Transformation of Cardiac Intensive Care Wards Into Cardiac Resuscitation Department. The Five-year Evolution

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ABSTRACT The article highlights the key elements and results of the restructuring of emergency care for patients with acute myocardial infarction, the core of which is the teamwork of surgeons, anesthesiologist-intensivists and cardiologists of the department. The restructuring included a change in ideology, personnel changes, updating and expanding the range of equipment, development of inner protocols and their implementation. It took two years to transform the intensive care unit for patients with acute myocardial infarction into the cardiac intensive care unit, where patients with acute cardiac pathologies of various etiologies are treated and preoperative preparation and postoperative nursing are carried out.

Keywords: quality management of medical care, acute myocardial infarction, intensive care unit, cardiogenic shock

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AMI – acute myocardial infarction
CAG – coronary angiography
CICU – Cardiac Intensive Care Unit
CPR – cardiopulmonary resuscitation
ECG – electrocardiogram
ECH – Emergency Care Hospital
ECMO – Extracorporeal Membrane Oxygenation
IABP – intra-aortic balloon counterpulsation
ICU – intensive care unit
MCS – mechanical circulatory support
MIH – myocardial infarction in history

NSTEMI – non-ST-elevation myocardial infarction
PCI – percutaneous coronary intervention
RUSH – Rapid Ultrasound for Shock and Hypotension
SCAI – Society for Cardiovascular Angiography and Interventions
STEMI – ST-elevation myocardial infarction
TLT – thrombolytic therapy
VA-ECMO – veno-arterial extracorporeal membrane oxygenation
VF – ventricular fibrillation

INTRODUCTION

Departments of coronary care were established in the early 1960s with the tasks of continuous monitoring of electrocardiograms (ECG) in patients with acute myocardial infarction (AMI) and timely defibrillation if necessary [1]. Subsequently, the structure of these departments continuously changed [2]. Since 2010, a cardiocluster has been operating at the Emergency Care Hospital (ECH) in Naberezhnye Chelny. It successfully solves the problems of coronary heart disease, acquired defects of the heart and great vessels at the initial stage. However, later we faced an increase in hospital mortality from heart disease. And, by combining modern technologies in medicine, the principles of quality management in the provision of medical care, in 2018 the work of the cardiocluster was reorganized. The intensive care unit became the core of the transformation.

The purpose and aims of the study: to show administrative and structural changes, as well as shifts in clinical approaches; to summarize the results of the transformation of the intensive care unit for patients with myocardial infarction into a cardiac intensive care unit as part of the cardiocluster of the ECH in Naberezhnye Chelny.

MATERIAL AND METHODS

ECH is a large multidisciplinary institution that began its history in 1978. In 2009–2010 a deep reconstruction of the building and equipment was carried out. With the new infrastructure, new technologies also came to the hospital. Since 2010, a cardiocluster has been operating at the ECH, consisting of the following departments: Cardiology with an intensive care unit, Vascular and Cardiac Surgery, and X-ray Endovascular Diagnostics and Treatment. The data for the publication are taken from the reporting documents and the internal registry of the Cardiac Intensive Care Unit.

Faced with an increase in hospital mortality (Fig. 1) due to AMI, the ECH's administration made the following organizational decisions:

1. The intensive care unit was transformed into a cardiac intensive care unit.

2. An anesthesiologist-resuscitator with experience in intensive cardiology and cardiac surgery was appointed as the head of the unit. The following interventions were carried out within the unit:

a) training of doctors and nurses in advanced hemodynamic monitoring (cardiac output, intracavitary pressures in the heart chambers);

b) wider use of respiratory therapy modalities in addition to invasive mechanical ventilation: non-invasive mask ventilation, high-flow oxygen therapy, etc.;

c) training of personnel and the formation of a protocol for the management of the difficult airway;

d) teaching the basics of cardiopulmonary bypass and assisted circulation; and the use of methods of mechanical circulatory support in patients with cardiogenic shock. At the facilities of the Federal State Budgetary Institute «The Nikiforov Russian Center of Emergency and Radiation Medicine» of the Ministry of Russian Federation for Civil Defense, Emergencies and Elimination of Consequences of Natural Disasters (Saint Petersburg), and the E.Meshalkin National Medical Research Center of the Ministry of Health of Russian Federation (Novosibirsk), 60% of the medical team were trained in extracorporeal membrane oxygenation (ECMO);

e) training of personnel in work with renal replacement therapy;

f) training of personnel in the basics of diagnostic ultrasound. Since January 2022, the Cardiac Intensive Care Unit has been equipped with an ultrasound machine (Mindray MX7Expert). Part of the Unit's doctors took advanced courses "Ultrasound technologies in anesthesiology and resuscitation" on the basis of the S. M. Kirov Military Medical Academy (Saint Petersburg). The introduction of the Rapid Ultrasound for Shock and Hypotension (RUSH) protocol into practice accelerated the diagnosis of life-threatening pathologies (aortic dissection, cardiac tamponade, etc.), as well as ultrasound navigation during catheterization of arterial and venous vessels and ultrasound diagnosis of the lungs (early signs of pulmonary edema, hydro/pneumothorax).

3. A registry of the Cardiac Intensive Care Unit was developed and introduced into everyday practice in the mid-2018, and on its basis the Unit's activities are analyzed. The registry takes into account anthropometric data, data on current and concomitant pathology, treatment methods (coronary angiography - CAG, percutaneous coronary intervention - PCI, thrombolytic therapy - TLT, open heart surgery, intensive care methods, time intervals, mortality).

Fig. 1. Dynamics of mortality and the number of patients with AMI

Figure 1 shows the dynamics of mortality and the number of patients with AMI. There is a steady increase in the number of patients with AMI, mortality ranges from 4.2 to 8.3%.

Until 2018, patients with AMI were admitted to the ECH in Naberezhnye Chelny, since 2018 the proportion of patients with decompensated chronic heart failure and acute aortic syndrome has increased. In response to this, the areas of work of the cardiocluster were formed:
- Patient with AMI with or without ST elevation.
- Patient with cardiogenic shock on the background of AMI.
- Patient with decompensated chronic heart failure.
- Patient-candidate for open heart surgery and/or with acute aortic syndrome.
- Patient after open heart surgery.

Since 2020, an alert system – the Code Blue – has been implemented, in order to warn about a patient with circulatory arrest outside the Intensive Care Unit. In the ECH, patients from several departments were "attached" to the Cardiac Intensive Care Unit, including patients of three departments of cardiology. An alert system for warning about a patient with circulatory arrest was created in the Cardiology department. With its introduction, the time of arrival of the resuscitation team was reduced to 1.5–2 minutes, depending on the floor (the ECH building has 11 floors).

Statistics. The data are presented as absolute values (number n) and percentages. Normally distributed data are presented as arithmetic mean and standard deviation, non-normally distributed data are presented as median, 25th and 75th percentiles.

RESULTS

As a result of organizational changes carried out in the ECH, a new team of doctors and nurses was formed in the Cardiac Intensive Care Unit within 10–14 months. The medical staff was renewed by 60%, the staff of nurses - by 45%. The renewal of the team was not an end in itself and proceeded naturally as the concept of work in the department changed. Since cardiologists traditionally worked in the intensive care unit for patients with myocardial infarction, an important organizational stage was the change in the status of the department: its transfer to the category of resuscitation and intensive therapy, which immediately attracted young doctors with a certificate of the anesthesiologist-resuscitator.

Table 1 shows the results of monitoring the work of the emergency team. In 2020, the team was activated 38 times, in 28 patients (74%) cardiac activity was restored as a result of cardiopulmonary resuscitation, hospital mortality among those patients was 36%. In 2021 and 2022 recovery of cardiac activity was achieved in 70% of patients with hospital mortality of 56% and 44%, respectively.

Table 1
The results of the Blue Code team's work

	2020	2021	2022
Number of patients	38	46	23
Proportion of patients with restored cardiac activity	28 (74%)	32 (70%)	16 (70%)
Hospital mortality in patients with restored cardiac activity	10 (36%)	18 (56%)	7 (44%)

3

Figure 2 shows the dynamics of PCI, CAG and open heart surgery (cardiac surgery). From 2014 to 2018, from 1711 to 2019 CAG, from 691 to 969 PCI, from 240 to 318 open heart surgeries were annually performed at the ECH.
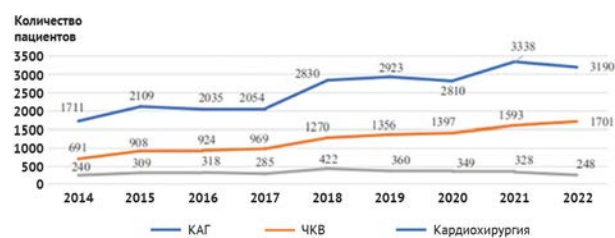

Fig. 2. Cardiac research and surgery
Notes: КАГ — coronary angiography; ЧКВ — percutaneous coronary intervention with stent implantation; кардиохирургия — all open heart surgeries

After 2018, there has been an increase in the number of CAG and PCI performed (2830–3338 and 1270–1701, respectively). The decrease in the volume of cardiac surgical care from 422 to 328 for the full 12 months of each year and for 10 months of 2022 (248 open heart interventions performed) is associated with the formation of a government task.

Since 2019, 42 transfemoral aortic valve implantations have been performed (6 of them were performed during circulatory support), and one endovascular mitral valve replacement using "valve-in-valve" technique.

ACUTE MYOCARDIAL INFARCTION

Two-thirds of patients admitted to the Cardiac Intensive Care Unit are diagnosed with AMI. Since the Unit registry was created in 2018 and the data began to arrive closer to the middle of that year, the absolute values of 2018 indicators are noticeably lower.

As can be seen from Table 2, there were 3819 patients with ST-segment elevation AMI (STEMI) in the study period, 69% of them were men, mean age 64±12 years. 30% of patients were over 70 years of age. The median time from the onset of pain to reperfusion (primary PCI or thrombolytic therapy) was 36 minutes (18–108 min); 29% of patients were admitted to the ECH within the first 2 hours of the onset of STEMI; 28% of patients received reperfusion therapy within the first 2 hours from the onset of the disease; 3002 patients underwent PCI during the period of treatment in the Cardiac Intensive Care Unit. In this group, 378 patients (10%) developed cardiogenic shock within the first 24 hours of admission. A detailed description of patients with cardiogenic shock against the background of AMI is presented below in the same section.

Table 2

Characteristics of patients with an acute ST-elevation myocardial infarction

	Years					Total
	2018	2019	2020	2021	2022	
Patients, n	676	738	819	791	795	3819
Males, n (%)	469 (69)	506 (69)	558 (68)	553 (70)	553 (70)	2639 (69)
Mean age, years	63	63	64	64	64	64±12
Patients over 70 years old, n (%)	176 (26)	228 (31)	254 (31)	246 (31)	248 (31)	1152 (30)
Pain-to-Balloon Time, min (median, 25th and 75th percentiles)	48 (18–186)	42 (18–168)	42 (24–108)	36 (18–86)	30 (18–60)	36 (18–108)
Proportion of patients admitted to the ECH during the first 2 hours of AMI, %	27	31	26	29	30	29
Proportion of patients received reperfusion in the first 2 hours of AMI, %	27	34	23	26	32	28
PCI, n (%)	498 (74)	571 (77)	640 (78)	633 (80)	660 (83)	3002 (79)
Cardiogenic shock in the first 24 hours, n (%)	70 (10)	68 (9)	64 (8)	83 (10)	93 (12)	378 (10)

Notes: ECH – the Emergency Care Hospital; AMI — acute myocardial infarction; PCI - percutaneous coronary intervention with stent implantation

On a yearly comparative basis, a stable value of the proportion of men is noted (69–70%), the mean age of patients is 63 years, the proportion of patients over 70 years is in the range of 26–31% from year to year. In 2018, the proportion of patients over 70 years of age was 26%, which is probably due to the start of the registry only from the middle of the year.

It is worth mentioning the reduction in the "Pain-to-Balloon Time" indicator from 48 minutes in 2018 to 30-36 minutes in 2021-2022; increase in the number of PCIs from 498 in 2108 (incomplete data) to 660 in 10 months of 2022.

As can be seen from Table 3, in the study period, there were 4073 patients with AMI without ST segment elevation, of which 61% were men, mean age 67±12 years. Age over 70 years was in 30% of patients. The median time from the onset of pain to reperfusion (primary PCI) was 10 hours (4–14), 26% of patients were admitted to the ECH within the first 2 hours from the onset of non-ST-elevation myocardial infarction (NSTEMI), and 23% of patients received reperfusion therapy within the first 2 hours from the onset of the disease. 1074 patients underwent PCI during the hospitalization period. In this group, 1.5% of patients developed cardiogenic shock within the first 24 hours of admission.

Table 3

Characteristics of patients with a non-ST segment elevation acute myocardial infarction

	Years					Total
	2018	2019	2020	2021	2022	
Patients, n	792	974	789	817	701	4073
Males, n (%)	469 (59)	613 (63)	469 (59)	487 (60)	429 (61)	2467 (61)
Mean age, years	66	67	68	68	67	67±12
Patients over 70 years old, n (%)	289 (36)	382 (39)	356 (45)	358 (44)	315 (45)	1700 (42)
Pain-to-Balloon Time, hour (median, 25th and 75th percentiles)	9 (5–23)	9 (6–21)	9 (7–21)	9,2 (4–15)	9,2 (2–13)	10 (4–14)
Proportion of patients admitted to the ECH during the first 2 hours of AMI, %	24	28	31	21	24	26
Proportion of patients received reperfusion in the first 2 hours of AMI, %	29	27	19	21	21	23
PCI, n (%)	139 (18)	193 (20)	186 (24)	246 (30)	310 (44)	1074 (26)
Cardiogenic shock in the first 24 hours, n (%)	17 (2,1)	9 (0,9)	11 (1,4)	11 (1,3)	13 (1,9)	61 (1,5)

Notes: ECH - Emergency Care Hospital; AMI − acute myocardial infarction; PCI - percutaneous coronary intervention with stent implantation

The ratio of patients with STEMI and patients with NSTEMI is stable during 2018-2022, being in the range of 48-52%.

PATIENTS WITH CARDIOGENIC SHOCK SECONDARY TO ACUTE MYOCARDIAL INFARCTION

Efforts were made to timely identification of cardiogenic shock and its early relief. Shock secondary to AMI was considered cardiogenic if it met the following criteria:
1. Shock developed within the first 24 hours from the onset of AMI.
2. Criteria for cardiogenic shock [3, 4].
a) systolic blood pressure less than 90 mm Hg with normovolemia;
b) clinical signs of hypoperfusion: cold skin, oliguria, low pulse pressure, impaired mental status;
c) laboratory signs of hypoperfusion: metabolic acidosis, blood lactate more than 2 mmol / l, blood creatinine level above the norm or the baseline of the patient.

Table 4 shows the demographic characteristics of patients with cardiogenic shock. In total, since 2018, the incidence of cardiogenic shock among patients with AMI was 5.6% (439 patients), the survival rate among patients with cardiogenic shock was 47%. The mean age of the survivors was 63±11 years, the deceased was 70±11.5 years. In the group of survivors, 84% of patients were under 70 years of age, while among those who died, 64% were under 70 years of age. Among the survivors, there were more men (69%), the survivors were less likely to have a history of a heart attack (14% vs. 18%) and type 1 or type 2 diabetes mellitus (19% vs. 23%).Among the survivors, 2% suffered a circulatory arrest at the prehospital stage, among the dead - 5%.The proportion of patients with in-hospital circulatory arrest is 15% and 16% in the group of survivors and deceased. In both groups,

cardiogenic shock developed mainly secondary to STEMI (88% and 85%, respectively). Time markers: the time period from the onset of the pain syndrome to admission to the ECH was 2.8 (1.4–9) hours among the survivors and 4.8 (2.3–16) hours in the group of the deceased, the "Door-Balloon" indicator was 0.5 (0.3–1.2) and 0.5 (0.4–1.5), respectively. There were 23 patients with mechanical complications of AMI, and in 88% of cases they died.

Table 4
Characteristics of patients with cardiogenic shock following acute myocardial infarction

	Total	Survivors	Deceased
Patients, n (%)	439 (5.6)	208 (47)	231 (53)
Age, years	67±12	63±11	70±11.5
Under 75 years, n (%)	322 (73)	175 (84)	147 (64)
Males, n (%)	267 (61)	143 (69)	124 (54)
MIH, n (%)	70 (16)	29 (14)	41 (18)
Diabetes mellitus, n (%)	94 (21)	40 (19)	54 (23)
Prehospital CPR, n (%)	16 (4)	5 (2)	11 (5)
Hospital CPR, n (%)	69 (16)	31 (15)	38 (16)
STEMI, n (%)	379 (86)	183 (88)	196 (85)
NSTEMI, n (%)	60 (14)	25 (12)	35 (15)
AMI duration, h	4 (1.8–11.4)	2.8 (1.4–9)	4.8 (2.3–16)
Door-to-Balloon Time, h	0.5 (0.3–1.3)	0.5 (0.3–1.2)	0.5 (0.4–1.5)
Pain-to-Balloon Time, h	4.8 (2.5–12)	4.2 (2–10)	5.8 (3–16)
Prehospital TLT, n (%)	42 (11)	21 (11)	21 (11)
In-hospital TLT, n (%)	21 (6)	9 (5)	12 (6)
Mechanical complications of AMI, n (%)	26 (6)	3 (12)	23 (88)

Notes: CPR - cardiopulmonary resuscitation; MIH - previous myocardial infarction outside the current hospitalization; AMI − acute myocardial infarction; STEMI - ST-elevation myocardial infarction; NSTEMI - non-ST-elevation myocardial infarction; TLT - thrombolytic therapy, in-hospital - performed during the current hospitalization, prehospital - performed between the onset of the current AMI and before admission to this clinic

Mechanical circulatory support (MCS) was used in 19% (84 patients) of all patients with cardiogenic shock. Venoarterial extracorporeal membrane oxygenation (VA-ECMO) — in 12 patients, intra-aortic balloon counterpulsation (IABP) — 62 patients, in 10 patients IABP and VA-ECMO were used simultaneously or sequentially. Of 62 patients after IABP, 30 (48%) survived, 32 (52%) died; in the VA ECMO group: 4 (33%) and 8 (67%), respectively; among 10 patients who underwent both IABP and VA ECMO, three survived (30%). Survival of patients with MCS was 44% (37 patients).

Table 5
The use of mechanical circulatory support methods in patients with cardiogenic shock in the presence of acute myocardial infarction

	Total	Survivors	Deceased
IABP, n (%)	62 (66% from all MCS)	30 (48)	32 (52)
VA ECMO, n (%)	12 13% from all MCS	4 (33)	8 (67)
VA ECMO+ IABP, n (%)	10 (11% from all MCS)	3 (30)	7 (70)
Number of patients who died during the first day of hospitalization, n (%)	138 (60)		
Duration of treatment in the ICU, h	33 (5–74)	47	33

Notes: IABP − intra-aortic balloon counterpulsation; VA ECMO − venoarterial extracorporeal membrane oxygenation; ICU- intensive care unit; MCS - mechanical circulatory support

Figure 3 shows the annual dynamics of utilizing VA ECMO: as the number of patients with VA ECMO increases, so does the survival rate. And if in 2018-2019 the survival rate was 0%, then in 2022 it was already 50%, which is explained both by the increase in experience and the earlier use of this type of therapy.
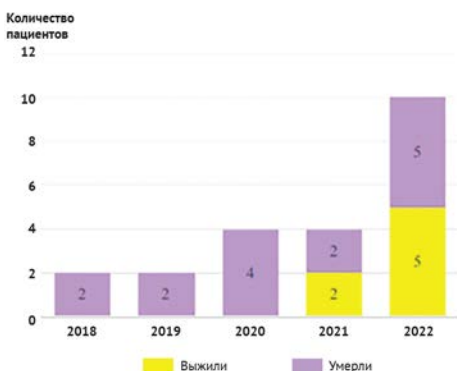

Fig. 3. Use of venoarterial extracorporeal membrane oxygenation in patients with cardiogenic shock following acute myocardial infarction

Mechanical complications of AMI occur in approximately 13% of all patients with cardiogenic shock [5] and are accompanied by extremely high mortality. The radical method of their treatment is open-heart surgery or endovascular closure of ventricular septal defects. In patients with papillary muscle rupture of the mitral valve, it is possible to reduce mortality up to 25-40%, and in patients with post-infarction ventricular septal defect - up to 40-50%. However, before surgical correction of such complications, it is necessary to stop all manifestations of cardiogenic shock, and the most effective approach is MCS. Of 26 patients with mechanical complications of AMI, three survived (Table 4).

DISCUSSION

D.G. Julian describes [1]: In the early 1960s, coronary care units were created, which solved the problem of ventricular fibrillation (VF) following AMI by means of round-the-clock monitoring of the electrocardiogram and the round-the-clock presence of personnel trained to recognize VF and perform cardioversion. By the 1980s, it became clear that the main cause of death in these patients was not VF, but ventricular (pumping, authors' note) failure [1].

And later on, the tasks facing these departments expanded: there were patients with terminal heart failure and patients who survived deep circulatory shock. As a result, these departments became known as the "cardiac intensive care unit" (CICU), where the entire arsenal of methods and principles of intensive care were applied. In Russian there are two terms "intensive care" and "resuscitation". Closer to the English-language CICU is our term "cardioresuscitation".

Borja Ibanez et al. recommend: the staff of cardiac intensive care units should be well trained in the treatment of ACS, arrhythmias, heart failure, the use of mechanical means of circulatory support, be proficient in the methods of hemodynamic, respiratory monitoring, mechanical ventilation and control of the patient's body temperature. The department should also be prepared to treat patients with severe pulmonary and renal pathologies [3].

For these reasons, the evolution of our Cardiac Intensive Care Unit was quite logical, and these changes unlocked the potential of endovascular and open cardiac surgery. Patients from the "Chest Pain" group are admitted to the ECH and, in addition to AMI, they are admitted with diseases such as aortic dissection, pulmonary embolism, and acquired heart valve defects. The alertness of the staff to acute cardiac pathology, the round-the-clock availability of computed tomography, diagnostic ultrasound and the department of X-ray endovascular research methods help make a diagnosis in the shortest possible time. This approach allows surgeons to perform annual coronary artery bypass grafting on 30–40 patients with AMI, 20–25 patients with DeBakey type 1 and 2 aortic dissection.

While in emergency situations decisions are made by the doctor individually, after reducing the severity of symptoms, a team discussion of strategies and stages of treatment is necessary. T. Bochaton et al. [6] recommend

a structured multidisciplinary approach to discussing treatment tactics, which is coordinated by the cardiac intensive care physician.

Since 2018, due to the training of medical personnel in the field of invasive monitoring (central venous pressure, pulmonary artery pressure, pulmonary artery wedge pressure, cardiac output) in shock, management of lung ventilation, renal replacement therapy, ultrasound-based navigation and diagnosis, the proportion of patients undergoing IABP and ECMO has increased.

The ranking of patients into groups based on the SCAI (Society for Cardiovascular Angiography and Interventions) classification system for cardiogenic shock played a significant role [7, 8]. Jacob C. Jentzer et al. in their study [7] ranked 10,004 patients according to the stages of shock and showed that as the group of cardiogenic shock changes from group A to group E, the severity of multiple organ failure, the aggressiveness of treatment methods, the number of patients with MCS, and ultimately the mortality, increase - from 3% to 67% respectively. In the conditions of the Naberezhnye Chelny ECH, on the basis of the existing laboratory base, a round-the-clock ultrasound machine using the RUSH protocol by resuscitators, invasive hemodynamic monitoring and SCAI classification of cardiogenic shock, it became possible to stop its progression at stages B–C: in 2022, 10 patients underwent VA ECMO with 50% survival rate. And if in 2021 in the Cardiac Intensive Care Unit the mortality rate from cardiogenic shock was 57%, then in 2022 it was at the level of 42%.

CONCLUSION

Thanks to teamwork and quality management of medical care, we discovered an increase in in-hospital mortality and in 2018 began the restructuring of the cardiocluster. Changes in organizational approaches to the management of patients with severe cardiac pathology, understanding of common goals and objectives in a short time led to an expansion of the types of care provided, an increase in the range of interventions in the cardiovascular system and in the survival rate of patients with acute myocardial infarction.

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