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TECHNICAL INNOVATION

Use of cryoanalgesia as a postoperative pain management for open pectus carinatum repair

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Abstract

Purpose Cryoanalgesia has shown to have safety and efficacy as an adjunct post-operative pain management for Nuss procedure. One retrospective study reported its efficacy for analgesia with the Ravitch procedure, with improved pain scores and decreased length of stay versus thoracic epidural. We describe our initial experience with the use of cryoanalgesia for an open repair of pectus carinatum.

Methods We retrospectively reviewed the medical records of all patients who received cryoanalgesia during an open repair of pectus carinatum from 2016 to 2019 at our institution. We recorded pain scores at immediate post-operative and at 1-week follow up after hospital discharge. Length of stay and mean follow up time were also recorded.

Results Five pediatric patients underwent open repair of pectus carinatum with cryoanalgesia. The median postoperative length of stay (LOS) was 1 (range 1–2) day. Only one patient reported a non-zero pain score during their hospitalization, and this was a 3 out of 10 in the post-analgesia care unit. At 1-week postoperative visit, all patients had a pain score of 0. Median follow up was 1 (0.5–2) year. No patients developed neuralgia.

Conclusion Cryoanalgesia is a safe and effective pain management strategy for pediatric patients undergoing open pectus carinatum repair.

Keywords Cryoanalgesia · Cryoablation · Pectus carinatum repair · Ravitch procedure · Pain control

Introduction

Pectus carinatum is a chest wall deformity that typically presents during early adolescence and is characterized by protrusion of the sternum and costal cartilages. The condition is usually asymptomatic. The main indication for treatment is to improve cosmesis and to increase sense of well-being [1]. First line therapy for patients with a flexible chest wall is to use compression orthotic. For those who fail orthotic or for patients whose chest is not amenable to orthotic therapy, surgical treatment is used. The standard surgical approach is open pectus carinatum repair (modified Ravitch procedure) where segments of sternocostal cartilages are removed while preserving the periosteum [2]. This operation causes significant and prolonged pain for patients. For postoperative pain management, epidural analgesia is commonly used [3] in combination with high-dose opioids [4, 5]. We were the first to report the use of cryoanalgesia as a pain management for the treatment of pectus excavatum using Nuss procedure [6, 7], which was found to reduce opioid use and length of postoperative hospitalization [8, 9]. One recent single-center retrospective study compared use of cryoanalgesia versus thoracic epidural after pectus carinatum repair and reported similar complication rates and equivalent inpatient morphine use; however, there was decreased pain scores and length of hospitalization with cryoanalgesia [10]. In this report, we describe our cryoanalgesia technique during an open pectus carinatum repair. Notably, our cryotherapy protocol applies treatment to the proximal intercostal nerve, rather than at distal intercostal nerve as previously reported by Pilkington et al.

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Technique

Five patients with median age 15 years (range 14–17; 4 males, 1 female) underwent open repair of pectus carinatum malformation after failure of orthotic bracing due to non-compliance among the male patients. The female patient could not be braced due to breast development. Patient characteristics are shown in Table 1.

The modified Ravitch procedure with cryoanalgesia was performed in the same manner for all patients in our cohort. After general anesthesia, a double lumen endotracheal tube was placed. The patient was positioned in a supine position with a layer of folded blanket laid longitudinally under the back to elevate the torso, causing the adducted arm to lay lower than the chest. The elevation of the chest with a folded blanket allows better access to the lateral chest wall without abducting the arms, which may cause brachial nerve injury. Marcaine 0.25% was first injected along the incision line. A transverse incision was made on the chest and the subcutaneous tissues were dissected superiorly and inferiorly to expose the pectoralis major muscle. Once this muscle was exposed, it was detached from the sternum exposing the medial sternal cartilages and ribs. A single lung ventilation was then used for the cryoanalgesia. A 5 mm port was introduced between the exposed rib space for carbon dioxide insufflation at 5 mm Hg pressure, and a 30° thoracoscope was used to view the internal thorax. Two superior intercostal spaces above the camera port, a cryoprobe (Atricure Corp, Mason, OH) was inserted, and the cryoprobe tip was applied to the proximal intercostal nerves slightly proximal to the mid-axillary line. Each nerve was treated at minus 60 °C for two minutes. After the cryoablation, the pneumothorax within the chest cavity was evacuated by ventilating the lung with positive pressure thus forcing the carbon dioxide/air to exit the chest through the port, which is attached to a tubing that has been placed under a pool of water. Contralateral chest was similarly treated with the cryoprobe. In other words, cryoanalgesia is performed sequentially on each side of the chest as needed. Thereafter, the open surgical repair was completed, with resection of sternocostal cartilages from the affected ribs and sternal osteotomy for symmetric pectus carinatum cases. For asymmetric pectus carinatum cases, sternal osteotomy was not done since the surgical appearance was satisfactory without osteotomy. At the conclusion of the case, a 10 French Jackson-Pratt (JP) drain was placed deep to the pectoralis major muscle through a separate stab incision in the chest. The pectoralis major muscle was reattached to the sternum with sutures. Epidural catheter was not used for pain control. Postoperatively, the patient was provided with intravenous morphine or oral oxycodone-acetaminophen for severe pain, both on an as-needed basis, or non-narcotic pain medication for mild pain. All five patients reported excellent pain control post-procedure, with only one patient reporting a non-zero pain score during the post-operative hospitalization period (3/10 in the post-anesthesia care unit). This was the only patient who received a 2 mg dose of morphine in the post-procedure room. All patients reported a pain score of 0 on post-operative day 1. The median postoperative length of stay was 1 (range 1–2) day. Two out of five patients were discharged with only ibuprofen and/or acetaminophen and the remaining three were given oxycodone-acetaminophen in case they needed stronger pain medication. JP drain was removed in clinic on day 5 (range 4–6). All five patients reported a pain score of 0 at their postoperative clinic visit on day 5. The median follow-up time was 1 (0.5–2) year. The numbness from cryoanalgesia resolved by three months for all patients. No patients reported neuralgia or paresthesia.

Institutional Review Board approval was obtained for the purpose of this study.

Table 1 Demographic and operative information of five patients who underwent modified Ravitch with cryoanalgesia

Patient #	Age (y)	Sex	Weight (kg)	Deformed ribs (side: rib levels)
1	14	Male	51.8	R: 4–7
2	14	Male	50.9	R:4–7
3	15	Male	56.5	R:4–8, L:4–8
4	16	Male	49.4	R:2–4, L:2
5	17	Female	64.1	R:4–6

y year; *R/L* right/left malformation laterality

Discussion

Like Nuss procedure, surgical repair of pectus carinatum is known for causing severe and prolonged postoperative pain. A typical postoperative pain regimen is to use epidural catheter and intravenous morphine, which is what we used at our institution prior to the introduction of cryoanalgesia. Prior to the use of cryoanalgesia, a typical patient at our institution stayed in our hospital for 3–5 days. After we first reported the use of cryoanalgesia as an effective and safe alternative to epidural or opioid analgesia for management of postoperative pain in patients undergoing Nuss procedure (5–7, 11), it became clear to us that cryoanalgesia can be used for open pectus carinatum repair as well. Recently, Pilkinton et al. retrospectively compared intercostal nerve cryoanalgesia to thoracic epidural for pain control after Ravitch procedure and reported decreased pain scores and length of stay (median 4 days versus 6) with the use of cryoanalgesia [10]. Their protocol applied cryotherapy to the distal intercostal nerve at the intersection of the membranous and muscular sections of the involved ribs. There was no

difference among their cohorts with respect to in-hospital or post-hospital morphine equivalents used. In contrast, we obtained shorter in-hospital stay and pain scores compared to the results reported by Pilkinton et al. The improved outcome is due to complete cryoablation of the intercostal nerve proximal to the branching point of lateral cutaneous nerve, which branches off from the intercostal nerve at the mid-axillary level. Therefore, it is important to apply the cryoprobe proximal to the mid-axillary line, which will ensure complete cryoablation of the intercostal nerve.

One lung ventilation need not be used for the cryoanalgesia. Carbon dioxide insufflation and decreased tidal volume ventilation can be used to suppress the lung to visualize the posterior chest wall medial to the mid-axillary line. Double lumen endotracheal tube intubation to achieve single lung ventilation gives the best visualization of the posterior chest and prevents lung tissue from adhering to the cryoprobe. Although there is increased preparation time for the double lumen endotracheal tube placement, the operative time is reduced.

The location of the cryoablation on the intercostal nerve is same for Nuss procedure and for modified Ravitch procedure. We described in three papers, two retrospective [6, 7] and one prospective study [8] concerning Nuss procedure for pectus excavatum with a larger cohort, that permanent neuralgia or paresthesia were not found for pediatric patients. Pilkington et al. [10] who reported their outcome of using cryoanalgesia for pectus carinatum repair also did not report incidence of neuralgia; although [11], they applied the cryoprobe close to the sternum, much lateral to the mid-axillary line. We do not expect the rate of neuralgia will be dependent on the location of the cryoablation on the nerve; we suspect that the rate of neuralgia is dependent whether the axon is ablated completely or partially due to improper positioning of the cryoprobe on the intercostal nerve axon.

We believe that the shorter length of stay and durable pain relief will be achieved if the cryoablation is applied to the intercostal nerves proximal to the mid-axillary line. The analgesic effect of cryoanalgesia is 2 months and appears to be greater than the time needed for complete resolution of postoperative pain after modified Ravitch procedure.

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Compliance with ethical standards

Conflict of interest Authors declare that we have no conflict of interest.

Ethical approval No animals were used for the study. All procedures performed involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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