

Research Paper

Use of cryoanalgesia in the treatment of pectus excavatum in children by the Nuss method – single center retrospective study

Michał Szostawicki¹, Michał Tomasz Puliński¹, Tomasz Janowicz¹,
Robert Marguła¹, Filip Krupienicz¹, Paulina Gisman¹, Michał Matecki¹,
Katarzyna Anna Szymak¹, Aleksandra Wochna¹

Department of Surgery, School of Medicine, Collegium Medicum, University of Warmia and Mazury in Olsztyn, Poland

ARTICLE INFO

Article history

Received: December 24, 2025

Accepted: February 25, 2026

Available online: May 25, 2026

Keywords

Nuss procedure

Opioids

Pectus excavatum

Cryoanalgesia

Pediatric surgery

Doi

<https://doi.org/10.31648/paom/218601>

User license

This work is licensed under

a [Creative Commons Attribution – NonCommercial – NoDerivatives 4.0 International License](#).



ABSTRACT

Introduction: The Nuss procedure is the gold standard for correcting pectus excavatum. Despite its effectiveness, the postoperative period is often associated with significant pain, which may persist for weeks and typically requires intravenous analgesia, often opioid-based. Cryoanalgesia, a reversible method that induces temporary intercostal nerve block, offers a safe alternative providing both early and long-lasting pain relief.

Aim: This study evaluates the impact of intraoperative intercostal nerve cryoanalgesia on postoperative pain intensity and hospitalisation duration in patients undergoing the Nuss procedure for pectus excavatum.

Material and methods: A retrospective analysis was performed on 57 patients treated over a 7-year period at a single centre. Patients were divided into two groups: those who received intraoperative cryoanalgesia ($n = 41$) and those without additional intraoperative analgesia ($n = 16$). Statistical analysis was performed using the Mann-Whitney test and Spearman rank correlation, with significance set at $p < 0.05$.

Results and discussion: Among the 57 patients, 53 (93%) were male, with a mean Haller Index of 3.98 and Correction Index of 33.78. Cryoanalgesia was applied in 71.9% of cases. Patients treated with cryoanalgesia demonstrated shorter hospital stays compared with the control group (3 ± 2 days vs. 5.5 ± 2 days; $p < 0.001$). Postoperative pain intensity measured by NRS was comparable between groups; however, opioid requirements were significantly lower in the cryogroup on day 3 (34% vs. 69%; $p = 0.02$) and day 4 (7% vs. 62.5%; $p < 0.001$).

Conclusions: Intraoperative cryoanalgesia reduces hospitalisation time and postoperative opioid use, offering an effective adjunct for pain management after the Nuss procedure.

1. INTRODUCTION

Pectus excavatum is among the most common congenital deformities, occurring in 1 per 400 births, 4–5 times more often in the male sex. The defect involves the posterior lowering of the lower half of the sternum with a curvature of the ribs joined at an equal level.¹ The exact cause of the deformity is not known, with probable causes including increased intrauterine pressure compressing the thorax, rickets, and diaphragm-related disorders causing compression of the sternum. It frequently coexists with Marfan syndrome, occurring in approximately 5%–10% of patients.^{2,3} The most common method for assessing the degree of pectus excavatum deformity is the Haller Index, which is determined by CT imaging. This is the quotient of the transverse dimension of the chest at its widest point to the distance between the posterior wall of the sternum and the anterior wall of the spine at its shortest dimension.^{1,12} The gold standard of the surgical treatment of pectus excavatum is the minimally invasive Nuss method,² which involves guiding a previously formed plate, adjusted to the patient, under the sternum in order to remedy the defect. Postoperative pain control after the Nuss surgery mainly relies on patient-controlled intravenous analgesia, thoracic epidural anaesthesia, and local or regional nerve blockades. The disadvantage of the above systems is the duration of action, as they provide relatively short pain control, whereas pain after the Nuss procedure persists for 2 to 4 weeks. Modern cryoanalgesia, as a technique using negative temperatures, is used in medicine to treat acute and chronic pain. Cryoanalgesia, which has been a method for treating pain for thousands of years, is widely used in many areas of medicine. The use of intercostal nerve cryoanalgesia, i.e., an analgesic treatment method based on freezing the nerves with temperatures of –50 to –70 degrees for a specific period of time, enables an analgesic effect for 4–6 weeks or longer, which is determined by the time of axonal regeneration.^{3,15}

2. AIM

The aim of the article is to investigate the effect of intraoperative intercostal nerve cryoanalgesia on the reduction of hospital time and postoperative pain in patients following the Nuss procedure for pectus excavatum.

3. MATERIAL AND METHODS

3.1. Retrospective review

The study involved a retrospective analysis of the medical histories of 57 patients operated on at the Research and Teaching Department of Paediatric Surgery and Urology with the Vascular Lesion Treatment Centre in the Regional Specialised Children's Hospital in Olsztyn from 1 January 2015 to 31 December 2022. The analysis covered the medical histories of patients who were operated on using the Nuss

method for pectus excavatum. The study compared two patient groups – the first, in which the cryoanalgesia procedure was performed (CG – cryoanalgesia group), and the second group of patients not subjected to intercostal nerve cryoanalgesia (NCG – non-cryoanalgesia group). The first operation using cryoanalgesia took place in March 2021 and it marked a point between those two groups

The median age of patients with cryoanalgesia was 15.4 years, while the median age in the group without cryoanalgesia was 16.2 years. In the first group, the median Haller Index (HI) was 4.12 and the median Correction Index (CI) was 35.78. In the second group, without cryoanalgesia, a median HI was 4.99 and a median CI was 41.23.

3.2. Analysis

The distribution of the variables was examined using the Shapiro-Wilk test. Non-parametric tests were used for the analysis, as the distribution of the variables was not close to normal. The two medians were compared using the Mann-Whitney test. The strength of the linear relationship of the quantitative variables was assessed using the Spearman rank correlation coefficient. The level of statistical significance was adopted to be $p < 0.05$. Statistical analysis was carried out using STATISTICA software version 13.

3.3. Surgical and cryoanalgesia technique

The surgery was performed under general anaesthesia, using single-lumen tube intubation. Due to the intravenous use of lignocaine, no infiltration anaesthesia was used for surgical wounds. The procedure was performed using the Nuss method, modified to include sternal traction, which was carried out using a sternal steel suture. Thoracoscopy was performed on the right side at the level of the III/IV intercostal space to visualise the mediastinum. Small incisions were made on both sides of the chest, in the anterior median axillary line, while planning the insertion site for the plates in relation to the greatest depth of the defect. One or two metal corrective plates, individually adjusted to the patients, were then introduced and rotated 180 degrees along its long axis to obtain the optimal shape of the patient's chest. The corrective plates were stabilised on both sides by connecting them using bolts, thus obtaining a stable structure and preventing the possibility of subsequent migration and rotation of the plate. A cryoprobe was inserted through the same incisions under visual control, introducing it near the neurovascular bundle at the lower pole of the rib. The cryoprobe was then used to perform the intercostal nerve freezing procedure. The level of cryoanalgesia performance was one intercostal space below and one intercostal space above the site of plate insertion into the chest. Cryoprobe operation parameters were set at 120 seconds, and the temperature it reached was –70 °C. The C3 CryoSystem device from Inomed was used for the procedure.

3.4. Pharmacological pain management and data collection

During the perioperative period, the pain level was measured 10 times a day and assessed according to the Numerical

Rating Scale (NRS). The average score for each patient was then obtained. The management of postoperative pain in patients after Nuss surgery with or without cryoanalgesia involved the use of drugs from the opioid group, topical analgesics, non-steroidal anti-inflammatory drugs, metamizole and acetaminophen. The opioids used, including morphine, nalbuphine, sufentanil and oxycodone, were used via a PCA pump or as intravenous infusions. Benzodiazepines (Dormicum) were used as preoperative premedication. In both groups, the standard postoperative pain management protocol consisted of morphine administered via a patient-controlled analgesia (PCA) pump in combination with NSAIDs and acetaminophen, given at maximum daily doses. Intravenous infusions of lignocaine and a magnesium sulphate solution were used as coanalgesics. A clinical trial analysed if opioids were used in patients after surgery, depending on the performance of cryoanalgesia and the day after surgery.

All analgesic medications used postoperatively were used according to a standardized postoperative pain management protocol.

All patients were provided with information regarding this treatment method, and consent was obtained for such an approach.

4. RESULTS

4.1. Patients

The study group comprised 57 patients: 53 males (93%) and 4 females (7%). The average Haller Index was 3.98. The average Correction Index was 33.78. The Nuss procedure involving intercostal nerve cryoanalgesia was performed in 41 patients (71.9% – CG). The Nuss procedure without intercostal nerve cryoanalgesia was performed in 16 patients (28.1% – NCG).

4.2. Effect of intercostal nerve cryoanalgesia on hospitalisation time after the Nuss procedure

In the group of patients subjected to cryoanalgesia, the shortest hospitalisation time after surgery was 1 day ($n = 6$). The longest hospital stay after surgery in this group was five days ($n = 2$). The median length of hospitalisation in this group was two days. The shortest hospitalisation time after surgery in the group without cryoanalgesia was three days ($n = 2$). The longest postoperative hospital stay in this group was 13 days ($n = 1$). The median length of hospitalisation after surgery in this group was 5 days. The CG patients were discharged from the hospital within three days of surgery – this is the average hospital stay value, which was statistically significantly reduced compared to the NCG patients (3 days vs. 5.5 days; $p < 0.001$).

4.3. Effect of intercostal nerve cryoanalgesia on NRS levels

The median NRS of the pain reported in patients during the first three days after surgery was four in both groups. No significant effects of the use of cryoanalgesia on the average NRS on days 1, 2 and 3 were demonstrated ($p > 0.05$). Patients in the non cryoanalgesia group needed opioids to maintain NRS levels of cryoanalgesia group. The relationship is shown in Figure 2.

4.4. Effect of intercostal nerve cryoanalgesia on the amount of opioids used

On day 1 after surgery, all patients required opioids. The analysis showed that on day 2 after surgery, the percentage of patients requiring opioids in the CG group was slightly higher compared to the NCG group (80% vs. 50%; $p = 0.02$). The difference is statistically significant. It was demonstrated that on day 3 after surgery, the percentage of patients requiring opioids was lower in the CG group compared to the NCG group (34% vs. 69%; $p = 0.02$). The difference is

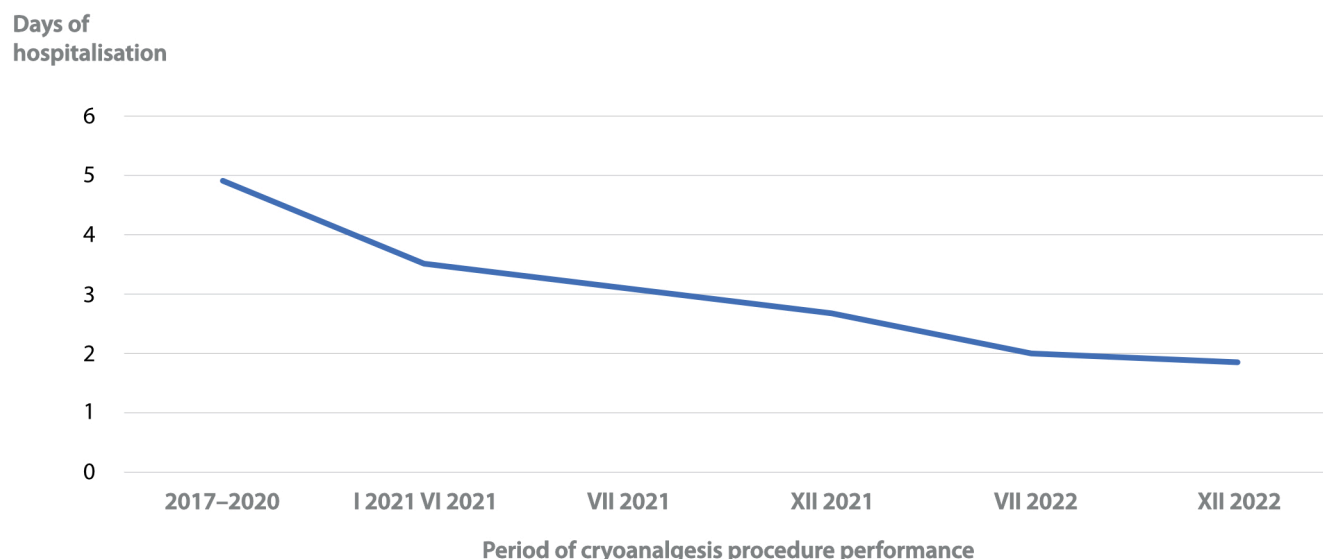


Figure 1. Diagram showing the effect of intercostal nerve cryoanalgesia on length of hospital stay.

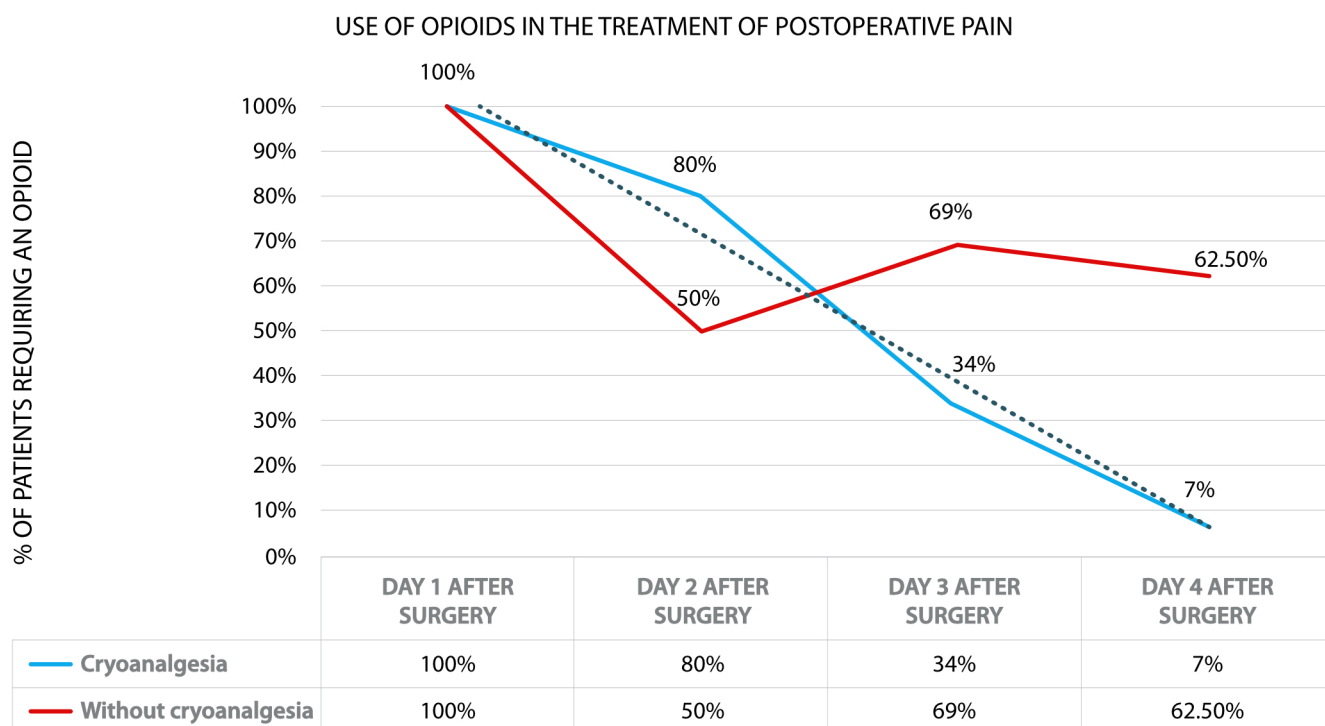


Figure 2. Diagram showing the impact of cryoanalgesia on opioid use during postoperative pain treatment over consecutive days.

statistically significant. On day 4 after surgery, the percentage of patients requiring opioids was lower in the CG group compared to the NCG group (7% vs. 62.5%; $p < 0.001$). The difference is statistically significant. The proportions in the subgroups were compared using the chi2 test.

4.5. Effect of cryoanalgesia procedure performance on hospitalisation time

In the years 2017–2020, eight surgeries were performed, with an average hospitalisation time of 4.875 days. From January 2021 to June 2021, four surgeries were performed, with an average hospitalisation time of 3.5 days. In March 2021, with the beginning of cryoanalgesia usage, six surgeries were performed, with an average hospitalisation time of 3.17 days. During the period from August 2021 to December 2021, the average hospitalisation time after surgery was 2.71 days after the performance of seven surgeries. During the two following periods, from January 2022 to June 2022 and from July 2022 to December 2022, eight surgeries were performed in each, and the average hospitalisation times were 2 days and 1.875 days, respectively. The relationship is shown in Figure 2.

5. DISCUSSION

The pain experienced by a patient after surgery affects the incidence of postoperative complications, the patient's quality of life, satisfaction with medical care, etc.^{4,5} Currently,

the treatment of postoperative pain after the Nuss surgery is mainly based on the administration of opioid drugs that have numerous side effects.^{3,6} Moreover, opioid abuse may lead to addiction, which is a major problem in the era of the opioid drug abuse epidemic.¹⁷ A reduction in the supply of opioid drugs may have the effect of reducing side effects. The effect of cryoanalgesia, performed intraoperatively after the Nuss surgery, on hospitalisation time, average NRS, and the percentage of patients requiring opioids within the first four days after surgery was retrospectively investigated.

The Nuss procedure for pectus excavatum was performed in 57 patients, 93% of whom were male. This is due to the higher prevalence of this deformity in males, as confirmed by researchers from other centres.¹ The average HI for the patients operated on was 3.98, and the average CI was 33.78%. According to the researchers, the indication for surgical treatment of pectus excavatum is a HI greater than 3.25 or a CI greater than 20%.⁷ Differences in defect severity parameters (HI and CI) between the two study groups may have resulted from a greater willingness of patients with less pronounced deformities to perform surgery, given the awareness of reduced postoperative discomfort following the introduction of cryoanalgesia.

The key outcome of the study was to demonstrate that the performance of intraoperative cryoanalgesia reduces hospitalisation time ($p < 0.001$). A reduction in hospitalisation time offers benefits for both the patient and the health care system, as it reduces hospital stay costs as well as the risk of hospital-acquired infections or postoperative complications.^{8,9}

Clare E. Graves et al. claim that performing cryoanalgesia after the Nuss procedure reduces hospitalisation time from five to three days while increasing the procedure duration by 46.5 minutes.³ The researchers R Luke Rettig et al., who compared the analgesic effect of intercostal nerve cryoanalgesia and thoracic epidural anaesthesia after a modified Ravitch procedure, demonstrated a reduction in hospitalisation time, treatment costs and an increase in the procedure duration in the group of patients after cryoanalgesia.^{14,20}

A comparative analysis of the median NRS during the first three days after surgery showed no statistically significant differences between the groups. The median in the CG and NCG groups was NRS 4. The lack of difference in the NRS level can be explained by a possible difference in the amount of opioids administered between the two groups, yet this was not investigated. This requires further analysis in future studies. The similar median NRS during day 1 is probably due to the postoperative supply of opioids to 100% of patients from the two groups. On day 2, CG patients probably require a supply of more opioids due to the phenomenon of hyperalgesia after the nerve cryoanalgesia procedure.¹⁸ Greater pain in the CG group on day 2 could require the supply of more opioids, resulting in an ultimately similar average NRS in the two groups. This relationship was not investigated and demonstrated. On days 3 and 4, the lack of difference in the median NRS between the two groups is probably due to an opposite situation, i.e., the supply of opioids in the NCG group, as compared to the CG group, which was demonstrated on day 4. A study by Sławomir Zacha et al. noted a decrease in NRS within the first 24 hours, which does not confirm the result of the current study.¹⁰ However, another study observed that during the first night after surgery, patients complained of severe acute pain and pressure, most often in the mid-thoracic region, and reported that 25% of the patients under study required periodic administration of analgesics for up to three months after surgery.¹³ There is a need for further research to analyse the NRS and the quality of pain treatment in postoperative patients, taking into account the supply of exact amounts and concentrations of analgesics. As already mentioned, the surgical method in the current study was the intercostal nerve cryoanalgesia performed intraoperatively, which provided a good field of vision but increased the duration of the surgery.

The effect of cryoanalgesia on the opioid need for the first four days after the Nuss procedure was investigated in both patient groups. It was observed that on day 1 after surgery, all patients required intravenous opioids in both groups. On day 2 after surgery, a greater proportion of patients requiring opioid supply were CG patients. The use of cryoanalgesia was observed to produce a full analgesic effect 24 hours after the procedure had been performed, as reported by other centres as well. What is most noteworthy is that on day 4, the percentage of patients requiring less opioid supply was statistically shown to be CG patients. This is a key finding, as it brings positive consequences in terms of reduced opioid drug supply. Seyed A Arshad et al. observed a statistically significant reduction in opioid supply when comparing

patients with and without cryoanalgesia.¹¹ The results from other centres confirm this result. At the same time, the above observations suggest an important limitation of the current study, i.e., the lack of follow-up after four days. There is a need for further multicentre studies specialising in intraoperative cryoanalgesia during the Nuss surgery, with a focus on determining the effects of pain treatment throughout the average duration of pain after pectus excavatum surgery.

The current study determined that for the group of patients who were followed up at a later stage of the study, a reduction in hospitalisation time was observed (4.875 days vs. 1.875 days). This is related to the procedure performance, which represents the time in which the surgical team has gained the necessary experience in performing the procedure. No early complaints related to cryoanalgesia were found in the study group. The surgeon's experience is an important factor that affects the therapeutic outcomes. Shinichi Togami et al. demonstrated that as the surgeon's experience increases, the duration of the procedure and the blood loss decrease.¹⁶ The conclusion of the study confirms the current results.

The hospitalization time was determined by the discharge criteria established at the center, which included the absence of a need for intravenous analgesics, a good overall condition, and a satisfactory level of well-being reported by the patient and their parents. These factors defined the hospitalization time used in this study and which are the goal of every surgical treatment. Discharge criteria did not influence opioid administration and were not associated with NRS values; therefore, they did not affect the study outcomes.

In the cryoanalgesia group, the longest hospitalization was 5 days ($n = 2$), with a median of 2 days. This indicates that most patients quickly met the discharge criteria, likely as a result of more effective pain management and a faster overall recovery. In the group that did not receive cryoanalgesia, there was a wider range in hospitalization duration – the shortest stay was 3 days ($n = 2$) and the longest extended to 13 days ($n = 1$). The extended hospitalization time in this group might have been due to the requirement for prolonged intravenous analgesic administration and a slower improvement in clinical condition, which delayed meeting the established discharge criteria.

A limitation of this study is the small number of patients included, which may reduce the strength of the statistical analysis and, as a result, make it harder to apply the findings to a larger population. Because the study was retrospective, randomization was not possible, nor could it be planned as a prospective or multicenter trial. Further research of this type could provide results with stronger scientific evidence.

The non-cryo group had mildly severe deformities, measured with HI and CI, which might have an influence on hospital stay and higher opioid use. Future studies could also be helpful to find a connection between these factors.

In both groups, authors analyzed only the requirement for opioid administration, correlating it with the NRS pain scores and length of hospital stay in order to assess the effect of cryoanalgesia. Expanding the study to include quantitative

opioid consumption would provide additional value to future research. Similarly, a multivariable analysis aimed at identifying significant correlations between defect severity, expressed by the CI and HI, and quantitative opioid use as well as NRS pain scores would strengthen the research. These aspects are planned to be addressed in future prospective studies.

Alternative techniques for managing postoperative pain include epidural anesthesia and peripheral nerve blocks. However, despite their rapid analgesic effect, these methods may be associated with risks of hemodynamic instability and complications resulting from catheter insertion or local anaesthetic toxicity. They also provide pain relief for only a limited duration. Consequently, cryoanalgesia appears to be a promising alternative in the treatment of funnel chest deformity, as one of the components of minimally invasive surgical techniques used in pediatric patients.^{19,21–22}

6. CONCLUSION

Cryoanalgesia is a simple and safe analgesic method that is very beneficial in the management of postoperative pain in patients treated for pectus excavatum. It produces an early effect, which is essential for this painful operation, and, at the same time, it is a spontaneously reversible method. According to literature from other centres, the analgesic effect in patients persists for up to 4–6 weeks after surgery, during which time sensation in the thoracic integuments returns in parallel. The use of cryoanalgesia enables a significant reduction in pain, expressed in a reduction in the use of analgesics, i.e., mainly opioids, from day 3 after surgery and a critical reduction in hospitalisation time. The hospital stay of patients without cryoanalgesia required several days' hospitalisation after surgery, whereas, when freezing is applied, the patient can leave the hospital on oral painkillers as early as 24 hours after the procedure. In addition, patients return to full physical performance more quickly in the later postoperative period, which is associated with a more efficient postoperative rehabilitation involving less pain and better living comfort directly after surgical treatment.

Ethics approval

None declared.

Conflict of interest

None declared.

Funding

None declared.

Author contributions

Study design: MS

Data collection: RM, FK, PG, MM, AW

Statistical analysis: RM, FK, PG, MM, KAS, AW

Data interpretation: MS, MTP, TJ, KAS

Manuscript preparation: MS

Literature search: MS

Funds collection: MS, MTP, TJ, KAS

References

- Huddleston CB. Pectus excavatum. *Semin Thorac Cardiovasc Surg.* 2004;16(3):225–32. <https://doi.org/10.1053/j.semtcvs.2004.08.003>. PMID: 15619190.
- Pilegaard H, Licht PB. Minimal Invasive Repair of Pectus Excavatum and Carinatum. *Thorac Surg Clin.* 2017;27(2):123–131. <https://doi.org/10.1016/j.thorsurg.2017.01.005>. Epub 2017 Mar 1. PMID: 28363366.
- Graves CE, Moyer J, Zobel MJ, et al. Intraoperative intercostal nerve cryoablation During the Nuss procedure reduces length of stay and opioid requirement: A randomized clinical trial. *J Pediatr Surg.* 2019;54(11):2250–2256. <https://doi.org/10.1016/j.jpedsurg.2019.02.057>. Epub 2019 Mar 17. PMID: 30935731; PMCID: PMC6920013.
- Berkowitz R, Vu J, Brummett C, Waljee J, Englesbe M, Howard R. The Impact of Complications and Pain on Patient Satisfaction. *Ann Surg.* 2021;273(6):1127–1134. <https://doi.org/10.1097/SLA.0000000000003621>. PMID: 31663968; PMCID: PMC7303925.
- Helden EV, Kranendonk J, Vermulst A, et al. Early postoperative pain and 30-day complications following major abdominal surgery: A retrospective cohort study. *Reg Anesth Pain Med.* 2024:105277. <https://doi.org/10.1136/rapm-2024-105277>. Epub ahead of print. PMID: 38839084.
- Benyamin R, Trescot AM, Datta S, et al. Opioid complications and side effects. *Pain Physician.* 2008;2(2):105–20. PMID: 18443635.
- Abid I, Ewais MM, Marranca J, Jaroszewski DE. Pectus Excavatum: A Review of Diagnosis and Current Treatment Options. *J Am Osteopath Assoc.* 2017;117(2):106–113. <https://doi.org/10.7556/jaoa.2017.021>. PMID: 28134952.
- Hashmi SA, Raja MHR, Arif A, Naseem Z, Pal KMB, Pal KMI. Reducing post-operative length of stay, is it worth the effort? *World J Surg.* 2024;48(5):1096–1101. <https://doi.org/10.1002/wjvs.12115>. Epub 2024 Mar 8. PMID: 38459712.
- Jeon CY, Neidell M, Jia H, Sinisi M, Larson E. On the role of length of stay in healthcare-associated bloodstream infection. *Infect Control Hosp Epidemiol.* 2012;33(12):1213–8. <https://doi.org/10.1086/668422>. Epub 2012 Oct 19. PMID: 23143358; PMCID: PMC3510977.
- Zacha S, Andrzejewska A, Jastrzębska-Ligocka B, et al. Intercostal nerve cryoanalgesia in the treatment of pain in patients operated on by the modified Nuss method with the BackOnFeet application—a new strategy to improve outcomes. *Front Pediatr.* 2023;10:1069805. <https://doi.org/10.3389/fped.2022.1069805>. PMID: 36714658; PMCID: PMC9878586.
- Arshad SA, Ferguson DM, Garcia EI, Hebballi NB, Buchanan AC, Tsao K. Cryoanalgesia is Associated With Decreased Postoperative Opioid Use in Minimally Invasive Repair of Pectus Excavatum. *J Surg Res.* 2022;271:1–6. <https://doi.org/10.1016/j.jss.2021.10.011>. Epub 2021 Nov 20. PMID: 34814047.

- ¹² Abdullah F, Harris J. Pectus Excavatum: More Than a Matter of Aesthetics. *Pediatr Ann.* 2016;45(11):403–406. <https://doi.org/10.3928/19382359-20161007-01>. PMID: 27841924.
- ¹³ Fraser JA, Briggs KB, Svetanoff WJ, et al. Short and long term outcomes of using cryoablation for postoperative pain control in patients after pectus excavatum repair. *J Pediatr Surg.* 2022;57(6):1050–1055. <https://doi.org/10.1016/j.jpedsurg.2022.01.051>. Epub 2022 Feb 15. PMID: 35277249.
- ¹⁴ Rettig RL, Yang CJ, Ashfaq A, Sydorak RM. Cryoablation is associated with shorter length-of-stay and reduced opioid use after the Ravitch procedure. *J Pediatr Surg.* 2022;57(7):1258–1263. <https://doi.org/10.1016/j.jpedsurg.2022.02.040>. Epub 2022 Mar 13. PMID: 35379492.
- ¹⁵ Law L, Rayi A, Hendrix JM, Derian A. Cryoanalgesia. 2024 Feb 14. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan–. PMID: 29489178.
- ¹⁶ Togami S, Kawamura T, Fukuda M, Yanazume S, Kamio M, Kobayashi H. Learning curve and surgical outcomes for laparoscopic surgery, including pelvic lymphadenectomy, for early stage endometrial cancer. *Jpn J Clin Oncol.* 2019;49(6):521–524. <https://doi.org/10.1093/jjco/hyz027>. PMID: 30855684.
- ¹⁷ Binswanger IA, Glanz JM, Faul M, et al. The Association between Opioid Discontinuation and Heroin Use: A Nested Case-Control Study. *Drug Alcohol Depend.* 2020;217:108248. <https://doi.org/10.1016/j.drugalcdep.2020.108248>. Epub 2020 Aug 27. PMID: 32927194; PMCID: PMC10959283.
- ¹⁸ Myers RR, Heckman HM, Powell HC. Axonal viability and the persistence of thermal hyperalgesia after partial freeze lesions of nerve. *J Neurol Sci.* 1996;139(1):28–38. PMID: 8836969.
- ¹⁹ Lai K, Eldredge RS, Zobel M, Hargis-Villanueva A, Ostlie A, Padilla BE. Intercostal Nerve Cryoablation for Postoperative Pain Control in Pediatric Thoracic Surgery: A Scoping Review. *J Laparoendosc Adv Surg Tech A.* 2023;33(10):994–1004. <https://doi.org/10.1089/lap.2023.0070>. Epub 2023 Jul 18. PMID: 37462727.
- ²⁰ Kroczek K, Gałazka P. Incidence of adverse effects and complications after application of cryoanalgesia during pectus excavatum surgery: A systematic review. *Pol Przegl Chir.* 2025;97(6):69–76. <https://doi.org/10.5604/01.3001.0055.2293>.
- ²¹ Grapatsas K, Tsilogianni Z, Papatriantafyllou A, et al. Undiagnosed Marfan Syndrome During Military Enlistment: Challenges for Medical Qualification and a Brief Clinical Review. *Pol Ann Med.* 2025;32(2):220–224. <https://doi.org/10.29089/paom/205116>.
- ²² Starczewski M, Choiński W, Puliński M. Heminephrectomy in the pediatric population – single-center comparison of the open versus transperitoneal laparoscopic approach. *Pol Ann Med.* 2023;30(2):87–90. <https://doi.org/10.29089/paom/157522>.

