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Systematic Review

# Cryoanalgesia for Pectus Excavatum Repair: A Systematic Review

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## Abstract

Cryoanalgesia, or cryoablation, has emerged as a promising approach for postoperative pain control in pediatric patients undergoing minimally invasive pectus excavatum repair. Traditional pain management strategies, including thoracic epidural and patient-controlled analgesia, can effectively reduce pain but often lead to increased hospital stays and opioid dependency, which may delay recovery and heighten risks. Cryoablation addresses these challenges by targeting intercostal nerves, temporarily blocking pain transmission and minimizing opioid requirements. This systematic review analyzes studies sourced from PubMed that evaluate cryoanalgesia's effectiveness, comparing short- and long-term outcomes of pain control, functional recovery, and patient quality of life following the Nuss procedure. Findings show that cryoanalgesia significantly reduces acute pain, hospital stay length, and opioid use. However, residual symptoms, including mild discomfort and chest sensations, persist in some patients, suggesting a need for improved long-term management and anticipatory guidance. This review provides evidence supporting cryoanalgesia as a beneficial alternative for pain control in pediatric pectus excavatum repair while addressing gaps in research on long-term symptomatology and quality of life.

***Keywords:** Cryoablation, Pectus Excavatum, Analgesia, Anesthesia, Surgery*

## Introduction

Pectus excavatum (PE) is the most prevalent congenital chest wall deformity, affecting approximately 1 in 1,000 children, with a predominance in males [1]. The minimally invasive Nuss procedure or MIRPE, which involves inserting a metal bar to reshape the chest wall, has become a standard correction technique for PE, yet the postoperative pain associated with this procedure can be severe [2]. Effective pain management is therefore essential to support recovery and minimize hospitalization, but conventional methods such as thoracic epidural analgesia and patient-controlled analgesia (PCA) present challenges, including prolonged hospital stays and opioid dependence, with the risk of long-term adverse effects [3,4].

In recent years, cryoanalgesia has been introduced as a novel technique to control postoperative pain in PE repairs [5]. This approach targets intercostal nerves, delivering a controlled, localized freeze (≈ -70ºC) that temporarily disrupts nerve signaling pathways, which reduces pain transmission without the need for continuous narcotic administration.

Cryoanalgesia has shown potential in significantly decreasing the length of hospital stays and reducing opioid consumption while preserving effective pain control [6].

Despite the clear benefits of cryoanalgesia in managing acute postoperative pain, there are gaps in understanding its impact on long-term pain outcomes and overall patient satisfaction. Persistent symptoms such as residual pain, numbness, or "popping" sensations in the chest may limit some patients' recovery, although the extent of these effects remains underexplored in current literature [7,8]. This systematic review aims to summarize the efficacy of cryoanalgesia in acute and long-term pain management post-pectus excavatum repair, assessing both the short-term pain control benefits and the potential for long-term complications.

## Methods

An UpToDate, DynaMed, Europe PMC, Biblioteca Virtual en Salud (BVS), Google Scholar and PubMed search was carried out with Medical Subject Headings (MeSH) terms by the syntax: ("cryoanalg*"[Title] OR "cryoab*"[Title]) AND ("pectus"[Title] OR "excavat*"[Title] OR "MIRPE"[Title] OR "Nuss"[Title] OR "ravitch"[Title] OR "surg*"[Title]). All relevant and non-duplicated articles published in English and Spanish in the last ten years were included in this review, after a blinded process of three reviewers filtering by title, abstract and finally by full manuscript.

## Results and Discussion

The review included 30 selected studies, focusing on cryoanalgesia's impact on postoperative pain and functional outcomes in pectus excavatum repair. The studies were primarily observational and randomized trials comparing cryoanalgesia with conventional methods such as epidural and PCA. Key findings indicate that cryoanalgesia offers significant advantages in reducing acute postoperative pain and opioid requirements. In nearly all studies, patients receiving cryoanalgesia reported lower pain scores on the Numeric Rating Scale (NRS) within 24 hours post-surgery, with a substantial reduction in opioid consumption compared to those who received thoracic epidural or PCA [9,10]. Cryoanalgesia was associated with a shorter average hospital stay, typically by 24–48 hours, due to faster pain resolution and the absence of continuous pain management interventions such as PCA pumps. In some studies, parents reported their child's pain as "better than expected," reinforcing that cryoanalgesia may enhance patient and caregiver satisfaction with the postoperative experience [11].

Long-term follow-up studies reveal a mixed picture of residual symptoms. A minority of patients continued to experience mild chest discomfort, numbness, or "popping" sensations at three months postoperatively. These symptoms did not typically interfere with daily activities, yet some patients required intermittent non-narcotic analgesics. Additionally, two studies documented a higher incidence of mild neuropathic symptoms at three months in patients undergoing cryoanalgesia, though these symptoms were not perceived as significantly distressing [12]. Cryoanalgesia has shown efficacy as a pain management tool in pediatric pectus excavatum repair, reducing acute pain, opioid use, and hospital stay length. These benefits make it a valuable alternative to traditional pain control methods, such as thoracic epidural and PCA, which are associated with prolonged recovery times and the risk of opioid-related side effects. The following discussion will address the clinical advantages, limitations, and areas for future research based on the existing literature.

### 1. Clinical Advantages

Cryoanalgesia's primary advantage lies in its ability to manage pain effectively without continuous medication administration. The nerve-freezing technique temporarily disrupts pain transmission, resulting in lower pain scores during the immediate postoperative period. Cryoanalgesia patients demonstrate shorter hospital stays, reduced opioid dependence, and improved comfort, which may lower healthcare costs and optimize resource use [13,14]. In a retrospective cohort study included 62 patients undergoing Nuss procedure: 15 who received epidurals, 18 cryoablation, and 29 with ERAS (Enhanced Recovery After Surgery), cryoablation was associated with a 62.3% ($p < 0.001$) decrease in length of stay, an 86.6% ($p < 0.001$) decrease in inpatient morphine milligram equivalents, and a 72.9% ($p < 0.001$) decrease in discharge opioids. Cryoablation was additionally associated with 24.5% ($p = 0.02$) longer operative times and 46.4% ($p= 0.04$) higher postoperative day one pain scores. Subsequent implementation of an ERAS protocol was associated with a further 82.8% ($p = 0.04$) decrease in discharge opioids and a 25% ($p = 0.04$) decrease in postoperative day one pain scores [15].

### 2. Long-Term Outcomes

Although cryoanalgesia is effective for acute pain, questions remain about its long-term effects. The literature suggests that mild symptoms such as numbness, tingling, or "popping" sensations may persist, although these are generally non-debilitating. Neuropathic pain, characterized by burning or tingling, appeared in a small percentage of patients, indicating that further investigation is needed to understand the prevalence and impact of these symptoms over time [16-18]. DiFiore et al. performed a prospective study of 121 patients undergoing Nuss bar placement with cryoablation for pectus excavatum to assess sensory recovery. In this study patients received cryoablation from T3-T8 and were followed at scheduled intervals. After the procedure, median time to normal sensation was 6.0 (range 1-12) months. This was achieved postoperatively by 14.9% at 3 months, 62.3% at 6 months, 85.1% at 9 months, and 98.3% at 12 months. 1.7% had a small area of persistent/permanent numbness in the lower central sternum; and the most common altered sensation was hypersensitivity which occurred in 20.7%. Hypersensitivity began on average at 3.0 months postoperatively (range 0.25-6 months) and lasted a median of 1.0 (range 0.5-9) months. Only 5.8% described their altered sensation as painful, and all of these were successfully treated with gabapentin and/or capsaicin cream. All others resolved spontaneously, with no description of chronic neuropathic pain [19,20].

### 3. Comparison with Traditional Pain Control

Traditional pain control modalities remain effective but are associated with higher opioid use and longer hospitalizations. Studies indicate that cryoanalgesia patients achieve similar, if not superior, pain control outcomes while reducing the burden of narcotic use, an essential consideration given the current emphasis on minimizing opioid exposure in pediatric populations [21,22]. The reduced reliance on opioids among cryoanalgesia patients may decrease the risk of dependency and other opioid-related complications, aligning with goals of enhanced recovery and patient safety. A retrospective review conducted in 579 patients ≤21 years old who underwent MIRPE (82.8% male, mean age 15.4 ± 2.0 years), cryoanalgesia was performed in 73.5% of patients. The total inpatient oral morphine equivalents (OME) use was less in the cryo group (0.89 ± 0.68 vs. 1.6 ± 0.5 OME/kg/day; $p < 0.001$), additionally, patients who underwent cryo were prescribed significantly less OME at discharge compared to the no-cryo group (3.9 ± 1.7 vs. 10.0 ± 4.1 OME mg/kg, $p < 0.001$). There was no statistically significant difference in the proportion of patients who required an opioid prescription refill (cryo 12.4% vs. no-cryo 11.5%, $p = 0.884$) or were readmitted (cryo 5.3% vs. no-cryo 4.6%, $p = 0.833$) [23]. Similarly, a cohort study of 66 patients undergoing Nuss procedure, analyzed the effectiveness of intercostal nerve cryoablation combined with patient-controlled systemic opioid analgesia (n=33) compared with continuous epidural analgesia (CEA) combined with PCA (n=33). The authors described that the cryoablation group exhibited lower NRS pain scores on postoperative day 1 and 2 ($p = 0.002$, $p = 0.001$) and a shorter length of stay (LOS): 3 vs. 6 days ($p < 0.001$). Furthermore, cryoablation resulted in less patients requiring opioids at discharge (30.3 vs. 97.0%; $p < 0.001$) and 1 week after surgery (6.1 vs. 45.4%; $p< 0.001$). In the CEA group, gabapentin use was more prevalent (78.8 vs. 18.2%; $p < 0.001$), although no neuropathic pain was reported [24].

### 4. Limitations of Current Research

Current research on cryoanalgesia is limited by short follow-up durations and the reliance on patient-reported outcomes, which can introduce bias. Most studies are observational, and randomized trials are few. Standardized methodologies and long-term studies are needed to validate these findings, particularly in assessing quality-of-life metrics beyond the immediate postoperative period [25,26].

### 5. Future Research Directions

Future studies should prioritize evaluating cryoanalgesia's impact on long-term recovery, including persistent symptoms and functional limitations. Additionally, assessing psychological outcomes may be beneficial, as severe postoperative pain has been linked to ongoing distress in some patients. Larger, multi-institutional trials may help establish consensus guidelines for cryoanalgesia in pediatric pectus excavatum repair and explore optimal dosing protocols [27-30].

## Conclusion

Cryoanalgesia offers a promising approach for managing postoperative pain in pediatric pectus excavatum repair, with significant reductions in acute pain and opioid use. Despite its advantages, mild long-term symptoms persist in some cases, highlighting the need for comprehensive follow-up. Further studies are necessary to optimize cryoanalgesia protocols and ensure sustained quality of life improvements.

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