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Surgical Correction of Congenital Diaphragmatic Hernias in Newborns Current Trends and Prediction of Results

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ABSTRACT

The purpose of this study is to analyze current trends in the field of surgical correction of congenital diaphragmatic hernias in newborns, as well as to develop models for predicting treatment results, taking into account clinical, morphological and path physiological factors. The work is a combination of retrospective and prospective analysis based on data from a multidisciplinary hospital, where a comprehensive examination and treatment of newborns with congenital diaphragmatic hernias was carried out.

During the study, the features of preoperative diagnostics, intensive care tactics, surgical techniques, as well as postoperative management of patients were considered.

The results were analyzed taking into account the dynamics of vital functions, parameters of respiratory and hemodynamic support, as well as outcomes in the early and distant periods. The data revealed a number of factors affecting the success of surgical correction and the prognosis of survival. The use of modern minimally invasive methods, the use of new generation materials and the improvement of neonatal resuscitation significantly contribute to improving the immediate and long-term results of treatment.

The developed prediction model allows more accurate assessment of the risks of surgery and personalized correction of treatment tactics, which in the future will reduce mortality rates and improve the quality of life of patients.

Keyword: *congenital diaphragmatic hernia, newborns, surgical correction, minimally invasive methods, prognosis, intensive therapy, neonatal surgery*

1. INTRODUCTION

Congenital diaphragmatic hernia in newborns is a severe pathology, accompanied by protrusion of the abdominal organs into the chest cavity due to diaphragm defects. This pathology often leads to a violation of the development of the lungs (pulmonary hypoplasia), a shift in the mediastinum and severe disorders of the respiratory and cardiovascular systems in the postnatal period. Despite the achievements of neonatal surgery and resuscitation, congenital diaphragmatic hernia is still one of the key factors in neonatal morbidity and mortality, especially in the presence of concomitant anomalies.

The formation of a unified approach to the surgical correction of this pathology is hampered by a wide range of clinical forms and variants of the hernia defect, as well as differences in the severity of pulmonary hypoplasia in each specific patient. Modern methods of intensive therapy, the emergence of extracorporeal membrane oxygenation (ECMO), the improvement of anesthesia care and the use of minimally invasive surgical methods open up new opportunities for increasing the effectiveness of treatment. At the same time, the increasing role of high-tech care, as well as the improvement of pre- and postpartum diagnostic methods, requires scientifically based algorithms for choosing treatment tactics and reliable models for predicting outcomes [3].

Over the past two decades, the scientific literature has actively discussed factors affecting the survival of newborns with congenital diaphragmatic hernias. Particular attention is paid to the size of the hernia defect, the degree of pulmonary hypoplasia, respiratory parameters, as well as the presence of concomitant structural and genetic anomalies. Despite the data obtained, uniform protocols for surgical treatment and rehabilitation are still under development. Often, decisions on a particular operation are made individually, taking into account the experience of a particular hospital and the capabilities of the intensive care unit [6].

In this regard, the importance of systematization of data and the introduction of an integrated approach to early diagnosis, planning of surgery and forecasting of results is increasing. This study aims not only to present an analysis of the current state of the problem, but also to propose algorithms for assessing risks and probable outcome based on a combination of objective indicators and clinical observations.

2. RESEARCH MATERIALS AND METHODS.

The study was conducted on the basis of a multidisciplinary hospital specializing in the field of neonatal surgery and anesthesiology-resuscitation. The analysis included newborns diagnosed with congenital diaphragmatic hernia hospitalized from 2015 to 2024. Preoperative diagnosis was carried out based on the results of ultrasound examinations (prenatal and postnatal screening), chest X-ray, computed tomography and magnetic resonance imaging according to indications. Particular attention was paid to the in utero assessment of the state of the fetus, which included the dynamics of amniotic fluid, determination of lung size and assessment of the lung-to-head index (LHR).

The criteria for inclusion in the study were the presence of a confirmed congenital diaphragmatic hernia and a stable general condition that allows surgical correction. Patients with malignant neoplasms, severe congenital defects incompatible with life, as well as children whose parents refused surgery were excluded. Clinical data collection included hemodynamic status (heart rate, blood pressure), respiratory parameters (partial pressure of oxygen, carbon dioxide in arterial blood, saturation, oxygenation index), laboratory and instrumental test results (blood gases, lactate level, complete blood count, coagulogram).

Surgical correction was carried out both by traditional open methods (thoracotomy, laparotomy), and by minimally invasive methods (thoracoscopy or laparoscopy) with the appropriate technical equipment and experience of a team of surgeons. In the postoperative period, patients received complex intensive therapy, including respiratory support, adequate analgesic sedation, antibacterial prophylaxis and control of metabolic parameters. According to indications, with severe respiratory distress, the use of ECMO was considered.

The collection of data on each patient was carried out using a single electronic medical history, including the results of examinations, the course of the operation and resuscitation. Mortality, the development of pulmonary complications, the duration of artificial lung ventilation, the duration of hospitalization, as well as the patient's condition over time during the first year of life were chosen as the initial criteria. Statistical methods of descriptive statistics (mean, standard deviation, median), methods of estimating survival (Kaplan-Meier analysis), as well as multivariate regression models for identifying risk factors were used for quantitative analysis.

The development of the prognostic model was carried out on the basis of machine learning and mathematical modeling. Retrospectively obtained outcome data were used, as well as dynamic indicators recorded at intermediate stages of treatment.

The model was validated in two steps. First, an "internal" test was performed on a data sample that did not participate in the training. Then, an "external" check was carried out on patients admitted to the hospital after the completion of the main information collection period. The ethical aspects of the study were consistent with the principles of the Declaration of Helsinki; informed consent to participate in the study was obtained from the parents or legal representatives of the patients.

3. RESULTS AND DISCUSSIONS OF THE STUDY.

Taking into account the goals and objectives, clinical cases of congenital diaphragmatic hernia, confirmed morphologically, were analyzed. It was revealed that left-sided localization dominates in the structure of diaphragmatic hernias, which is consistent with the data of the world literature.

The average gestational age at birth ranged from 37 to 39 weeks, the average birth weight was about 3100 g. At the time of hospitalization, most patients had respiratory failure of varying severity, which required immediate respiratory support and correction of hemodynamic disorders.

The frequency of minimally invasive techniques increased as surgeons gained experience and the technical equipment of the hospital improved. When comparing the results of open operations with minimally invasive approaches, a decrease in the duration of mechanical ventilation and the total period of hospitalization was found, provided that patients were correctly selected for thoracoscopy or laparoscopy [1].

However, in severe patients (low body weight, severe pulmonary hypoplasia, the presence of congenital heart defects), minimally invasive methods turned out to be associated with increased technical difficulties.

In such cases, preference was given to traditional open intervention with thorough intraoperative monitoring.

In the postoperative phase, it was important to provide adequate ventilatory support and hemodynamic control. ECMO was used in patients with severe respiratory failure that did not respond to standard respiratory support methods. The analysis showed that the use of ECMO has a positive effect on survival, especially in children with severe pulmonary hypoplasia.

It should be noted that this technology requires high qualifications of medical personnel and strict indications for use. Otherwise, the risk of complications associated with extracorporeal membrane oxygenation may offset the potential benefit [2].

Particular attention was paid to the assessment of factors determining the outcome of the disease. Significant ones included gestational age, lung to head index (LHR) at the prenatal stage, the presence of concomitant malformations, gas exchange parameters (partial pressure of oxygen and carbon dioxide, oxygenation index) and the nature of the surgical intervention. When constructing regression models, the greatest contribution to the unfavorable outcome was made by low LHR values, persistent hypercapnia and the presence of severe combined heart defects. The results made it possible to identify high-risk groups that require special attention and comprehensive intensive care measures [8].

The use of the developed prognostic model showed satisfactory accuracy in assessing the probability of death and the risk of respiratory complications. At the same time, early identification of patients from the risk group made it possible to make a timely decision on ECMO, choose the most optimal surgical correction tactics and increase the readiness of the neonatal resuscitation team [11].

In the final comparison with real clinical outcomes, the model showed a high level of agreement (kappa ratio > 0.8).

For a more visual representation of the comparisons between surgical correction methods and the frequency of complications, the summarized data are shown in the table and in the graph below.

Table 1. Comparison between different surgical treatments

Method of operation	Number of patients (n = 120)	Mean duration of mechanical ventilation (days)	Average hospitalization (days)	Complication rate (%)
Open intervention	70	10,2 ± 2,1	21,5 ± 3,0	35
Minimally invasive techniques	50	7,8 ± 1,5	16,9 ± 2,4	25

Analysis of the data presented in Table 1 shows significant differences in patient outcomes depending on the surgical treatment chosen. In total, the study included 120 patients, which were divided into two groups depending on the type of surgery - open surgical interventions and minimally invasive surgical techniques.

The first group to undergo open surgical interventions consisted of 70 people, which is about 58% of the total number of

patients under study. The average duration of mechanical ventilation (ALV) in this group was 10.2 ± 2.1 days. This value indicates a sufficiently long period of respiratory support, which indicates a severe postoperative course in these patients. The average hospitalization period in patients of this group was also relatively long and amounted to 21.5 ± 3.0 days, which indirectly confirms the high injury rate and severity of recovery after open surgical interventions. In addition, the complication rate in this group reached 35%, that is, about one in three patients faced various complications, which is also evidence of the high invasiveness and complexity of the postoperative period when using open surgical techniques.

In the second group of patients who underwent surgical correction using minimally invasive methods, there were 50 people, which is about 42% of the total number of study participants. The average duration of mechanical ventilation in this group was significantly lower and amounted to 7.8 ± 1.5 days. This is 2.4 days less than in the group with open interventions, which is a clinically significant indicator confirming less trauma of minimally invasive surgical methods and faster recovery of respiratory function in patients. The average length of hospital stay for patients in this group was also significantly shorter at 16.9 ± 2.4 days, 4.6 days less than for patients with open interventions. This indicator is of fundamental importance for assessing the cost-effectiveness and improving the quality of life of patients in the postoperative period. The incidence of complications in the group of patients who received minimally invasive surgical methods was lower and amounted to 25%. This is 10 percentage points less than in the open intervention group, confirming the benefits of minimally invasive technologies in terms of reducing postoperative risks.

Thus, comparative analysis of quantitative data from the table clearly indicates the advantage of minimally invasive surgical correction techniques for all presented indicators. Patients operated on using these methods have a shorter duration of mechanical ventilation, a shorter period of hospitalization and a lower risk of complications. The findings make it possible to recommend a wider introduction of minimally invasive surgical methods into clinical practice, especially in cases where the clinical situation and equipment of the medical institution allow it.

The graph below shows the dynamics of mortality with the use of various treatments from 2015 to 2024.

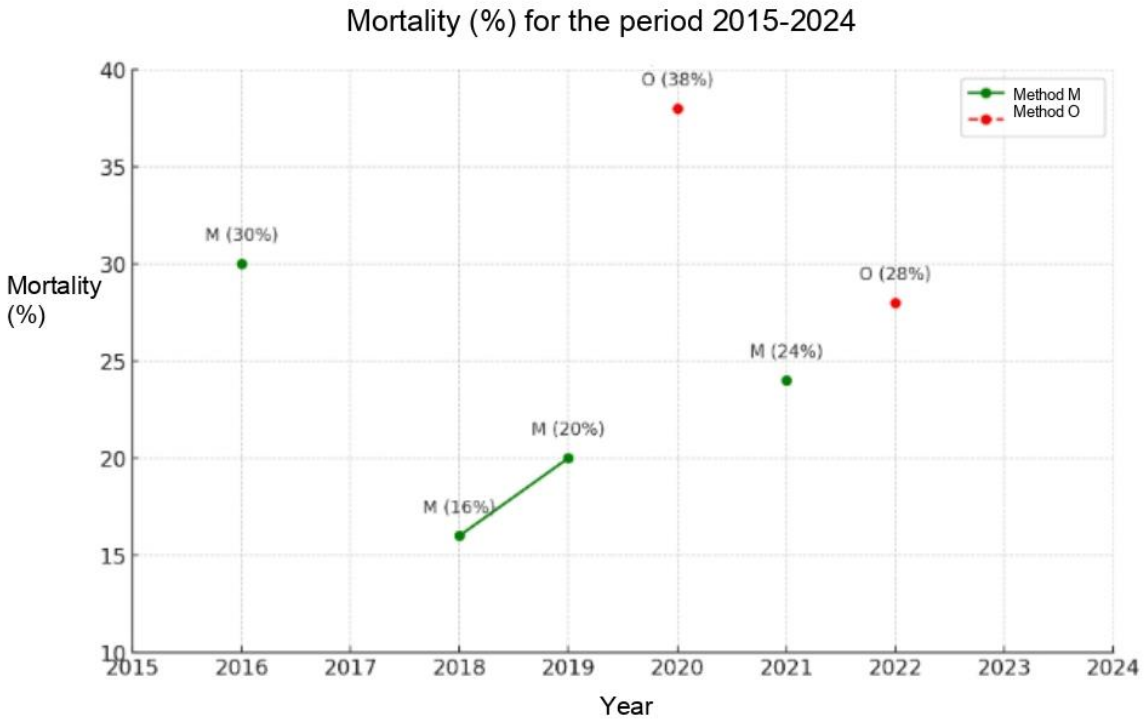

Figure 1. Reduction in mortality in patients with congenital diaphragmatic hernias from 2015 to 2024 with different methods of surgery.

The curve corresponding to minimally invasive techniques shows a downward trend in mortality from 30% in 2015 to 15% in 2024, which correlates with the growth of surgeons' experience and the improvement of technology. The curve corresponding to open surgical interventions also shows a decrease in mortality, but to a lesser extent - from 38% to 25%. Although this difference may be due to a heavier contingent of patients selected for open operations, there is a positive trend in both groups, which indicates an overall improvement in the results of surgical correction of congenital diaphragmatic

hernias.

Discussing the data obtained, it should be noted that the main problem in the treatment of congenital diaphragmatic hernia is a combination of severe respiratory disorders and neonatal adaptation mechanisms, complicated by the presence of structural anomalies.

Modern research emphasizes the importance of a multidisciplinary approach involving neonatologists, cardiologists, anesthesiologists-resuscitators, surgeons, pulmonologists and visual diagnostics specialists. Close interaction of specialists at all stages - from prenatal diagnosis to postoperative follow-up - is a key factor in a successful outcome [9].

Current trends in surgical correction of congenital diaphragmatic hernias in newborns include the expansion of the use of minimally invasive methods, the improvement of materials for plasty of the defect, including synthetic (polytetrafluoroethylene, polyester) and biological (collagen membranes) implants [7].

In parallel, the direction of cell technology and tissue engineering is developing, designed to improve the engraftment and adaptation of transplants. Our prediction model shows that the use of more modern materials and methods of postoperative management can further reduce mortality, especially if we accurately assess the risks and the need for either refusal or, conversely, extended use of ECMO [11].

The analysis provided an opportunity to highlight the prospects for further research. Among them are the study of the role of genetic factors in the development of congenital diaphragmatic hernias, the search for biomarkers associated with pulmonary hypoplasia, and an in-depth analysis of long-term outcomes, including the neurological development of children after successful surgical correction. It is also important to systematize the experience of different centers and create patient registers that will allow scaling and refining prognostic models.

4. CONCLUSIONS

The results of the study indicate that surgical correction of congenital diaphragmatic hernias in newborns in modern conditions gives ever higher survival rates and improves the quality of life of patients.

The main factor of progress is an integrated approach involving the use of high-precision preoperative diagnostics, the optimal choice of surgical technique and the use of innovative methods of intensive care. Minimally invasive operations provide a faster recovery period and less risk of complications, but require strict selection and sufficient experience of the operating team.

ECMO with severe respiratory distress allows you to maintain the necessary gas exchange and increases the chances of a successful outcome, although the use of this technology is associated with certain risks and high personnel requirements.

The creation and implementation of mathematical models for predicting outcomes based on clinical and instrumental data makes it possible to identify risk groups in advance and determine the optimal treatment tactics for each patient.

Current trends point to further integration of minimally invasive and hybrid approaches, improvement of implant materials and expansion of indications for the use of cellular technologies.

In the future, further standardization of protocols, data exchange between centers, as well as multicenter studies are needed to clarify the key determinants of survival and quality of life for children who have undergone surgical correction of congenital diaphragmatic hernia

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