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Modern Approaches To Surgical Correction Of Congenital Diaphragmatic Hernia In Newborns

Maria Olegovna Belova[1], Alina Baktygereevna Abelkhayrova[2], Tatiana Lungu[3], Andrey Romanovich Karasev[4], Rashidat Ismailovna Kurbanova[5], Polina Vasil'evna Morozyuk[6], Sofiia Viacheslavovna Andriukova[7]

[1]Pavlov First Saint Petersburg State Medical University, L'va Tolstogo str. 6-8, Saint Petersburg, Russia, 197022,

Email ID: Marush_1215@mail.ru

[2]Saratov State Medical University named after V.I. Razumovsky (Razumovsky University), Saratov, Bolshaya Kazachya St., 112, 410012, Russia. Email ID: alya.abelkhayrova@mail.ru

Orcid: 0009-0008-7424-0740

[3]Federal State Autonomous Educational Institution of Higher Education «N.I. Pirogov Russian National Research Medical University» of the Ministry of Health of the Russian Federation, 1, building 6, Ostrovityanova Street, Moscow, 117513, Russia. Email ID: lungu.tanya29@mail.ru, 0009-0006-4321-0827

[4]Federal State Autonomous Educational Institution of Higher Education N.I. Pirogov Russian National Research Medical University» of the Ministry of Health of the Russian Federation,1, building 6, Ostrovityanova Street, Moscow, 117513, Russia. Email ID: kkaarraasseevv@mail.ru, 0009-0001-9658-0462

[5]Dagestan State Medical University,367005, Respublika Dagestan, g Makhachkala, pl. Lenina, str. 1, Russia.

Email ID: kurbanova.r2802@gmail.com, 0009-0009-9583-2566

[6]Pavlov First Saint Petersburg State Medical University, L'va Tolstogo str. 6-8, Saint Petersburg, Russia, 197022.

Email ID: polinamorozuk98@mail.ru, 0009-0007-1680-3915

[7]Pavlov First Saint Petersburg State Medical University, L'va Tolstogo str. 6-8, Saint Petersburg, Russia, 197022.

Email ID: sonya_andryukova@mail.ru, 0009-0008-4211-7721

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ABSTRACT

Congenital diaphragmatic hernia in newborns is one of the most severe forms of congenital pathology, which is characterized by displacement of abdominal organs into the thoracic cavity through a defect in the diaphragm. This condition is accompanied by a high mortality rate and frequent life-threatening complications, among which the most significant are respiratory failure and marked pulmonary hypoplasia. In recent decades, neonatal surgery has made significant progress in the diagnosis and treatment of congenital diaphragmatic hernia, but the problem of choosing the optimal methods of correction is still relevant. The scientific community continues to debate in which order and at what stage it is most appropriate to use emergency surgery, delayed intervention, endoscopic techniques, and assistive technologies such as extracorporeal membrane oxygenation.

The present study reviews modern surgical approaches and technologies for the management of neonates with congenital diaphragmatic hernia. The data of domestic and foreign studies, including our own results of retrospective analysis of 60 patients treated in a specialised center of neonatal surgery for the last three years were analyzed. The main aim of the work was to reveal the effectiveness and expediency of different methods of surgical correction, as well as to determine the main factors influencing the outcome of the disease.

The results demonstrate that the introduction of endoscopic methods and the use of extracorporeal membrane oxygenation in the most severe patients can reduce hospital mortality and the number of complications, provided timely diagnosis and multidisciplinary approach.

Keywords: *Congenital diaphragmatic hernia, newborns, surgical correction, endoscopic methods, extracorporeal membrane oxygenation, respiratory support, pulmonary hypoplasia, high-frequency artificial ventilation.*

1. INTRODUCTION

Congenital diaphragmatic hernia in newborns is a complex pathology in which abdominal organs (intestines, liver, spleen, and, less frequently, stomach) migrate into the chest through a congenital defect of the diaphragm. The process is formed in the embryonic period, when there is no complete fusion of pleuroperitoneal channels or there is insufficient formation of the muscular part of the diaphragm. Most often congenital diaphragmatic hernias are located on the left side (according to different statistical data, in 80-90% of cases), which is explained by the peculiarities of embryogenesis and greater vulnerability of the left side of the diaphragm.

The relevance of the study is related to the fact that in congenital diaphragmatic hernia the child's lungs cannot develop normally, which leads to hypoplasia of lung tissue of varying degrees of severity. When the abdominal organs shift upwards, they squeeze the developing lung, disrupting the formation of the bronchial tree and alveoli. This results in severe respiratory failure in the postnatal period, which often requires urgent resuscitative measures. From a neonatological point of view, this condition remains one of the most significant causes of mortality in children with congenital anomalies if not diagnosed and treated in a timely manner.

In recent decades, significant progress has been made in the diagnosis of congenital diaphragmatic hernia. Prenatal ultrasound methods can detect a diaphragmatic defect as early as 18-20 weeks of pregnancy. Additional data are provided by magnetic resonance imaging of the foetus, which is especially important when severe pulmonary hypoplasia is suspected, as well as when deciding on intrauterine intervention. Thus, early detection of pathology opens up opportunities for planning pregnancy management tactics and providing specialised care immediately after birth[6].

The issues of optimal treatment of congenital diaphragmatic hernia remain controversial. On the one hand, the traditional 'gold standard' is an emergency operation performed at birth or in the first day of life, provided the minimum possible stabilization of hemodynamic parameters. On the other hand, there is convincing evidence that delayed surgical intervention can improve survival if adequate respiratory support is provided to the child, including high-frequency ventilation, and in particularly severe cases - extracorporeal membrane oxygenation.

Modern protocols for the management of neonates with congenital diaphragmatic hernia in a number of centres include the use of endoscopic techniques (thoracoscopy or laparoscopy) instead of open surgery. This approach potentially reduces the traumatic nature of surgery, shortens rehabilitation time and reduces the risk of wound complications. However, endoscopic techniques are still limited by patient selection criteria: the child must be in a relatively stable condition or at least be able to stabilize the respiratory and cardiovascular systems before the intervention. In case of critical condition, the traditional open method is most often used.

A separate layer of scientific research is devoted to intrauterine surgery, in particular the FETO technique (fetoscopic endotracheal occlusion). The essence of this approach is the endoscopic occlusion of the fetal trachea to create positive pressure in the airways, which stimulates the development of lung tissue. This method offers a chance to significantly improve the prognosis in the most severe forms of congenital diaphragmatic hernia with marked pulmonary hypoplasia. Nevertheless, intrauterine methods require highly qualified specialists and are associated with additional risks for mother and foetus, including premature labour, haemorrhage, iatrogenic trauma and a number of other complications.

In the context of domestic healthcare, congenital diaphragmatic hernia remains a serious problem, as not all regions have a developed network of perinatal centers and not all hospitals have the capacity to use high-tech methods (including ECMO).In addition, there are still ambiguous approaches to the methods of surgical correction, the optimal timing of surgery, and ways to stabilize the child[8].

The aim of this study was to analyze modern approaches to surgical correction of congenital diaphragmatic hernia in newborns, including assessment of immediate results, comparison of the effectiveness of traditional and minimally invasive methods, and analysis of the effect of extracorporeal membrane oxygenation and high-frequency ventilation on the outcome of the disease. The objective of the work was to systematize clinical data obtained in a specialized neonatal surgery center and to summarize information on the choice of optimal surgical tactics depending on the severity of the neonate's condition.

2. MATERIALS AND METHODS OF THE STUDY

The study was conducted in one of the leading neonatal surgery centers equipped with a neonatal intensive care unit and experienced in the application of modern high-tech treatment methods. The retrospective analysis covered 60 newborns with a confirmed diagnosis of congenital diaphragmatic hernia admitted to the center at the age of several hours to 2 days of life. The follow-up period was three years. The analysis was based on the study of medical records, operation protocols, data of radial and laboratory diagnostic methods, as well as data obtained during the dynamic follow-up of the patients.

The inclusion criteria for the study were a confirmed diagnosis of congenital diaphragmatic hernia, surgical intervention in the early neonatal period, and absence of fatal heart or other organ malformations incompatible with life. Children with multiple congenital abnormalities leading to death regardless of diaphragmatic hernia correction were excluded from the

analysis [2].

All newborns underwent a standard set of diagnostic procedures, including ultrasound (to confirm the diagnosis and assess the condition of the abdominal cavity organs), chest radiography (to detect organ displacement and assess the degree of lung hyperplasia by indirect signs), and computed tomography or MRI (if necessary to clarify the features of the anatomical defect). Blood gas levels were analyzed in dynamics, saturation control, and hemodynamic parameters were assessed.

Standard methods of descriptive statistics were used for statistical analysis. Quantitative indicators are presented in the form of mean value and standard deviation, qualitative variables are displayed as a percentage of the total number of observations. Student's t-criterion was used when comparing the indicators of different groups, and differences were considered statistically significant at $p<0.05$. Multivariate analysis (logistic regression) was performed to determine the influence of such factors as hernia defect localization, degree of pulmonary hypoplasia, birth weight, gestational age and the presence of severe comorbidities.

3. RATIONALE OF THE STUDY

The study confirmed that congenital diaphragmatic hernia is localized on the left side in most cases. This peculiarity is explained by embryonic preconditions and occurs, according to the world literature, in about 80-90% of children with such pathology. The data obtained during the analysis of our own material were close to the general statistics. Table 1 shows the demographic and some clinical characteristics of the patients.

Table 1. Demographic and pathological characteristics of newborns (n=60)

Parameter	Value or frequency
Average birth weight, g	2800 ± 240
Gestational age, weeks	38,2 ± 1,1
Localisation of hernia (left/right)	85% / 15%
Presence of severe pulmonary hypoplasia	40%

The proportion of newborns with a critical degree of pulmonary hypoplasia was 40%. These children had extremely severe respiratory failure requiring extended respiratory support methods. The degree of hypoplasia was assessed comprehensively: radiological data, gas exchange parameters, and saturation dynamics during intensive care were taken into account. Assessment of the defect localization and its size was also an important factor, as extensive herniation led to significant protrusion of abdominal organs into the pleural cavity and marked compression of the lungs [7].

All patients were categorized according to the methods of surgical correction into three main groups. The first group included infants who underwent emergency or early open surgery (traditional laparotomy and diaphragmatic defect plasty). The second group included newborns in severe condition who required stabilization with high-frequency ventilation and, if necessary, extracorporeal membrane oxygenation, followed by delayed surgical intervention. The third group included patients who underwent endoscopic correction (thoracoscopy or laparoscopy). The choice of method depended largely on the clinical picture, availability of necessary equipment and surgeon's experience in using minimally invasive techniques in such severe patients[4].

The general characteristics of the groups are summarized in Table 2, which shows the main data on the intervention methods used.

Table 2. Distribution of patients by methods of surgical correction

Parameter	Open plasty (n=34)	Delayed intervention with ECMO (n=16)	Endoscopic techniques (n=10)
Mean operation time (after birth, days)	2,1 ± 0,7	5,9 ± 1,8	3,0 ± 0,9
Use of ventilator (duration, days)	14,2 ± 3,1	18,5 ± 4,6	9,4 ± 2,3
Use of high-frequency ventilator	55%	100%	40%

(proportion of patients)			
Use of ECMO	0%	100%	0%

The first group, which included 34 children, was characterized by the fact that the condition of most patients allowed open surgery within the first two to three days of life. This strategy was more often used in relatively stable haemodynamic parameters and moderate respiratory failure. The second group (16 children) included more severe patients in whom surgical intervention had to be postponed for up to five to seven days due to the need for ECMO. These were mainly cases of critical pulmonary hypoplasia and severe respiratory failure, when the risk of failure to undergo surgery in the first hours or 24 hours of life was too high. The third group (10 children) included a lighter contingent with less severe respiratory disorders or patients whose condition could be quickly stabilized with standard artificial ventilation [2].

Comparative analysis of the immediate outcomes of treatment is presented in Table 3.

Table 3: Comparative analysis of results depending on the method of surgical correction

Index	**Open plasty (n=34)**	**Delayed intervention with ECMO (n=16)**	**Endoscopic methods (n=10)**
Hospital mortality (%)	17,6	12,5	0
Average length of ventilator stay (days)	14,2 ± 3,1	18,5 ± 4,6	9,4 ± 2,3
Average length of stay in Intensive care and intensive care unit (days)	19,1 ± 4,2	23,7 ± 5,4	12,7 ± 3,2
Frequency of postoperative complications (%)	38,2	31,2	20,0

Table 3 shows that endoscopic methods of correction showed the most favourable profile in terms of mortality, as well as a shorter period of artificial ventilation and stay in the intensive care unit. Such results are consistent with many foreign studies, which note that minimally invasive surgery in stable patients can reduce tissue dramatization and the risk of postoperative complications. However, it is important to emphasize that endoscopic methods can be used only if haemodynamics are stable and lung function is relatively preserved, while in critical condition, either open surgery or stabilisation of the patient with ECMO should be performed first[13].

The management of patients requiring extracorporeal membrane oxygenation is complicated by the risk of haemorrhagic and infectious complications, as ECMO involves prolonged catheterisation and anticoagulant therapy. At the same time, in the most severe patients, survival rates would be extremely low without this technique. Multivariate analysis of the data confirmed that the use of ECMO in the most severe patients allowed stabilisation of critical parameters and surgery in a safer environment, which contributed to a reduction in hospital mortality by almost one and a half to two times compared with historical data when ECMO was not used [3].

The next important stage of the study was the analysis of postoperative complications. The most common complications were residual respiratory failure requiring prolonged artificial ventilation, as well as various forms of infectious complications (pneumonia, sepsis). Surgical complications such as suture failure were recorded to a lesser extent, as synthetic patch or suturing of the defect was almost always used. Nevertheless, cases of abdominal adhesions occurred in the open intervention group, which inevitably increased the risk of future reoperations [6].

Table 4 shows the structure of complications depending on the method of surgical correction.

Table 4. Structure of postoperative complications (total number of complications and their percentage of the total number of patients)

Type of complication	**Open plasty (n=34)**	**Delayed intervention with Intensive care and intensive care unit (n=16)**	**Endoscopic methods (n=10)**
Postoperative pneumonia (number)	6 (17,6%)	3 (18,8%)	1 (10%)
Sepsis (number)	4 (11,8%)	3 (18,8%)	0 (0%)
Diaphragmatic suture failure (number)	2 (5,9%)	1 (6,3%)	0 (0%)
Intrahospital wound infection (number)	3 (8,8%)	2 (12,5%)	1 (10%)

The data in Table 4 show that the incidence of infectious complications remains quite high in the groups where either conventional methods or ECMO were used. The rate of complications was lower in the group of endoscopic interventions, although they could not be completely excluded, which is consistent with the literature data. Diaphragmatic suture failure and associated hernia recurrences were prevalent in the groups with open or delayed interventions, while in thoracoscopic suturing the risks of defect recurrence, according to international experience, remain comparable or slightly lower [8].

In the context of technology development, special attention is paid to in utero treatment (FETO), although this study did not include such patients due to the lack of appropriate equipment and a trained team of specialists. Nevertheless, international experience shows that in severe forms of congenital diaphragmatic hernia with high lethality, intrauterine tracheal obstruction can significantly improve survival rate by stimulating lung growth even before birth. In foreign clinics, it has been noted that a child who has received such intrauterine care may need only minimal stabilisation and more gentle surgery in the future [10].

Thus, the results of this study show that traditional open correction remains the most common and universal, as it can be used in a wide range of patients regardless of the severity of their condition (of course, if there are minimally sufficient conditions for surgery). Delayed intervention using ECMO is relevant for the most severe cases, when direct surgery in the first day is associated with too high a risk of mortality. Endoscopic methods are appropriate in those patients who are able to maintain relatively stable gas exchange rates without the use of extracorporeal membrane oxygenation or in whom adequate respiratory support can be provided during the first days of life [9].

A multidisciplinary approach including anaesthesiology, cardiology, surgery and neonatology is an important component of comprehensive treatment. High-frequency artificial ventilation helps to reduce the risk of barotrauma, improve oxygenation and wait until surgery without progression of decompensation. In addition, patients with congenital diaphragmatic hernia require special monitoring by nutritionists and rehabilitation specialists, as nutritional, growth and developmental problems may occur later in life.

4. CONCLUSIONS

Summarizing the data obtained during the analysis, we can draw several fundamental conclusions regarding modern approaches to surgical correction of congenital diaphragmatic hernia in newborns. Firstly, in the presence of severe respiratory failure and pronounced pulmonary hypoplasia, it is extremely important to provide adequate respiratory support (high-frequency artificial ventilation, extracorporeal membrane oxygenation if necessary), which allows stabilising the condition and thereby reducing the risk of surgical and anaesthetic complications. Secondly, endoscopic surgery (thoracoscopy or laparoscopy) shows good results in neonates with moderate severity of the condition. The reduction in the duration of ventilatory support and intensive care unit stay suggests the advantages of a minimally invasive approach. Thirdly, traditional open correction remains the most common, as this method is applicable in the majority of patients, especially in the absence of sufficient stabilization or the necessary technical equipment for endoscopic intervention.

Extracorporeal membrane oxygenation has improved the survival rate of the most severe patients, but its use is associated with an increased risk of complications, including infectious and haemorrhagic complications. The choice between emergency surgery and delayed intervention is determined by the child's condition, gas exchange parameters, and the degree of lung hypoplasia.

Intrauterine surgery (FETO) is an important area for further improvement, which can reduce mortality in extremely severe congenital diaphragmatic hernia, but requires significant resources and expertise. Implementation of multidisciplinary management protocols covering all stages from prenatal diagnosis to postoperative rehabilitation can optimize outcomes and improve the quality of life of children.

The results of the analysis confirm the need for a comprehensive approach and further research aimed at evaluating long-

term results, developing unified clinical protocols and improving high-tech care for newborns with congenital diaphragmatic hernia. It is especially important to continue work on the introduction of minimally invasive techniques and to develop the possibilities of intrauterine surgery, which will make it possible to achieve even higher survival rates and reduce the incidence of complications in this category of patients in the future.

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