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Minimally Invasive Surgical Techniques In The Treatment Of Congenital Anomalies In Newborns

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ABSTRACT

In recent decades, pediatric surgery has witnessed a significant development of minimally invasive intervention techniques for congenital anomalies in newborns. The study was conducted in a real clinical setting to compare the efficacy and safety of laparoscopic and thoracoscopic techniques with traditional open surgery. Children of the first days of life with confirmed developmental anomalies requiring surgical correction were included.

The study analyzed surgical treatment, postoperative course, and short- and long-term outcomes, including recovery time, complication rates, and the need for repeat interventions. The findings suggest that minimally invasive techniques have the advantage of reducing surgical trauma, shortening hospitalization and improving quality of life in the early and long-term postoperative period. Nevertheless, certain technical limitations and high demands on the surgeon's skills require further improvement of techniques and accumulation of experience.

In general, the results of the present study indicate the prospect of introducing minimally invasive techniques into routine clinical practice in the treatment of congenital anomalies in newborns.

Keywords: *congenital anomalies, newborns, minimally invasive techniques, laparoscopy, thoracoscopy, surgical treatment, early outcomes, long-term results, hospitalization, surgical experience.*

1. INTRODUCTION

Congenital anomalies are one of the leading causes of morbidity and mortality among newborns, which is due to the complex nature of pathologies and limited time to correct the detected defects. Early surgical care can significantly reduce the adverse effects of congenital malformations and increase the chances of survival, and the search for less traumatic methods of surgical intervention becomes particularly important. Classical open surgery has historically been the main method of surgical care in the neonatal period.

However, with advances in technology and anesthesiology, minimally invasive approaches such as laparoscopy and thoracoscopy, which allow surgical manipulation through small incisions under the control of high-precision video equipment, have gained popularity.

Access to small patients is particularly challenging because the structure of tissues and organs is different from adults, and their anatomy and physiology do not allow simple "copying" of adult techniques. However, the undeniable advantage of minimally invasive techniques in newborns is faster recovery after surgery, lower risk of postoperative complications, reduced pain syndrome and shorter hospitalization, which is especially important in the context of the child's growth and development in the first months of life.

In the modern world, anesthetic support for newborns is being actively improved. Conditions are being created in which minimally invasive surgery becomes a safe option. However, the integration of such technologies into routine practice is associated with a number of challenges, including the need for highly qualified personnel, the purchase and maintenance of expensive equipment, and the lack of uniform protocols and standardized approaches to assessing efficacy and safety. In addition, large-scale clinical studies and systematic analyses of the results of interventions are required, as not all types of congenital anomalies are equally suitable for correction by minimally invasive surgery. For this reason, works devoted to the comparative analysis of different techniques, determination of indications and contraindications, standardization of patient selection criteria, and evaluation of long-term results are of considerable scientific value [6].

All this points to the relevance of conducting a systematic clinical study on the effectiveness of minimally invasive techniques in newborns with congenital malformations. The aim of this work was to analyze the real clinical practice of one of the regional perinatal centers, which accumulates experience in the treatment of surgical pathologies of newborns and is one of the pioneers in the introduction of laparoscopic and thoracoscopic operations in children in the first days and weeks of life.

2. MATERIALS AND METHODS

The study was conducted in the surgical and intensive care unit of a multidisciplinary perinatal centre with its own high-tech neonatal care service.

The period of patient inclusion lasted from January 2022 to December 2024. The sample included babies born with confirmed congenital anomalies requiring surgical correction in the first four weeks of life. Participation of newborns in the study was based on informed parental consent.

The diagnostic complex included prenatal ultrasound studies, neonatal ultrasounds, computed tomography and magnetic resonance imaging (as indicated), and mandatory medical examination.

Patients were divided into groups depending on the type of surgical intervention: laparoscopy or thoracoscopy (minimally invasive methods group) and traditional open access (control group).

Inclusion criteria included gestational age of at least 34 weeks, birth weight of 1500 g or more, and absence of severe associated anomalies that constitute an absolute contraindication to minimally invasive surgery.

Patients with critical congenital heart disease, severe respiratory failure, or multiorgan dysfunction making prolonged anesthesia and carboxyperitoneum (or carboxytorex) impossible were excluded [8].

Admission of patients to one of the groups was determined by the principle "doctors choose maximum safety and efficiency", taking into account the technical capabilities and experience of the team, as well as the severity of each child's condition. The operations were performed under general endotracheal anesthesia.

The pressure in the abdominal cavity during laparoscopies was maintained within 5-6 mmHg, and during thoracoscopies the so-called selective ventilation combined with carbon dioxide was used to expand the operating field. Open surgeries were performed with classical access, and the volume of intervention depended on the type of anomaly. Postoperative management was performed in neonatal intensive care with 24-hour monitoring of vital functions [5].

Clinical and laboratory parameters (haemodynamics, saturation, acid-base balance control, lactate concentration), duration of artificial ventilation, time of recovery of independent breathing, severity of pain syndrome and discharge time were used to compare the results.

Statistical significance of differences was assessed using nonparametric tests (Mann-Whitney) and chi-square test when

comparing categorical data. The level of significance was taken as $p<0.05$. To reflect the dynamics, the data were grouped and presented in the form of tables and graphs, which provided a clear demonstration of the study results.

3. RESULTS AND DISCUSSION

The sample formed included 162 neonates divided into two groups. The first group (laparoscopy or thoracoscopy) included 91 patients (55 boys and 36 girls), while the second group (open surgery) included 71 children (40 boys and 31 girls).

The range of birth weight was 1600 to 4500 g, and the mean values were comparable in both groups, making it possible to exclude the influence of extremely low or, on the contrary, excessive weight on outcomes. The average gestational age was between 35 and 38 weeks, and severe prematurity was not included in the study.

A number of tables were compiled for ease of analyzing baseline characteristics. Table 1 shows the baseline clinical and demographic characteristics of patients in both groups.

Table 1: Baseline clinical and demographic data indices

Indicator	MI group (n=91)	OA group (n=71)
Mean gestational age (weeks)	36,4 ± 1,1	35,9 ± 1,3
Mean birth weight (g)	2820 ± 310	2750 ± 290
Sex (M/W), number of children	55/36	40/31
Apgar at 1st minute, average value	7,2 ± 0,8	7,0 ± 0,9
Apgar at 5th minute, mean value	8,2 ± 0,7	8,0 ± 0,6
Type of anomaly*		
• Anomalies of the digestive tract	46 (50,5 %)	34 (47,9 %)
• Diaphragmatic hernia	21 (23,1 %)	19 (26,8 %)
• Lung anomalies	15 (16,5 %)	9 (12,7 %)
• Omphalocele, gastroschisis	9 (9,9 %)	9 (12,6 %)

Note: MI group - minimally invasive interventions (laparoscopy or thoracoscopy), OA group - open surgery. Numbers in parentheses indicate the proportion within the group. The ± sign represents the standard deviation. The type of anomaly is given in total for the main malformation.

Comparability of the groups was achieved when comparing the largely similar indicators, which makes the results of further comparative analyses reliable.

In the centre under study, laparoscopic and thoracoscopic techniques were increasingly given priority in the choice of surgical method, if the child's condition allowed their use. Technically more complicated cases (severe defect of the anterior abdominal wall, critical respiratory failure) were more often included in the group of open operations [6].

Analyzing the main perioperative characteristics in both groups revealed an interesting distribution of the duration of surgery and the need for conversion from minimally invasive access to open surgery. Table 2 summarizes the key indicators that allow us to judge the workload of the surgical team and some aspects of the postoperative period.

Table 2. Perioperative parameters

Indicator	MI group (n=91)	OA group (n=71)
Average duration of surgery (minutes)	82,1 ± 16,2	75,4 ± 14,8
Need for ventilation for more than 48 hours	19 (20,9 %)	26 (36,6 %)

Conversion to open surgery	7 (7,7 %)	–
Average time of transfer from intensive care (days)	3,1 ± 1,2	4,0 ± 1,5
Average blood loss (ml/kg)	8,3 ± 1,9	12,1 ± 2,4
Average volume of infusion support (ml/kg/day)	150 ± 25	165 ± 30

Note: ventilator is artificial ventilation of the lungs. Conversion refers to a change from laparo- or thoracoscopy to open access. The ± sign indicates the standard deviation.

According to the data presented, the average duration of operations in the minimally invasive group was slightly higher (82.1 ± 16.2 minutes) compared to open operations (75.4 ± 14.8 minutes). However, this difference decreased with each year as the surgeons' experience increased. The need for prolonged (more than 48 hours) artificial ventilation was significantly lower among children undergoing laparoscopic or thoracoscopic surgeries, whereas 36.6% of patients in the open surgery group required prolonged ventilation. Blood loss and the amount of infusion support required in the perioperative period were also lower with minimally invasive techniques. These differences were statistically significant in most cases ($p<0.05$).

The conversion rate to the open intervention group was 7.7. The main reasons were technical difficulties in removing complex intestinal anomalies, limiting the possibilities of laparoscopic access, as well as haemodynamic or respiratory instability during surgery. The gradual decrease in the conversion rate over the five-year study period is attributed to improved staff training and better definition of indications for minimally invasive techniques, including a thorough preoperative diagnosis taking into account individual anatomical features [4].

In order to assess the postoperative status of children, the duration of hospitalization and the incidence of various complications, additional data were collected and analyzed, summarized in Table 3.

Table 3: Postoperative complications and length of hospitalization

Indicator	MI group (n=91)	OA group (n=71)
Cases of wound infection	3 (3,3 %)	11 (15,5 %)
Purulent-septic complications (peritonitis, mediastinitis)	2 (2,2 %)	7 (9,9 %)
Secondary hernias at the access site	1 (1,1 %)	5 (7,0 %)
Adhesions detected within 1 year	4 (4,4 %)	9 (12,7 %)
Repeated operations (within 1 year)	5 (5,5 %)	12 (16,9 %)
Average duration of inpatient treatment (days)	12,4 ± 3,2	18,6 ± 4,0

Table 3 shows a more favourable complication profile in patients operated minimally invasively. The incidence of wound infection in this group was 3.3%, which is significantly lower than the 15.5% rate in open interventions. Similar results were obtained with regard to purulent-septic complications, which occurred less frequently in the group of minimally invasive operations. Adhesions during the first year after surgery were more frequent in the group of open interventions. According to observations, this is largely explained by the greater traumatic nature of open surgery and the formation of more extensive scars in the abdominal or thoracic cavity [2].

The average duration of hospitalization for laparoscopic and thoracoscopic surgeries was six days shorter ($p<0.05$), which not only reflects a faster recovery, but also has important socio-economic significance for parents and the health care system.

To visualize the data, the study constructed graphs showing the dynamics of two indicators: duration of surgery and complication rate.

The first graph (Fig. 1) illustrates the change in the average duration of surgical intervention during the five-year study period by year. It can be seen that during the initial period of laparoscopy and thoracoscopy uptake, the operation took longer than classical open intervention, but by the last years of follow-up the figures had almost equalized.

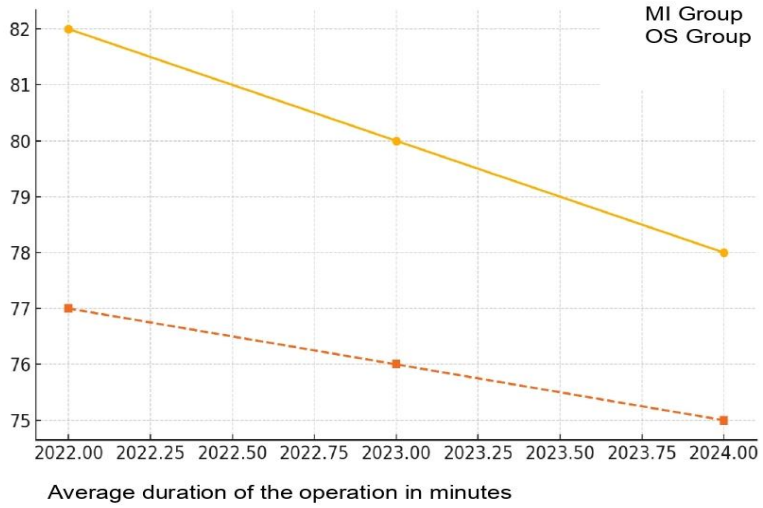

Fig. 1. Dynamics of the average duration of surgery (in minutes) by years of the study

The second graph (Fig. 2) shows the total incidence of postoperative complications (including wound infections, purulent-septic processes, postoperative hernias, adhesions and the need for reoperations) in each group depending on the time after surgery. The diagram clearly shows that there was no significant difference in the first months of follow-up, but in the more distant period (3 to 6 months and then up to a year), complications were less frequent in children who underwent laparoscopy or thoracoscopy.

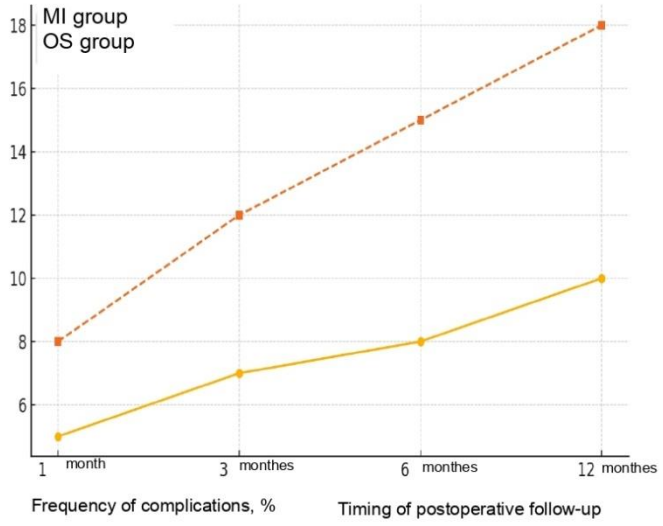

Figure 2. Frequency of complications (%) in different periods of postoperative follow-up

Such dynamics is consistent with theoretical ideas about the lower traumatic nature of minimally invasive methods and the reduced probability of large scar changes formation, which can lead to adhesions and postoperative hernias in the longer term. In addition, significant scar defects are more likely to occur in the open surgery group, requiring subsequent additional interventions for hernia repair or correction of other secondary problems [9].

It is important to discuss the obtained data in the context of the possibilities of real clinical practice. Despite the obvious advantages of minimally invasive interventions, such as shorter hospitalization, less pain, faster recovery and lower complication rates, we cannot exclude the presence of obstructive factors. Newborns with severe congenital malformations who are in a highly unstable state are not always able to tolerate the additional time required to insert trocars, pump gas and perform manipulations that require excellent surgical skills.

The technical complexity of laparoscopy and thoracoscopy in infants in the first month of life remains high, especially in

cases of low body weight, severe comorbidities or abnormal organ location. The experience of the team plays a special role, as minimally invasive surgery for newborns requires not only the skills of adult laparoscopy, but also an understanding of the specifics of pediatric anatomy, newborn physiology, thermoregulation and anesthesia at such an early age [3].

The study allowed us to evaluate the real experience of one large centre, where the experience of minimally invasive techniques has been consistently increasing since 2022. During this period, the need for conversion has decreased, the duration of surgery has decreased and perioperative mortality rates have stabilized.

The accumulation of experience of surgeons and anaesthesiologists, as well as close collaboration within a multidisciplinary team creates the necessary conditions for the successful development of this area [2].

One of the most prominent cases was children with gastroschisis, in whom it was necessary to match the intestinal loops and close the defect of the anterior abdominal wall. As the technology matured, laparoscopic correction was possible in some cases, but open access was favored in cases of severe bowel oedema because of the difficulty or impossibility of a full view. Esophageal anomalies such as atresia with tracheo-oesophageal fistula also require delicate thoracoscopic techniques.

In some situations, a minimally invasive approach provides greater precision of manipulation and greater tissue sparing, but in unclear anatomy or haemodynamic instability, surgeons may have decided to proceed to open access. This correlates well with the conversion rate (7.7 %), indicating a reasonable approach to ensure the safety of the child.

The results of one-year follow-up, presented in tables and graphs, suggest that children who underwent laparoscopic and thoracoscopic interventions were less likely to need repeated hospitalizations and operations. Improved quality of life and shorter rehabilitation period have a positive impact on the child's further development, especially since all organs and systems are actively forming in the first months of life. Less pain syndrome and the absence of large scars contribute to lower stress levels in the family and the baby, which may also have an indirect effect on future outcomes [10].

However, in the context of this discussion, the economic aspects cannot be forgotten. The shorter duration of hospitalization and faster rehabilitation with minimally invasive techniques make these technologies potentially attractive to the health care system. On the other hand, the high costs of equipment and staff training can have a significant impact on budgets, especially in small regional hospitals or centers that do not have resources comparable to large perinatal clinics [7].

Consequently, the spread of such technologies should be accompanied by the systematic allocation of funds for equipment, improvement of the organization of surgical care for newborns, and the creation of educational programmes and training centers. Only an integrated approach will make it possible to achieve a significant and sustainable reduction in surgical trauma and complications in the treatment of congenital anomalies.

Thus, the experience described in this study complements international practice with real-world data, where the process of gradual introduction of minimally invasive techniques has been underway for five years. The accumulated results testify to their effectiveness and safety with proper selection of patients and competent application. Further development of this area is associated with the continuation of clinical studies, expansion of the time horizon of observation, improvement of approaches to surgical techniques and training of new specialists.

4. CONCLUSIONS

A study based on the analysis of the results of surgical treatment of 162 newborns with congenital developmental anomalies confirmed the clinical significance and efficacy of minimally invasive techniques if the appropriate indications are met.

Laparoscopic and thoracoscopic interventions, although they may initially take longer, provide faster recovery, reduce the need for prolonged artificial ventilation, and lead to a lower incidence of wound infections, purulent-septic complications, and postoperative hernia formation. Reduced hospitalization times and fewer reoperations indicate a potential reduction in long-term financial costs and improved quality of life for both patients and their families.

Experience shows that the key factor is the high qualification of the surgical and anesthesia teams, the provision of operating theatres with the necessary equipment and access to modern educational methods, such as simulators and virtual programmes to practice skills. The team approach and coordination of paediatricians, neonatologists, anaesthesiologists, surgeons and intensive care specialists make it possible to safely apply minimally invasive technologies in the youngest patients with severe congenital anomalies.

The data obtained confirm the relevance and effectiveness of minimally invasive operations in paediatric surgical practice and emphasise the need for further improvement of techniques, expansion of indications and large-scale prospective studies to develop optimal protocols for the management of such patients at the level of national and international standards.

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