



OPERATIVE TREATMENT OF PEDIATRIC PECTUS EXCAVATUM: CLINICAL AND FUNCTIONAL OUTCOMES



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ABSTRACT

**Background:** Pectus excavatum (PE) is the most common congenital chest wall deformity in children and adolescents and may be associated with cardiopulmonary compromise as well as psychosocial distress. Several surgical techniques have been developed to correct this deformity, including open and minimally invasive approaches. Comparative evaluation of these methods remains essential for optimizing outcomes.

**Objective:** This study aimed to assess and compare the short- and long-term outcomes of three different surgical techniques for PE correction in pediatric patients: Ravitch thoracoplasty, modified thoracoplasty, and the minimally invasive Nuss procedure.

**Methods:** A total of 183 patients aged 3–18 years who underwent surgical correction for PE between 1997 and 2018 were retrospectively analyzed. Patients were divided into three groups: Ravitch thoracoplasty (n=76), modified thoracoplasty (n=77), and Nuss procedure (n=30). Operative parameters, early postoperative complications, duration of pain, hospital stay, and long-term outcomes including relapse and cosmetic results were compared.

**Results:** The Nuss procedure demonstrated the shortest operative time ( $55 \pm 5.8$  minutes), while Ravitch thoracoplasty was associated with greater intraoperative blood loss ( $46.4 \pm 12.5$  mL). The modified thoracoplasty group had significantly shorter postoperative pain duration ( $2.1 \pm 0.7$  days,  $p < 0.05$ ). Pneumothorax occurred in 5.2% of Ravitch cases and 10% of Nuss cases. Excellent cosmetic results were highest in the modified thoracoplasty group (94.8%), followed by the Nuss group (93.3%). Relapse was predominantly observed in the Ravitch group.

**Conclusion:** Modified thoracoplasty and the Nuss procedure demonstrated superior cosmetic and long-term outcomes with lower relapse rates compared to the classical Ravitch technique. Effective postoperative pain management, particularly via intercostal blockade, significantly improved recovery.

**Keywords:** Pectus excavatum; pediatric chest wall deformity; thoracoplasty; Ravitch procedure; Nuss procedure; minimally invasive surgery; surgical outcomes; postoperative complications; relapse; cosmetic results.



**ОПЕРАТИВНОЕ ЛЕЧЕНИЕ ВОРОНКООБРАЗНОЙ ДЕФОРМАЦИИ ГРУДНОЙ  
КЛЕТКИ У ДЕТЕЙ: КЛИНИЧЕСКИЕ И ФУНКЦИОНАЛЬНЫЕ РЕЗУЛЬТАТЫ**

**АННОТАЦИЯ**

**Актуальность:** Воронкообразная деформация грудной клетки (ВДГК) является наиболее распространённой врождённой деформацией грудной стенки у детей и подростков и может сопровождаться нарушением кардиореспираторной функции, а также выраженным психоэмоциональным дискомфортом. Для коррекции данной патологии разработаны различные хирургические методы, включая открытые и малоинвазивные подходы. Сравнительная оценка этих методов имеет принципиальное значение для оптимизации результатов лечения.

**Цель исследования:** Оценить и сопоставить краткосрочные и отдалённые результаты трёх различных хирургических методик коррекции ВДГК у детей: торакопластики по Ravitch, модифицированной торакопластики и малоинвазивной операции по Nuss.

**Материалы и методы:** Проведён ретроспективный анализ 183 пациентов в возрасте от 3 до 18 лет, перенёсших хирургическую коррекцию ВДГК в период с 1997 по 2018 гг. Пациенты были распределены на три группы: торакопластика по Ravitch (n=76), модифицированная торакопластика (n=77) и операция по Nuss (n=30). Сравнивались интраоперационные показатели, ранние послеоперационные осложнения, продолжительность болевого синдрома, сроки госпитализации, а также отдалённые результаты, включая рецидив и косметический эффект.

**Результаты:** Наименьшая продолжительность операции отмечена при выполнении процедуры по Nuss ( $55 \pm 5,8$  мин), тогда как наибольшая интраоперационная кровопотеря зарегистрирована при торакопластике по Ravitch ( $46,4 \pm 12,5$  мл). В группе модифицированной торакопластики отмечено достоверное сокращение длительности послеоперационного болевого синдрома ( $2,1 \pm 0,7$  суток,  $p < 0,05$ ). Пневмоторакс выявлен у 5,2% пациентов после операции по Ravitch и у 10% после процедуры по Nuss. Наилучшие косметические результаты отмечены в группе модифицированной торакопластики (94,8%), затем в группе Nuss (93,3%). Рецидивы преимущественно наблюдались после операции по Ravitch.

**Заключение:** Модифицированная торакопластика и операция по Nuss продемонстрировали лучшие косметические и отдалённые результаты с более низкой частотой рецидивов по сравнению с классической методикой Ravitch. Эффективное послеоперационное обезболивание, в частности межрёберная блокада, способствует более быстрому восстановлению пациентов.

**Ключевые слова:** Воронкообразная деформация грудной клетки; деформация грудной стенки у детей; торакопластика; операция Ravitch; операция Nuss; малоинвазивная хирургия; хирургические результаты; послеоперационные осложнения; рецидив; косметический эффект.

**BOLALAR VA O‘SMIRLARDA GIRDOBSIMON SHAKLIDAGI KO‘KRAK QAFASI  
DEFORMATSIYASINING JARROHLIK DAVOLASH USULLARI: KLINIK VA  
FUNKSIONAL NATIJALAR**

**ANNOTATSIYA**

**Dolzarbliqi:** Girdobsimon shaklidagi ko‘krak qafasi deformatsiyasi (PE) bolalar va o‘smirlar orasida eng ko‘p uchraydigan tug‘ma ko‘krak devori nuqsoni hisoblanadi va yurak-qon tomir hamda nafas olish tizimi faoliyatining buzilishi, shuningdek psixologik noqulaylik bilan kechishi mumkin. Ushbu patologiyani tuzatish uchun ochiq va minimal invaziv jarrohlik usullari ishlab chiqilgan. Mazkur usullarni qiyosiy baholash davolash natijalarini optimallashtirish uchun muhim ahamiyatga ega.



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2 - TOM, MAXSUS SON. 2026

14.00.00 - TIBBIYOT FANLARI ISSN: 3093-8740

**Tadqiqot maqsadi:** Bolalarda PE ni tuzatishning uch xil jarrohlik usuli — Ravitch torakoplastikasi, modifikatsiyalangan torakoplastika va minimal invaziv Nuss operatsiyasining qisqa va uzoq muddatli natijalarini baholash va taqqoslash.

**Materiallar va usullar:** 1997–2018 yillar davomida PE sababli jarrohlik amaliyoti o‘tkazilgan 3–18 yoshdagi 183 nafar bemor retrospektiv tahlil qilindi. Bemorlar uch guruhga ajratildi: Ravitch torakoplastikasi (n=76), modifikatsiyalangan torakoplastika (n=77) va Nuss operatsiyasi (n=30). Operatsiya davomiyligi, erta operatsiyadan keyingi asoratlar, og‘riq davomiyligi, shifoxonada qolish muddati hamda uzoq muddatli natijalar (qaytalanish va kosmetik natija) solishtirildi.

**Natijalar:** Eng qisqa operatsiya vaqti Nuss usulida kuzatildi ( $55 \pm 5,8$  daqiqa), eng katta qon yo‘qotish esa Ravitch torakoplastikasida qayd etildi ( $46,4 \pm 12,5$  ml). Modifikatsiyalangan torakoplastika guruhida operatsiyadan keyingi og‘riq davomiyligi sezilarli darajada qisqa bo‘ldi ( $2,1 \pm 0,7$  kun,  $p < 0,05$ ). Pnevmtoraks Ravitch guruhida 5,2%, Nuss guruhida esa 10% holatda kuzatildi. Eng yuqori kosmetik natijalar modifikatsiyalangan torakoplastika guruhida (94,8%), undan keyin Nuss guruhida (93,3%) qayd etildi. Qaytalanish asosan Ravitch usulida kuzatildi.

**Xulosa:** Modifikatsiyalangan torakoplastika va Nuss operatsiyasi klassik Ravitch usuliga nisbatan yaxshiroq kosmetik va uzoq muddatli natijalarni, shuningdek pastroq qaytalanish darajasini ko‘rsatdi. Ayniqsa, interkostal blokada yordamida samarali og‘riqni boshqarish bemorlarning tezroq tiklanishiga xizmat qiladi.

**Kalit so‘zlar:** Girdobsimon ko‘krak qafasi deformatsiyasi; bolalarda ko‘krak devori deformatsiyasi; torakoplastika; Ravitch operatsiyasi; Nuss operatsiyasi; minimal invaziv jarrohlik; jarrohlik natijalari; operatsiyadan keyingi asoratlar; qaytalanish; kosmetik natija.

## INTRODUCTION

Pectus excavatum (PE) represents the most prevalent congenital deformity of the anterior chest wall and is characterized by posterior depression of the sternum and adjacent costal cartilages. The condition may range from mild cosmetic indentation to severe deformities associated with cardiopulmonary compression and functional impairment [1,2]. In addition to physiological consequences, adolescents frequently experience significant psychosocial distress related to body image concerns.

Surgical correction remains the definitive treatment for moderate to severe PE, particularly in cases with a Haller index  $\geq 3.25$  or documented cardiopulmonary dysfunction. Historically, open techniques such as the Ravitch procedure have been widely employed. With advancements in surgical technology, minimally invasive methods—most notably the Nuss procedure—have gained popularity due to reduced tissue trauma and improved cosmetic results [3,4].

Nevertheless, open approaches continue to be refined. Modified thoracoplasty techniques aim to preserve structural stability while minimizing complications and postoperative pain. Despite widespread use of these methods, direct comparative data on their short- and long-term outcomes remain limited, especially across extended follow-up periods [5].

This study presents over two decades of institutional experience, comparing three distinct surgical strategies for PE correction in children and adolescents. Emphasis is placed on operative parameters, complication profiles, relapse rates, and cosmetic outcomes [6].

## MATERIALS AND METHODS

### Study Design and Population

This retrospective study analyzed 183 pediatric patients aged 3–18 years who underwent surgical correction for PE between 2020 and 2025 in two tertiary pediatric centers in Uzbekistan.

### Group Allocation

Patients were divided into three groups:

- ✓ **Group I (Ravitch thoracoplasty):** 76 patients (41.5%)



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✓ **Group II (Modified thoracoplasty):** 77 patients (42.1%)

✓ **Group III (Nuss procedure):** 30 patients (16.4%)

There were no statistically significant differences between groups in terms of age or sex distribution ( $p > 0.05$ ).

## **Preoperative Evaluation**

Clinical examination included physical assessment and radiographic analysis. The degree of deformity was evaluated via lateral chest radiography, and in severe cases, the Haller index was calculated using computed tomography. Surgical indication included:

- ✓ Haller index  $\geq 3.25$
- ✓ Significant cardiopulmonary dysfunction

## **Surgical Techniques**

### **Ravitch Thoracoplasty**

Involved resection of deformed costal cartilages and sternal osteotomy with external traction fixation (Marshev device) maintained for 30–45 days.

### **Modified Thoracoplasty**

Included parasternal chondrotomy, T-shaped wedge osteotomy of the sternum, and stabilization using Ilizarov needles. One or two needles were inserted depending on age and severity [7,8]. Hardware was removed after 12–18 months.

### **Nuss Procedure**

Performed thoroscopically using a pre-bent metal bar inserted retrosternally and removed after 24 months.

### **Postoperative Management**

All patients received standardized anesthesia and postoperative care. Intercostal Novocain blockade was performed only in the modified thoracoplasty group, resulting in reduced analgesic requirements.

## **Outcome Measures**

### **Short-term Outcomes ( $\leq 10$ days)**

- Operative duration
- Blood loss
- Hospital stay
- Pain duration
- Seroma
- Pleural effusion
- Atelectasis/pneumonitis
- Pneumothorax

### **Long-term Outcomes ( $\leq 2$ years)**

- Cosmetic results
- Relapse (partial or complete)
- Migration of metal structures
- Keloid scar formation
- Mortality

Statistical analysis was performed using SPSS v24. Student's t-test was used; significance set at  $p < 0.05$ .

## **Demographics**

Among 183 patients:

- 124 (67.8%) male
- 59 (32.2%) female

Age distribution showed majority between 6–8 years (30.6%).

Asymmetric deformity was most common (50.3%).



**Table 1. Operative and Postoperative Continuous Variables**

Variable	Ravitch (n=76)	Modified (n=77)	Nuss (n=30)	p-value
Operative time (min)	96 ± 8.6	75 ± 8.9	55 ± 5.8	<0.05
Blood loss (mL)	46.4 ± 12.5	No significant difference	No significant difference	>0.05
Pain duration (days)	5.2 ± 1.3	2.1 ± 0.7	5.32 ± 1.5	<0.05
Hospital stay (days)	Comparable	Comparable	Comparable	>0.05

**Table 2. Early Postoperative Complications**

Complication	Ravitch (n=76)	Modified (n=77)	Nuss (n=30)
Pneumothorax	4 (5.2%)	0	3 (10%)
Pleural effusion	4 (5.2%)	0	3 (10%)
Atelectasis	Present	0	Present
Pneumonitis	Present	0	Present

**Table 3. Long-Term Outcomes (Up to 2 Years)**

Outcome	Ravitch (n=76)	Modified (n=77)	Nuss (n=30)	p-value
Excellent cosmetic result	73.5%	94.8%	93.3%	<0.05
Partial relapse	4.1%	1.3%	3.3%	<0.05
Complete relapse	2.7%	0%	0%	<0.05
Metal migration	0%	0%	3.3%	—
Mortality	0%	0%	0%	—

## DISCUSSION

The evolution of PE surgery reflects ongoing efforts to reduce morbidity while improving cosmetic outcomes. Although the Ravitch technique remains historically significant, it demonstrated higher relapse and complication rates in this series [9].

The Nuss procedure provided shorter operative time and favorable cosmetic outcomes, consistent with contemporary literature. However, pneumothorax incidence was slightly higher, possibly reflecting thoracoscopic manipulation [10,11].

The modified thoracoplasty method demonstrated superior pain control and cosmetic results. The use of Ilizarov needle stabilization offers a cost-effective alternative to metal bars and may reduce hardware-related complications.

Pain control is critical in preventing pulmonary complications. Intercostal blockade significantly reduced analgesic requirement and may explain absence of atelectasis in this group.

Hospital stay duration was similar across groups, though longer than reported internationally, likely reflecting institutional and socioeconomic factors.

Relapse rates were lowest in the modified technique, highlighting structural stability advantages.



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**CONCLUSION**

Modified thoracoplasty and the Nuss procedure demonstrate superior cosmetic and long-term outcomes compared with classical Ravitch thoracoplasty. The modified technique offers additional benefits including reduced postoperative pain and minimal hardware-related complications.

Early surgical correction, careful technique selection, and optimized postoperative pain management are key determinants of successful outcomes in pediatric PE surgery.

**References:**

1. Aly, A. M., & Nasr, A. (2020). Surgical correction of pectus excavatum in children: A comparative review of techniques and outcomes. *Journal of Pediatric Surgery*, 55(6), 1028–1036. <https://doi.org/10.1016/j.jpedsurg.2020.01.012>
2. Jaroszewski, D. E., Johnson, K., McMahon, L., & Notrica, D. (2016). Sternal elevation before substernal bar placement in pectus excavatum repair: A novel approach to improve safety. *Annals of Thoracic Surgery*, 101(2), 772–776. <https://doi.org/10.1016/j.athoracsur.2015.09.081>
3. Kelly, R. E., Jr., Obermeyer, R. J., & Nuss, D. (2016). Diminished pulmonary function in pectus excavatum: From denying the problem to finding the mechanism. *Annals of Cardiothoracic Surgery*, 5(5), 466–475. <https://doi.org/10.21037/acs.2016.08.05>
4. Lopez, M., Patoir, A., Costes, F., et al. (2018). Preliminary study of the impact of pectus excavatum on cardiopulmonary function in children. *European Journal of Cardio-Thoracic Surgery*, 53(3), 552–558. <https://doi.org/10.1093/ejcts/ezx364>
5. Nuss, D., Obermeyer, R. J., & Kelly, R. E., Jr. (2016). Nuss bar procedure: Past, present and future. *Annals of Cardiothoracic Surgery*, 5(5), 422–433. <https://doi.org/10.21037/acs.2016.08.04>
6. Obermeyer, R. J., & Goretsky, M. J. (2016). Chest wall deformities in pediatric surgery. *Surgical Clinics of North America*, 96(5), 1167–1189. <https://doi.org/10.1016/j.suc.2016.05.009>
7. Park, H. J., Sung, S. W., Park, J. K., Kim, J. J., & Jeon, H. W. (2015). How early can we remove the pectus bar after the Nuss procedure? Long-term results. *European Journal of Cardio-Thoracic Surgery*, 47(5), 897–902. <https://doi.org/10.1093/ejcts/ezu357>
8. Rothenberg, S. S. (2018). Thoracoscopic repair of pectus excavatum in children. *Seminars in Pediatric Surgery*, 27(3), 150–155. <https://doi.org/10.1053/j.sempedsurg.2018.05.005>
9. Schaarschmidt, K., Kolberg-Schwerdt, A., Lempe, M., & Jaeschke, U. (2017). Long-term follow-up after pectus excavatum repair: Evaluation of recurrence and patient satisfaction. *European Journal of Pediatric Surgery*, 27(5), 423–430. <https://doi.org/10.1055/s-0036-1597580>
10. St Peter, S. D., Sharp, S. W., Holcomb, G. W., III, & Ostlie, D. J. (2016). Clinical outcomes of minimally invasive pectus excavatum repair in children. *Journal of Pediatric Surgery*, 51(6), 935–939. <https://doi.org/10.1016/j.jpedsurg.2016.02.060>
11. Zhang, Y., Wang, H., Li, Y., et al. (2020). Comparison of minimally invasive repair versus open repair for pectus excavatum: A meta-analysis. *Interactive Cardiovascular and Thoracic Surgery*, 30(1), 73–80. <https://doi.org/10.1093/icvts/ivz240>