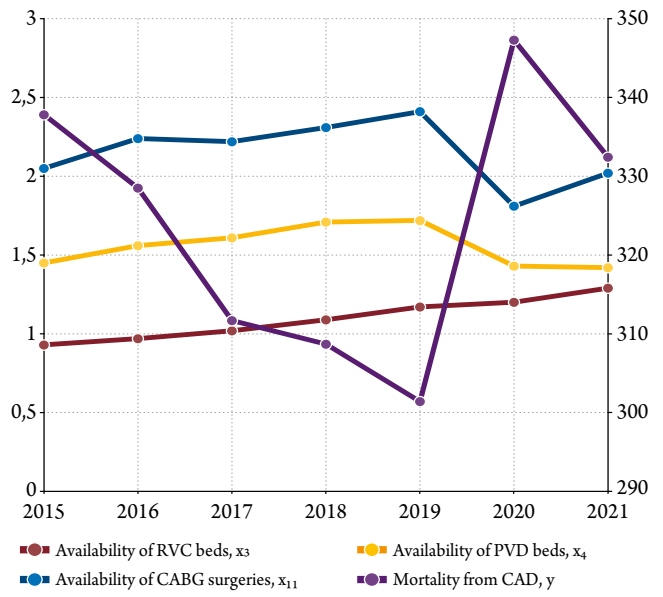
of RVCs and PVDs between 2008 and 2012. This was corroborated by a reduction in mortality from myocardial infarction (MI) from 47.1 to 39.1 and a decline in the incidence of recurrent MI from 24.7 to 23.1 cases per 100,000 population [8]. In this regard, the implementation of a set of measures aimed at equipping and re-equipping PVDs and RVCs within the framework of the Federal Project «Health Care» is regarded as a promising tool for achieving the project's planned mortality rates from CSDs of up to 450 per 100,000 population. Furthermore, in addition to the aforementioned considerations, the actual task is the establishment of new RVCs to guarantee the two-hour accessibility demanded by contemporary clinical guidelines for patients with ACS [9]. This is because, based on the calculations utilizing the initial algorithm proposed by O.V. Sagaidak and E.V. Oshchepkova [10], the necessary number of RVCs with angiographic units for the Russian Federation is 239 units. Given that, as of 2021, there are only 189 RVCs in operation in the Russian Federation, there is still a notable deficit of these facilities. Addressing this deficit is a crucial step in reducing mortality from CAD in Russia. On the other hand, the circumstances surrounding the ongoing pandemic of Covid-19, along with the sanctions imposed by Western countries, present significant challenges to the construction and provision of new RVCs. In this context, the utilization of interregional communication in the development of routing schemes for emergency patients, including the incorporation of modern information technologies, represents a promising avenue for ensuring the two-hour accessibility of PCI for ACS patients [11].

In regard to the co-integration correlation between the number of PVD beds and mortality from CAD, it can be proposed that despite the requirements of modern clinical guidelines regarding the necessity of hospitalization of patients with ST-segment elevation ACS directly to the primary PCI hospital, bypassing the nearest hospitals without X-ray surgery [12], due to the geographical peculiarities of our country, such as low population density and vast distances between major populated areas and hospitals equipped with angiographic units, it is not currently feasible to abandon the routing of patients to PVDs in a number of regions of the Russian Federation. In this regard, a balanced approach to the optimization of PVD beds is essential, taking into account the specific characteristics of the area in question.

The data obtained by our research team are corroborated by the findings of Boitsov et al. [8], who demonstrated a correlation between the number of RVCs/PVDs and mortality from ACS, with a coefficient of –0.25 ($p < 0.05$) in 2017.

The efficacy of CABG surgery in improving survival rates among patients with multi-vessel CAD has been demonstrated in numerous large-scale clinical trials [13]. It thus appears reasonable to conclude that an increase in the number of such surgical procedures contributes to a reduction in mortality from CAD at the national level. The impact of the increase in the number of CABG procedures on the reduction of mortality from CAD has been demonstrated with convincing evidence in the USA using the original statistical model, IMPACT. The model examined the changes in mortality rates among adults aged 25 to 84 years over the period from 1980 to 2000. The analysis revealed that surgical revascularization contributed to a 5% reduction in mortality. [14]. The prospective population-based analytic study in Ontario, Canada, also examined the contribution of CABG to the reduction in CAD mortality using the updated IMPACT model. From 1994 to 2005, the mortality rate from CAD in this region decreased by 35%, from 191 to 125 cases per 100,000 population. The estimated contribution of coronary artery bypass grafting (CABG) for chronic CAD was 17% (ranging from 7% to 35%) [15]. A similar Polish study revealed that CABG contribution to a twofold reduction in CAD mortality from 1991 to 2005 was 7% [16].

Figure 1. Relationship between the availability of RVC beds (x3), PVD beds (x4), and CABG procedures (x11) (per 10 thousand population) and mortality from CAD (y) (per 100 thousand population) in the Russian Federation



CAD, coronary artery disease; RVC, regional vascular center; PVD, primary vascular department; CABG, coronary artery bypass grafting.

It is also noteworthy that the number of CABG surgeries performed in the Russian Federation is more than four times less than the estimated need [17, 18]. The consolidation of healthcare resources with the aim of increasing the number of such surgeries represents a significant reserve for reducing mortality from CAD.

In addition, the absence of co-integration correlations between mortality from CAD and key indicators of population access to specialized medical care, such as the availability of cardiology and cardiac surgery beds, cardiologists, cardiovascular surgeons, and physicians of X-ray endovascular diagnosis and treatment, as well as PCI procedures, merits separate consideration.

Notwithstanding the existence of a number of foreign studies indicating a correlation between the availability of cardiologists in outpatient clinics [19, 20] and hospitals [21, 22], Russian authors hold the opposing view that there is no association between the availability of beds and cardiologists and standardized CSD mortality rates across the regions of the Russian Federation. The Russian authors posit that the elevated CSD mortality rates in the Russian Federation relative to European countries are attributable to inadequate bed utilization and staffing efficiency in the Russian Federation [8]. Meanwhile, the primary factor influencing improved clinical outcomes for cardiovascular disorders is the workload of medical personnel, rather than the quantitative indices of healthcare professional accessibility [23]. Our findings corroborate those of two prominent Russian cardiology centers – the National Medical Research Center of Cardiology and the Almazov National Medical Research Center – which have previously demonstrated that there is no correlation between the availability of beds and cardiologists in the Russian Federation.

With regard to the question of the impact of PCI in patients with stable angina pectoris on mortality from CAD, the COURAGE study, which included 2,287 patients with stable angina, has provided definitive answers. It demonstrated that PCI, when performed in conjunction with the administration of the best possible medical therapy, did not result in a reduction in mortality, the incidence of non-fatal MI or other cardiovascular complications when compared with medical therapy alone [24]. The results of the COURAGE study made it possible to reconsider approaches to the medical care provided to patients with stable CAD, leading to a reduction of over 60% in the number of coronary artery stenting procedures and in the overall need for cardiac surgery among the population. In consideration of the aforementioned, the lack of correlation between the availability of PCI procedures for patients with stable angina pectoris and mortality from CAD appears to be a reasonable finding.

At the same time, there is a substantial scientific and practical interest in the absence of an impact of the availability of PCI for ACS on CAD mortality. This is despite the fact that we established the relationship between this indicator and the number of beds in RVCs and PVDs, that is in the facilities where these procedures are performed. In our view, this can be explained by three factors. The time factor is of paramount importance in reducing mortality from ACS. The deployment of a network of RVCs and PVDs serves to bring this type of medical care as close as possible to the patient, thereby helping to minimize time losses and thus reducing mortality. If we estimate the total number of PCI procedures performed for ACS, it becomes evident that, unfortunately, in our country, a disappointingly low number of patients with ST-segment elevation ACS are hospitalized within the optimal time frame of less than two hours from the onset of a pain attack. According to the Monitoring of Measures to Reduce Mortality from CAD in the Russian Federation, the percentage of such patients was only 25.5% in 2021.

This considerably restricts the influence of PCI on the clinical outcomes of the disease. Another factor that presumably affects CAD mortality is the coding of types of medical care. Due to the peculiarities of financing, part of elective surgeries in patients with stable angina pectoris are documented as interventions in ACS. This undoubtedly has an impact on the objective analysis of information. The third factor is the assumption that acute forms of CAD contribute insignificantly to the overall mortality from CAD. This is due to the particularities of the manner in which causes of death are coded in our country [25–27], which precludes the identification of statistical dependencies between the number of PCI procedures in ACS and mortality from CAD.

Conclusion

The results of our study indicate that the most promising avenues for concentrating healthcare resources with the objective of reducing mortality from coronary artery disease in the shortest possible time are the further expansion of a network of regional vascular centers and primary vascular departments, coupled with an increase in the number of coronary artery bypass grafting procedures conducted.

Funding

No funding was received for this study.

No conflict of interest is reported.

The article was received on 20/05/2023

ISSN 0022-9040. Kardiologiia. 2024;64(6). DOI: 10.18087/cardio.2024.6.n2490

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ISSN 0022-9040. Kardiologiia. 2024;64(6). DOI: 10.18087/cardio.2024.6.n2490