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Research on Surgical Strategies for the Correction of Pectus Excavatum in Children via an Extrapleural Approach

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Abstract: *Objective*: To investigate the clinical efficacy and safety of the extrapleural approach versus the traditional intrathoracic approach in minimally invasive correction of pectus excavatum in children, providing a more scientific basis for selecting a more appropriate surgical method in clinical practice. *Methods*: This study included 50 children who underwent pectus excavatum correction at Harbin Children's Hospital from January 2023 to January 2025. All patients were divided into two groups based on surgical approach: the observation group (n = 26) and the control group (n = 24). Children in the observation group underwent correction surgery via an extrapleural approach, while those in the control group underwent correction surgery via the traditional intrathoracic approach. Both groups underwent Nuss bar placement surgery under thoracoscopic guidance. Intraoperative indicators were compared between the two groups, including operative time, blood loss, pain scores at 24 and 48 hours postoperatively, hospital stay duration, thoracic correction outcomes, and the incidence of complications during a 6-month postoperative follow-up. *Results*: The intraoperative blood loss in the observation group was significantly lower than that in the control group ($p < 0.05$), and the pain scores at 24 and 28 hours postoperatively were also significantly lower ($p < 0.05$). The improvement in thoracic index postoperatively was relatively similar between the two groups, with no statistically significant difference ($p > 0.05$). During the 6-month postoperative follow-up period, no complications such as pneumothorax, hemothorax, pleural effusion, plate displacement, or infection occurred in the observation group, whereas the overall complication rate in the control group was 25%, showing a significant difference ($p < 0.05$). *Conclusion*: The extrapleural approach for corrective surgery can ensure the efficacy of thoracic deformity correction while reducing intraoperative blood loss, lowering the incidence of complications, alleviating postoperative pain, and accelerating recovery. It is a safe and effective approach for minimally invasive Nuss correction of pediatric pectus excavatum.

Keywords: Pectus excavatum; Extrapleural approach; Thoracoscopy; Nuss procedure; Pediatric surgery

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1. Introduction

Pediatric pectus excavatum (PE) is a common thoracic deformity characterized primarily by sternal depression and

a shortened anteroposterior diameter of the thoracic cage. In severe cases, it may compress the cardiopulmonary organs, thereby affecting cardiopulmonary function and exercise tolerance [1].

Additionally, the noticeable depression in the chest of children can easily trigger negative emotions, increasing the risk of low self-esteem and social difficulties, and may also impact normal development and daily life. Therefore, timely and effective treatment is crucial for the physical and mental health of affected children.

The NUSS procedure, as a minimally invasive orthopedic surgery, is now widely applied. This surgery involves the implantation of a metal plate to elevate the sternum, thereby restoring the normal shape and function of the thoracic cage. The advantages of this technique lie in its minimal invasiveness and rapid recovery. In contrast, the traditional intrathoracic approach requires penetration of the pleura during surgery, making it prone to complications such as pneumothorax, hemothorax, pleural effusion, and mediastinal vascular injury in pediatric patients. Literature indicates that the incidence of postoperative complications in patients undergoing traditional intrathoracic approach surgery abroad has reached 21% to 67%, while in China, due to richer surgical experience, the incidence has been reduced to around 15%, yet further improvement is still needed [2].

For younger children or those with more severe thoracic deformities, the intraoperative risks and postoperative complication rates are even higher, making safe and reliable modified techniques particularly crucial.

In recent years, the modified extrapleural approach has gradually become a key focus of clinical research. This surgery is characterized by its operation through the extrapleural space, effectively avoiding damage to the thoracic cavity and mediastinal muscles, thereby reducing the incidence of complications and promoting postoperative recovery. Combined with thoracoscopic visualization, it can clearly display the boundaries of mediastinal vessels and the heart, effectively reducing the risks associated with blind operations. Meanwhile, by optimizing the plate fixation technique, such as the “W8 + S3” method, the stability of the plate can be increased, thereby reducing the probability of postoperative displacement and recurrence [3]. Single-center research results have indicated that even in complex cases, the extrapleural approach can successfully and safely facilitate the implantation of double plates, whereas the traditional intrathoracic approach is more prone to causing pleural effusion after double plate implantation.

Although preliminary studies suggest that the extrapleural approach offers certain advantages, systematic clinical data remains relatively limited thus far, particularly regarding its applicability in children of different ages, genders, and varying degrees of illness severity, which still requires further validation.

This study, based on a project approved by the Health Commission of Heilongjiang Province, selected children with pectus excavatum from Harbin Children’s Hospital and employed a modified extrapleural NUSS procedure, comparing it with a group undergoing the traditional intrathoracic approach. The focus was on analyzing surgical safety, postoperative recovery, complications, and the effectiveness of thoracic correction, providing scientific evidence and operational references for minimally invasive correction of pediatric pectus excavatum.

2. Materials and methods

2.1. General information

This study included 50 pediatric patients with pectus excavatum who met surgical indications at Harbin Children’s Hospital, with 26 cases in the observation group and 24 cases in the control group. There were 31 males and 19 females, with ages ranging from 3 to 12 years and an average age of (8.21 ± 1.03) years. Based on the Haller index, all patients were classified into mild (2.5–3.25), moderate (3.25–3.5), and severe (> 3.5) groups, with

balanced distribution across groups. Prior to surgery, all patients underwent three-dimensional reconstruction of chest CT scans, echocardiography, and electrocardiography to evaluate thoracic deformities and cardiac function, providing references for surgical planning.

2.1.1. Inclusion criteria

(1) Meeting the diagnostic criteria for pectus excavatum with a thoracic index (HI) ≥ 3.2
(2) Completion of preoperative evaluation and having indications for Nuss procedure
(3) Aged 3–16 years and able to cooperate with follow-up
(4) Family members signing informed consent for clinical research

2.1.2. Exclusion criteria

(1) Patients with extremely severe deformities requiring thoracotomy
(2) Those with severe pleural adhesions due to previous thoracotomy or pleural cavity surgery
(3) Patients with severe cardiopulmonary dysfunction or coagulation abnormalities
(4) Those with immune abnormalities or potential for severe rejection reactions
(5) Patients unable to complete follow-up

2.2. Methods

Both groups underwent the placement of Nuss plates assisted by thoracoscopy. In the observation group, tunnels were established in the extrapleural space without entering the pleural cavity; in the control group, the stent channels were completed through an intrapleural approach. Perioperative management was standardized, including preoperative evaluation, anesthesia protocols, pain management, drainage, and anti-infection measures. Chest tubes and plates were removed postoperatively based on recovery status.

2.3. Observation indicators

(1) Intraoperative indicators
Operation time, blood loss
(2) Postoperative recovery
Pain scores (VAS) at 24 h and 48 h, and length of hospital stay
(3) Orthopedic effect
Improvement rate of thoracic index
(4) Postoperative complications
Pneumothorax, pleural reaction, atelectasis, plate displacement, etc.
(5) Follow-up
Complications at 6 months.

2.4. Statistical methods

SPSS 26.0 was used. Measurement data were expressed as mean ± standard deviation, and comparisons between two groups were made using the *t*-test; count data were analyzed using the χ^2 test or Fisher's exact test. A *p*-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of surgical and recovery indicators between the two groups

The observation group had shorter operation time, less intraoperative blood loss, and a shorter hospital stay compared to the control group ($p < 0.05$), indicating that this approach can shorten surgical and recovery times and reduce bleeding, as shown in **Table 1**.

Table 1. Comparison of surgical and recovery indicators between the two groups of children ($\bar{x} \pm s$)

Group	Operative time (min)	Intraoperative blood loss (mL)	Hospital stays (days)
Observation group (n = 26)	75.35 ± 10.20	8.54 ± 3.15	6.32 ± 1.27
Control group (n = 24)	88.77 ± 12.51	15.42 ± 4.27	8.31 ± 1.55
t-value	5.124	7.110	5.456
p-value	0.001	0.001	0.001

3.2. Comparison of postoperative complications between the two groups

The observation group had lower incidences of pneumothorax, hemothorax, and air leakage compared to the control group, with a significantly reduced overall complication rate ($p < 0.05$), demonstrating a marked safety advantage, as shown in **Table 2**.

Table 2. Comparison of postoperative complications between the two groups of children (n, %)

Group	Pneumothorax	Hemothorax	Pleural effusion	Plate displacement	Infection	Total complication rate
Observation group (n = 26)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Control group (n = 24)	2 (8.3%)	1 (4.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3/24 (12.5%)
χ^2-value	4.00	2.00	1.00	1.00	1.00	7.50
p-value	0.046	0.157	0.317	0.317	0.317	0.006

3.3. Postoperative pain scores and thoracic cage recovery in the two groups

The observation group exhibited significantly lower postoperative pain compared to the control group ($p < 0.05$). Although the improvement rate in thoracic cage index was higher in the observation group, the difference was not statistically significant ($p > 0.05$). This indicates that the extrapleural approach offers superior postoperative comfort, as shown in **Table 3**.

Table 3. Comparison of postoperative pain and thoracic cage recovery between the two groups of children ($\bar{x} \pm s$)

Group	VAS score at 24 h	VAS score at 48 h	Thoracic index improvement rate (%)
Observation group (n = 26)	1.82 ± 0.61	1.27 ± 0.42	85.64 ± 7.84
Control group (n = 24)	3.52 ± 0.86	2.53 ± 0.79	83.44 ± 8.75
t-value	6.203	7.111	1.039
p-value	0.001	0.001	0.284

4. Discussion

Pediatric pectus excavatum is a highly prevalent thoracic deformity that not only affects the physical appearance of children but may also cause long-term disturbances to their cardiopulmonary function and mental health [4]. The NUSS procedure, a minimally invasive orthopedic surgery, utilizes steel plates to support the sternum, aiming to restore its anteroposterior diameter. This technique is widely applied in clinical settings due to its advantages of minimal trauma and rapid recovery. In contrast, the traditional intrathoracic approach requires penetration of the pleural cavity during the operation, and the operator's visual field is limited, which can easily lead to damage to thoracic organs, triggering complications such as pneumothorax, hemothorax, pleural effusion, and mediastinal vascular injury, with higher risks in younger children or those with severe thoracic deformities. This study compared the clinical outcomes of the traditional intrathoracic approach and the extrapleural approach in the correction of pediatric pectus excavatum. The results showed that the intraoperative blood loss in the observation group was significantly lower than that in the control group ($p < 0.05$), indicating that the extrapleural pathway has a milder impact on the pleura and lung tissue, helping to reduce the risk of vascular injury. In terms of operative time, the extrapleural approach still demonstrated certain operational advantages. Postoperative pain scores are a key factor in assessing the comfort of patients undergoing minimally invasive surgery [5]. This study revealed that the VAS scores of the observation group at 24 and 48 hours postoperatively were significantly lower than those of the control group ($p < 0.05$), suggesting that the extrapleural approach can effectively reduce surgical traction on the pleura and damage to tissue structures. The hospital stay in the observation group was also significantly shorter, further validating that the extrapleural approach can accelerate recovery, reduce medical costs, and alleviate economic burdens.

In terms of complications, none of the children in the observation group developed complications such as pneumothorax, hemothorax, pleural effusion, steel plate displacement, or infection. In contrast, two children in the control group developed pneumothorax and one developed hemothorax, resulting in an overall complication rate of 12.5% ($p < 0.05$). The results indicate that the extrapleural approach significantly reduces the incidence of intraoperative and postoperative complications, enhancing surgical safety. This is because the extrapleural approach operates through an extrapleural tunnel, avoiding direct exposure of the thoracic cavity and mediastinal organs, thereby effectively reducing surgical risks.

Regarding the thoracic deformity correction effect, both groups of children showed improvement in thoracic index after surgery, with good outcomes. The observation group demonstrated slightly better results, but the difference was not statistically significant ($p > 0.05$). This suggests that while both approaches can ensure satisfactory correction outcomes, the extrapleural approach offers a balance between intraoperative safety and postoperative comfort. Considering indicators such as intraoperative blood loss, postoperative pain scores, and hospital stay duration, the extrapleural approach demonstrates overall clinical advantages. However, it should be noted that the extrapleural approach is more challenging and requires higher technical proficiency from the operator. The operator must be well-versed in the extrapleural anatomical structures and steel plate channel manipulation techniques, and utilize the visualization capabilities of thoracoscopy to ensure safety and avoid blind spot injuries [6]. For children with severe thoracic deformities or a history of previous pleural cavity surgeries, the difficulty and complexity of the operation will be higher. Therefore, preoperative evaluation and intraoperative preparation are particularly crucial. The adoption of an optimized steel plate fixation protocol, such as the "W8 + S3" method, can enhance support stability and reduce postoperative displacement and recurrence. The results of this study confirm that the combination of an extrapleural approach and thoracoscopic-assisted NUSS procedure

offers significant advantages in the correction of pediatric pectus excavatum. This approach is characterized by minimal surgical trauma, low intraoperative blood loss, rapid recovery, and a low incidence of complications, with correction outcomes comparable to those of traditional approaches [7]. This surgical method not only enhances the safety and comfort of the procedure for children but also shortens the recovery period and reduces the burden on families and healthcare systems, providing a reference for the clinical application of minimally invasive surgeries.

5. Conclusion

In summary, the extrapleural approach provides a surgical option for minimally invasive correction of pediatric pectus excavatum that ensures therapeutic efficacy while offering higher safety and greater comfort. Future multi-center studies can be conducted to verify its long-term efficacy and optimize the technique to provide individualized surgical plans.

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Disclosure statement

The authors declare no conflict of interest.

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