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ACTUAL PROBLEMS IN SURGICAL TREATMENT OF CONGENITAL ANTERIOR ABDOMINAL WALL DEFECTS

Y.A. Novoseltseva[1], A.V. Zapalianski[2]

[1]Republican scientific and practical center of pediatric surgery, Minsk, Belarus
[2]Department of pediatric surgery, Belarusian State Medical University, Minsk, Belarus

Resume. Congenital malformations of the anterior abdominal wall, such as omphalocele and gastroschisis, are the most common causes of compartment syndrome after primary closure. Modern methods for diagnosing intra-abdominal pressure allow us to predict the risk of an unfavorable outcome after primary abdominoplasty and guide the choice of surgical treatment, monitoring the timing of the staged surgical procedures.\

Aim. Clinical evaluation of the effectiveness of surgical treatment of patients with malformations of the anterior abdominal wall depending on the degree of intra-abdominal hypertension.

Materials and methods. A retrospective analysis of the results of surgical treatment of 18 newborns with omphalocele, 23 newborns with gastroschisis, treated at the Republican Scientific and Practical Center for Pediatric Surgery in the period from 2015 to 2024. Depending on the surgical treatment performed, the children were divided into 4 groups: I – primary abdominoplasty in patients with omphalocele (11), II – two-stage abdominoplasty with an active traction system (6) and III – Bianchi technique (22), IV – siloplasty (2).

Results. Primary abdominoplasty for small and medium-sized omphaloceles, as well as the Bianchi technique for gastroschisis, are effective when preoperative intra-abdominal pressure (IAP) is no more than 5 cm H_2O, intraoperative pressure is less than 13.6 cm H_2O, and visceroabdominal disproportion (VAD) is grade 1, which corresponds to intra-abdominal hypertension (IAH) of grades 1-2. For grade 2 VAD and grade 3 IAH, a two-stage abdominoplasty allows for effective closure of the defect by 7-8 days of life, preventing the formation of postoperative ventral hernias and the development of compartment syndrome.

Conclusion. Modern methods of indirect diagnostics of intra-abdominal pressure, as well as indirect signal parameters of an increased risk of compartment syndrome development: tightening of mechanical ventilation parameters, increase in creatinine level above reference values, duration of stimulation of diuresis, duration of cardiotonic support, allow us to predict the degree of risk of an unfavorable outcome, and therefore should be introduced into the routine list of monitored parameters in the management of patients with congenital malformations of the anterior abdominal wall throughout the entire stage of intensive care in order to select a surgical intervention to correct the defect and monitor its effectiveness.

Keywords: *omphalocele, gastroschisis, intra-abdominal pressure, newborn.*

Relevance. Congenital malformations of the anterior abdominal wall such as omphalocele and gastroschisis are on the first place in terms of frequency of the Compartment-syndrome- development after the primary closure of the defect. Modern methods of the intraabdominal pressure's measurement predict the risk of the unfavorable outcome of the primary abdominoplastics and determine the choice of surgical treatment method also controlling time frames of the surgical performance.

Purpose of the study. To analyze the efficiency of the surgical treatment among the patients with congenital malformations of the anterior abdominal wall depending on the degree of intra-abdominal hypertension.

Material and research methods. We have analyzed the results of the surgical treatment among 18 patients with omphalocele and 23 patients with gastroschisis, being treated in the Republican scientific and practical center of pediatric surgery from 2015 to 2024. Depending on the provided surgical treatment children were divided into 4 groups: I – primary abdominoplasty among patients with omphalocele (11), II – two-stage surgical correction with the Gross active traction system (6), III – Bianchi technique (22), IV– siloplastics (2).

Research results. Primary abdominoplasty among the patients with omphalocele of the small and middle size as well as the Bianchi technique among the patients with gastroschisis are considered to be effective while preoperative intraabdominal pressure is less then 5 centimeter of water column, and intraoperative intraabdominal pressure is less then 13,6 centimeter of water column, 1 degree of viscero-abdominal disproportion (VAD) that meet the requirements of the 1–2 degree of intra-abdominal hypertension (IAH). While 2 degree of VAD and 3 degree are present, IAH two-stage surgical correction with the Gross active traction system allows effective closure by the 7–8th day

of living, avoiding formation of the postoperative ventral hernia and the development of the compartment- syndrome.

Conclusions. Modern methods in the indirect measurement of the intraabdominal pressure measurement as well as indirect signal parameters of the increased risk of the Compartment-syndrome- development such as strict parameters of artificial ventilation of the lungs, increased creatinine, prolonged stimulation of diuresis, prolonged cardiotonic support, predict risk-degree of the unfavorable outcome, that is why it must be integrated into the routine monitoring during the whole intensive care management of the patient with congenital anterior abdominal wall defect in order to choose method of the surgical treatment and to control its efficiency.

Introduction. Currently, the most common congenital causes of compartment syndrome in neonatal practice are congenital malformations of the anterior abdominal wall: omphalocele and gastroschisis [1]. Omphalocele is essentially a persistent embryonic hernia of the umbilical cord, in which the hernial orifice is a ventral defect in the area of the umbilical aponeurosis, the hernial sac is the amnion, Wharton's jelly, and peritoneum, and the contents are the intestine due to its impaired return to the abdominal cavity, and in some cases, also the liver. Gastroschisis, on the contrary, is the eventration of abdominal organs through a paraumbilical defect to the right of a normally formed umbilical cord without the presence of a hernial sac [2].

Due to the pronounced underdevelopment of the abdominal cavity volume and the presence of viscero-abdominal disproportion, the risk of an increase in intra-abdominal pressure (IAP) with subsequent outcome in compartment syndrome during primary closure of the defect is quite high, which determines the difficulty of choosing a surgical tactic.

To date, the World Society of Abdominal Compartment Syndrome (WSACS) has adapted the parameters characterizing the degrees of intra-abdominal hypertension (AHI) and defining compartment syndrome to pediatric criteria. According to these parameters, in pediatric practice, stage 1 AHI develops with an IBP of 10-12 mm Hg (13.6–16 cm H_2O), stage 2 - 13-15 mm Hg (17.68–20 cm H_2O), stage 3 – 16-18 mm Hg (21.76-24.48 cm H_2O), and stage 4 – more than 18 mm Hg (more than 24.48 cm H_2O) [3]. However, IAH is not the same as compartment syndrome without signs of organ failure, which can manifest itself in childhood and with IBP values greater than 10 mm Hg (13.6 cm H_2O).

Abdominal compartment syndrome is characterized by dysfunction of the respiratory, urinary, cardiovascular, nervous, and gastrointestinal systems, accompanied by the inability to expand the anatomical region due to increased pressure in a confined space. Given the variability of intra-abdominal compression manifestations, including respiratory distress, decreased venous return with oliguria and decreased cardiac output, and intestinal ischemia, modern methods of indirect intra-abdominal pressure diagnostics, such as central venous pressure and intravesical pressure measurements, as well as indirect indicators of an increased risk of compartment syndrome development (such as tightening mechanical ventilation parameters, increased creatinine levels above the age-appropriate norm, duration of diuresis stimulation, and duration of cardiotonic support), can systematically predict long-term outcomes at a multi-component level.

The risk of developing compartment syndrome, which limits the possibility of performing primary plastic surgery of the defect, is considered high with the following parameters: the presence of 2-3 degrees of viscero-abdominal disproportion, central venous pressure (CVP)> 15 cm H_2O, intravesical pressure (IVP)> 15–20 cm H_2O, tightening of mechanical ventilation parameters (PEEP> 5, Pin> 25), creatinine level more than 80 **μ**mol/l, decreased diuresis less than 2 ml/kg/h.

Despite the fact that numerous methods for defect closure have been proposed, there is currently no global gold standard for surgical treatment for patients with a high risk of developing compartment syndrome, particularly in cases of large omphaloceles and pronounced visceroabdominal disproportion in gastroschisis. Many authors agree that surgical correction of congenital malformations of the anterior abdominal wall in the neonatal period without the use of synthetic plastic materials achieves the most favorable cosmetic and functional results [4].

Purpose of the study. To conduct a clinical evaluation of the effectiveness of surgical treatment of newborns with omphalocele and gastroschisis at the Russian Scientific and Practical Center for Pediatric Surgery depending on the degree of intra-abdominal hypertension. To determine treatment outcomes for varying degrees of viscero-abdominal disproportion and to assess the availability and effectiveness of dynamic intra-abdominal pressure monitoring methods in the pre- and postoperative periods to identify the causes of postoperative complications and ways to prevent them.

Materials and methods. A retrospective study included 41 children treated at the Republican Scientific and Practical Center for Pediatric Surgery from 2015 to 2024. Of these, 18 newborns had

omphalocele (11 boys and 7 girls) and 23 newborns had gastroschisis (13 boys and 10 girls). Small omphalocele, with a defect size of up to 2-3 cm and the location of intestinal loops in the hernial contents, was observed in 4 children, medium-sized omphalocele (with a defect of up to 4–5 cm in the anterior abdominal wall) was observed in 6 patients, and large omphalocele (with a defect greater than 5 cm, with the liver located in the hernial contents) was observed in 8 patients. Primary abdominoplasty was performed in 11 patients with omphalocele, three of whom underwent combined entero-enteroanastomosis due to concomitant intestinal malformations: two patients with Meckel's diverticulum and one with cystic ileal duplication. Two-stage abdominoplasty with active abdominal wall traction was used in six cases for patients with large omphalocele, and the siloplasty technique was used in one case. The Bianchi technique was used in 22 of the 23 patients with gastroschisis, and siloplasty was performed in only one patient.

For a detailed clinical evaluation of the treatment, the following parameters were studied: gestational age of the child and birth weight, defect size, concomitant congenital anomalies, type and number of surgical interventions performed, characteristics of the postoperative period, the presence of viscero-abdominal disproportion and parameters indirectly characterizing an increase in intra-abdominal pressure: parameters of mechanical ventilation, central venous pressure, intravesical pressure (IVP), creatinine level over 80 μmol/l, diuresis parameters, duration of cardiotonic support.

According to WSACS recommendations, the ICP was measured after emptying the bladder, in the supine position, at the end of expiration. Before measurement, the patient was given 1 ml/kg of warm sterile saline (up to a maximum of 25 ml) intravesically. A transparent tube was then connected to the Foley catheter, and the height of the fluid column was measured in centimeters. The zero reference point was at the level of the pubic symphysis. Measurements were taken every 4 hours. This method is simple to use and does not require any expensive equipment.

Statistical data processing was performed using Statistica 10. The analysis of the conformity of the feature distribution type with the normal distribution law was performed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The presentation of quantitative data in a sample with a normal distribution was given as M ± m, where M is the arithmetic mean, and m is the standard error of the arithmetic mean. In the description of quantitative data in a sample with a distribution different from normal, the median and interquartile range were used: Me (25%–75%), where Me is the median, 25% is the 25th percentile, and 75% is the 75th percentile. When comparing two samples with a feature distribution

Table 1. Structure of associated developmental defects

Defect	N	Associated defects	n
Omphalocele	1	Formative coarctation of the aorta, borderline development of the aortic isthmus, hyperplasia of the isthmus	5
	2	VPS: DMPP	1
	3	VSD: VSD	2
	4	MARS: LLC	7
	5	OAP	5
	6	Incomplete intestinal rotation	4
	7	Pyeelectasia, calicoectasia	2
	8	Cystic form of duplication of the ileum	1
Gastroschisis	1	Small intestinal atresia	2
	2	NECK	2
	3	VPS: DMPP	4
	4	VSD: VSD	2
	5	MARS: LLC	9
	6	OAP	1
	7	Incomplete intestinal rotation	3
	8	Megaureter	1
	9	Choroid plexus cysts	3
	10	Cystic form of duplication of the ileum	1
	11	Pyeelectasia, calicoectasia	4

different from normal, the analysis was performed using the nonparametric Mann-Whitney test. For all statistical methods used, the significance level of the statistical criterion was taken to be $p < 0.05$.

Results and their discussion. The data analysis revealed that the average gestational age in children with omphalocele was 270 (269-274) days, birth weight was 3390±260 g, and in children with gastroschisis - 262 (233-274) days, 34% of them were premature. The diagnosis of congenital malformations in all cases was established prenatally by ultrasound at 12-16 weeks of pregnancy. Isolated cases of late diagnosis of the defect were associated with the small size of the defect and small hernial protrusions. The predominant method of delivery was cesarean section: 13/18 omphalocele (72%), 19/23 gastroschisis (82%).

Associated malformations in the overall patient sample were present in 25/41 (65%) patients. In the group of patients with omphalocele, congenital heart defects (developing coarctation of the aorta, multiple muscular VSD, ASD, PDA) and gastrointestinal malformations (small intestinal duplication, Meckel's diverticulum, incomplete intestinal rotation) were prevalent (see Table 1). In newborns with gastroschisis, necrotizing enterocolitis, small intestinal atresia, ASD, and urinary tract malformations (calic- and pyelectasis) were prevalent, MARS: OOO. Isolated omphalocele was recorded in 6 of 18 cases, isolated gastroschisis – in 8 of 23 cases.

In patients with omphalocele, the choice of surgical intervention was determined by the size of the defect, as well as the recorded CVP and EPP parameters. Surgical intervention options based on defect size are presented in Table 2.

The method of choice in the treatment of patients with omphalocele is the earliest possible closure of the defect during the first days of life. Primary abdominoplasty was possible in 10/18 patients with small and medium-sized defects and in 1 patient with a large defect. In this sample of patients, viscero-abdominal disproportion was mild (grade 1) or absent, while the pre- and postoperative IPP

Table 2. Types of surgical interventions in patients with omphalocele

Omphalocele		Defect diameter, cm	Hernial contents	Type of surgical intervention
Small (n=4)	1	1	Meckel's diverticulum	Resection of a section of the ileum with Meckel's diverticulum, entero-enteroanastomosis, plastic surgery of the anterior abdominal wall (2)
	2	2		
	3	1,5	Loop of the transverse colon	Primary abdominoplasty (2)
	4	2		
Average (n=6)	1	4	Small intestine	Primary abdominoplasty (5)
	2	5		
	3	5	Small and large intestine	
	4	4		
	5	5		
	6	4		Resection of a section of the ileum with duplication, entero-enteroanastomosis, plastic surgery of the anterior abdominal wall (1)
Large (n=8)	1	12	Intestines and liver	Siloplasty (1)
	2	7		Primary abdominoplasty (1)
	3	10		Two-stage abdominoplasty with active traction system (6)
	4	6		
	5	10		
	6	6		
	7	5		
	8	7		

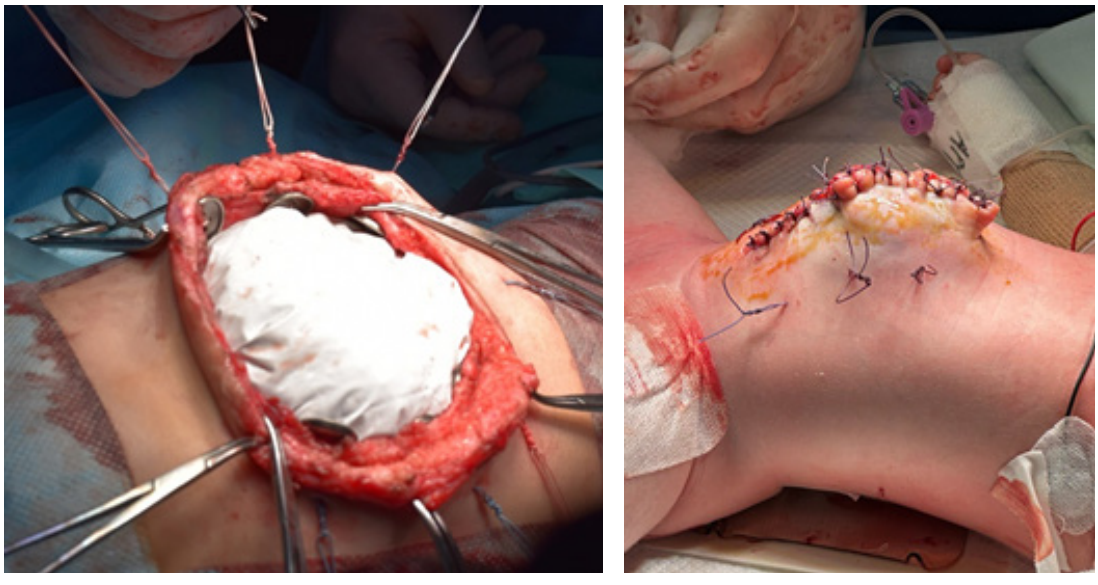

Figure 1. The first stage of correction: formation of a ventral hernia and an active traction system: intraoperative stage (left), intermediate result of the first stage (right)

values were 5-6 cm H_2O, and the maximum postoperative CVP was 8 cm H_2O, the creatinine level before occlusion repair was less than 80 μmol/L. Before surgery and throughout the postoperative period, "soft" mechanical ventilation parameters (Pin < 25) (PEEP 4.0–4.3) were maintained, and on postoperative days 1–3, children were already transferred to spontaneous breathing. In this group of patients, cardiotonic support was stopped on days 2–3 of life. The average stay of these patients in the intensive care unit was 8 days. There were no postoperative complications. Subsequently, there were no complaints during routine follow-up examinations, the cosmetic outcome was satisfactory, and no systemic dysfunction was noted.

In 6 patients with large omphaloceles and moderate viscero-abdominal disproportion, a two-stage surgical correction of the anterior abdominal wall defect was performed. This procedure involved a modified Gross procedure using external traction of the muscular-aponeurotic layer of the abdominal wall to create abdominal cavity volume. The average duration of traction was 5 days (range, 5–13

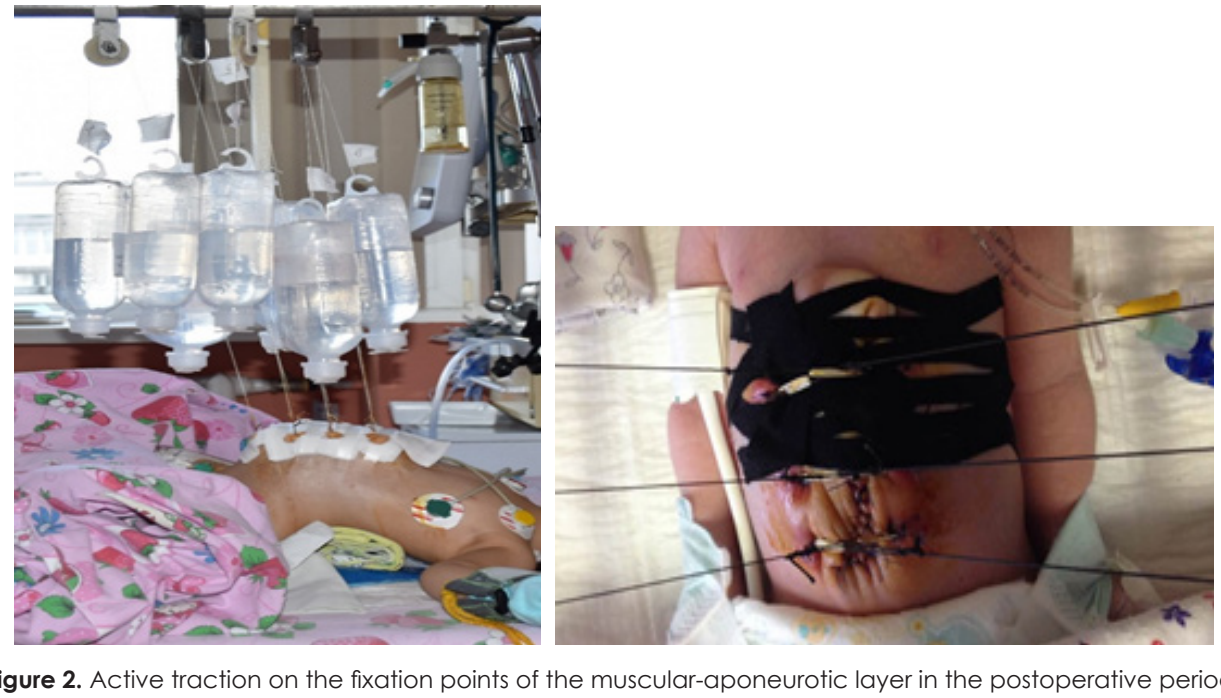

Figure 2. Active traction on the fixation points of the muscular-aponeurotic layer in the postoperative period: appearance of the first 4–5 days of traction (left), crossing of ligatures to "close the defect" (right)

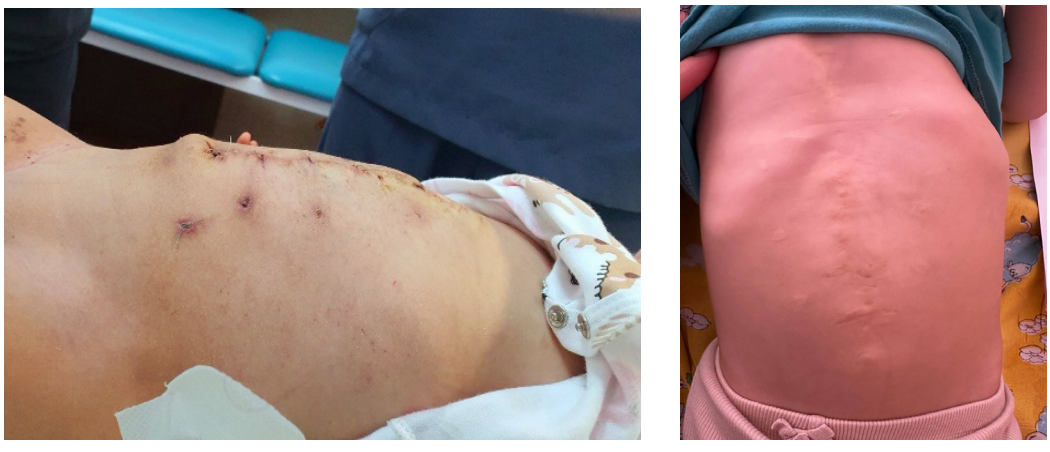

Figure 3. Cosmetic effect after two-stage correction of a large omphalocele – formation of a ventral hernia and an active traction system: 16 days after the second stage (left), 5 years later (right)

days), followed by full-layer grafting of the anterior abdominal wall using native tissues without the use of synthetic plastic materials. Prior to selecting the surgical method, intracranial pressure (IPP) was measured, which averaged 16–18 cm H_2O across the entire sample. The pressure was maintained at this level for the first 3 days postoperatively, subsequently decreasing to 10 cm H_2O.

Before the organs were immersed in the abdominal cavity, the central venous pressure (CVP) in a large omphalocele was 9 cm H_2O. During the reduction and repair stage, the pressure in the inferior vena cava did not exceed 12–15 mm Hg, and 4 hours after immersion, it was 11–12 cm H_2O. CVP stabilization occurred as early as the 3rd-4th day (up to 10–11 cm H_2O), and immediately before the second stage of correction, it was 10 cm H_2O. CVP values after layer-by-layer closure of the defect remained within 10–12 cm H_2O.

Throughout the pre-, intra-, and postoperative periods, "soft" mechanical ventilation parameters were maintained. Children were extubated on average after 8–11 days. The average duration of cardiac support was 4.9 (range, 1–11) days.

Due to the need for a two-stage surgery, the average duration of treatment in the intensive care unit was 14 days. After gastrointestinal function was restored and enteral feedings were initiated, the children were transferred to the surgical department for further treatment and care. The total duration of hospital stay was 26 days. No patients with omphalocele required subsequent surgeries for the underlying condition. There were no deaths.

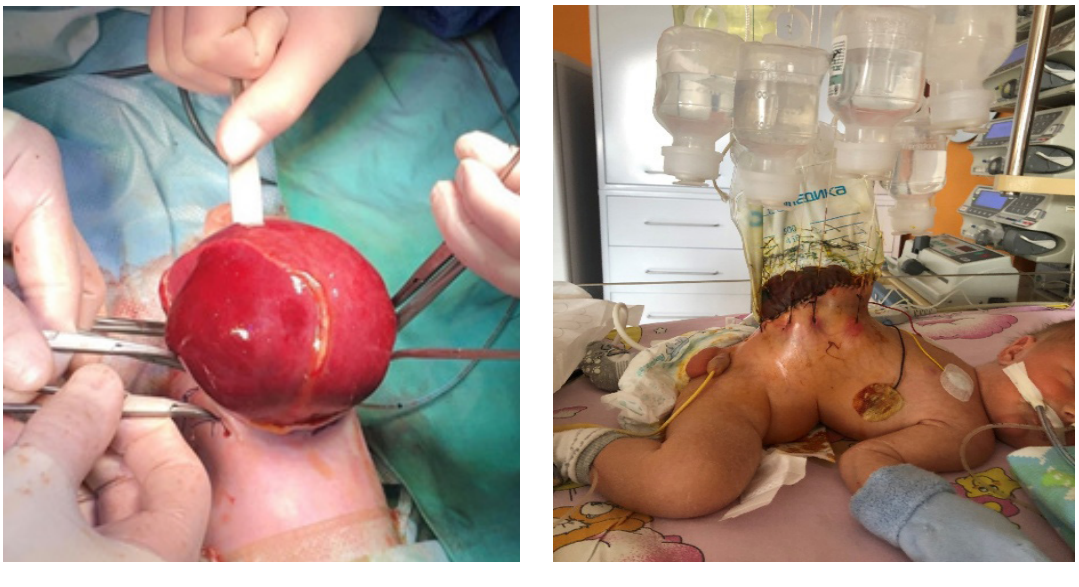

Figure 4. Large omphalocele with grade 3 viscero-abdominal disproportion (left), patient's appearance after performing siloplasty with the formation of muscular-aponeurotic traction (right)

Table 2. Indicators of recovery of gastrointestinal functions depending on the type of surgical intervention in patients with omphalocele

Type of surgical intervention	Start of enteral feeding, 24 hours after surgery	Independent bowel movements, 24 hours after surgery
Resection of a section of the ileum with duplication, entero-enteroanastomosis, plastic surgery of the anterior abdominal wall (n=1)	4	2
Resection of a section of the ileum with Meckel's diverticulum, entero-enteroanastomosis, plastic surgery of the anterior abdominal wall (n=2)	5	1
	4	3
Two-stage abdominoplasty with active traction system (n=6)	9 (7–11)	6 (4,5–6,5)
Primary plastic surgery of the anterior abdominal wall (n=9)	2 (2–3)	2 (1–3)

In one patient with grade 3 visceroabdominal disproportion and the inability to form a ventral hernia according to Gross due to a shortage of skin flaps, a mixed operation was performed – siloplasty with muscular-aponeurotic traction.

The favorable course of the postoperative period was assessed by the restoration of gastrointestinal function: a decrease in the volume of stagnant discharge through the gastric tube, the beginning of enteral feeding and the appearance of independent stool. After primary abdominoplasty, even with bowel resection, the ability to begin enteral feeding appears on the 2–3 day after surgery, whereas after two-stage surgical treatment on the 9th (7–11) day (U=0.5; p=0.03). Another indicator – the appearance of independent stool also significantly differed in the compared groups (U=0.9; p=0.04): after primary plastic surgery on the 2nd (1–3) postoperative day, after two-stage treatment on the 6th (4.5–6.5). The obtained data from the analysis of gastrointestinal function restoration are presented in Table 2.

The Bianchi technique—primary radical abdominoplasty with repositioning of the vented organs–remains the global gold standard for treating patients with gastroschisis. At our clinic, we perform a variation of this technique: children are operated on in the operating room instead of the intensive care unit, under general anesthesia instead of epidural anesthesia, and after colonic lavage, three to four ligatures are applied to the edges of the defect to provide traction on the anterior abdominal wall.

In 19 out of 23 patients, after reduction of the eventrated organs, ligation of the umbilical vessels was also performed with cutting off the umbilical cord and plastic surgery of the skin of the navel with an immersion purse-string suture in order to prevent infection of the paraumbilical wound and exclude the presence of umbilical fistulas.

Immediately after gastroschisis reduction, central venous pressure (CVP) increased to 19–20 cm H_2O, and normalized to 10.8–11.5 cm H_2O on days 3-4. Venous pressure (EPP) immediately after reduction increased to 19–21 cm H_2O, and decreased to 12–16 cm H_2O on days 3–4. Signs of moderate compartment syndrome in the postoperative period were detected in 7/22 (32%) patients operated on using the Bianchi technique. Prolonged analgesia with relaxation and adequate respiratory support were used to correct this condition. On average, intraabdominal compression values normalized and fell within the reference values by days 4–5 after surgery. Given the absence of renal dysfunction and stable hemodynamics, there were no indications for surgical treatment of compartment syndrome. Two patients with gastroschisis required repeated interventions after the primary operation using the Bianchi method due to the clinical picture of early adhesive intestinal obstruction.

All patients with gastroschisis had mild mechanical ventilation parameters in the postoperative period: PEEP was 4.0–4.5, PINS less than 25. Patients were restored to spontaneous effective breathing on average by the fourth postoperative day. The average duration of cardiac support was 3.6 days (range, 1–16).

Following the Bianchi technique, rapid restoration of gastrointestinal transit was observed: spontaneous bowel movements appeared on the 4th to 6th day after surgery, and enteral feeding

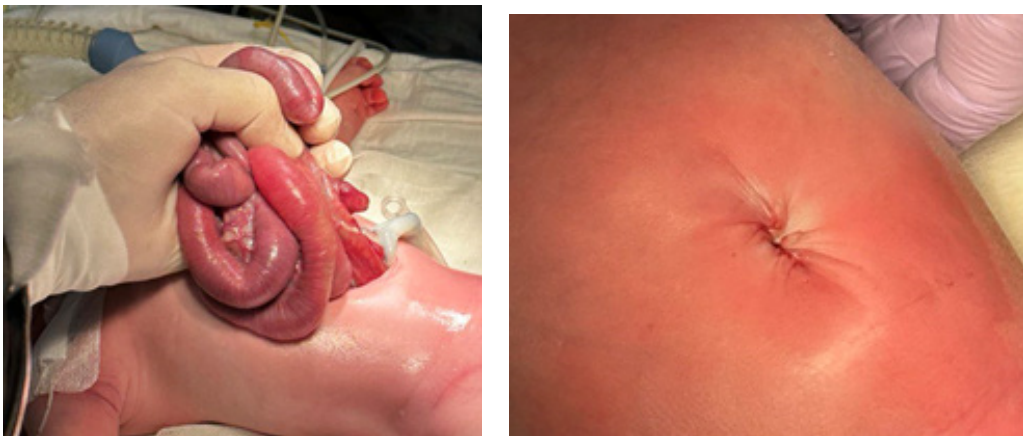

Figure 5. Appearance of a patient with gastroschisis before the Bianchi procedure (left), cosmetic effect after the Bianchi procedure, ligation of the umbilical vessels, and umbilical skin grafting (right)

was possible on the 12th to 14th day after the procedure. Postoperative antibacterial therapy lasted an average of 14 days. Once stable enteral feeding was achieved, the children were transferred to the surgical department.

In one premature infant with gastroschisis, primary reduction was unsuccessful due to severe viscero-abdominal disproportion, necessitating siloplasty. The duration of immersion in the bag was 8 days. During this period, the IPP fluctuated between 14–10 cm H_2O, and the CVP ranged from 12–11–10 cm H_2O. On the 8th day, delayed abdominoplasty was performed with a good functional and cosmetic result.

The mortality rate in patients with gastroschisis was 8.6% (2/23). In one case, the fatal outcome was associated with bleeding into the pleural cavity in the early postoperative period (placement of a central venous catheter). A thoracotomy was performed to stop the bleeding, but postoperative MODS developed, leading to death. In the second patient, the postoperative period was complicated by early adhesive intestinal obstruction, ileal perforation, and peritonitis, which required a repeat intervention and the development of MODS and septic shock.

Postoperatively, daily urine output and the duration of stimulation were measured in all children to assess renal function. A decrease in urine output and an increase in serum creatinine levels indicate intra-abdominal compression syndrome.

In the first group of patients, who underwent primary abdominoplasty in patients with small and medium-sized omphalocele, the daily diuresis was 3.5 (3.4–3.6) ml/kg/h, the average number of days of furosemide stimulation was 3.2±0.7 days. In the second group of patients with two-stage surgical correction of omphalocele and the fourth group with siloplasty, the daily diuresis values did not differ from those in group 1, but the duration of stimulation was significantly longer – 10 (7–14.5), (U=1.5; p=0.03).

In the 3rd group of patients with gastroschisis, operated on using the Bianchi method, the daily diuresis was 3.4 (2.6–3.56) ml/kg/h, the average number of days of stimulation with furosemide was 11 (2–27).

Conclusion. Primary abdominoplasty for small and medium-sized omphaloceles, as well as the Bianchi technique for gastroschisis, are effective with preoperative intra-abdominal pressure of up to 5 cm H_2O, intraoperative intra-abdominal pressure of less than 13.5 cm H_2O, and grade 1 visceroabdominal disproportion.

For intra-abdominal hypertension of grade 2 or higher, a two-stage abdominoplasty allows for effective closure of the defect by 7–8 days of life, preventing the development of compartment syndrome and postoperative ventral hernias. Central venous pressure (CVP) and ventricular pressure (VPP) parameters return to normal within 4–5 days postoperatively.

Modern methods of indirect assessment of intra-abdominal pressure, such as measurement of central venous pressure, intra-abdominal pressure, as well as indirect signal parameters of an increased risk of developing compartment syndrome: tightening of mechanical ventilation parameters, increase in creatinine levels, duration of stimulation of diuresis, duration of cardiotonic support, should be used in the treatment of patients with congenital malformations of the anterior abdominal wall.

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