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Intraoperative cryoanalgesia for managing pain after the Nuss procedure

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ABSTRACT

Background: Cryoanalgesia prevents pain by freezing the affected peripheral nerve. We report the use of intraoperative cryoanalgesia during the Nuss procedure for pectus excavatum and describe our initial experience, modifications of technique, and lessons learned.
Materials and methods: We retrospectively reviewed the medical records of patients who received cryoanalgesia during the Nuss procedure between June 1, 2015, and April 30, 2016, at our institutions and analyzed modifications in surgical technique during this early adoption period.
Results: Eight male and two female patients underwent the Nuss procedure with cryoanalgesia. The mean postoperative length of stay (LOS) was 2 days (range 1–3). Average inpatient pain scores were 3.4, 3.2, and 4.6 on postoperative days 1–3, respectively (N = 10, 7, and 2). At a 1-week postoperative visit, mean pain score was 1.1 (N = 6). Compared to the preceding 15 Nuss patients at our institution, who were treated with a thoracic epidural, postoperative LOS was significantly shorter with cryoanalgesia (2.0 ± 0.82 vs. 6.3 ± 1.3 days, $P < 0.001$). We modified our technique for patient habitus and adopted single-lung ventilation for improved visualization.
Conclusions: Cryoanalgesia may be the ideal pain management strategy for Nuss patients because it is effective and long lasting. Intraoperative application is easily integrated into the Nuss procedure.
Study type: Treatment study: case series; Evidence level IV.

The Nuss procedure has become a common thoracoscopic corrective operation for pectus excavatum since it was introduced in 1997. The benefits compared to open repair include smaller incisions, no cartilage resection or osteotomy, and reduced operative time [1]. However, the procedure causes significant and lengthy postoperative pain, which may last for weeks, causing distress for patients, families, and clinicians [2,3]. There is no standardized optimal pain management following this procedure. Epidural analgesia and patient controlled analgesia (PCA) are the two most commonly used techniques, employed either independently or together [2–5]. Thoracic epidural analgesia has been shown to be more effective than PCA alone in the early postoperative period, but it carries significant risks, including nerve damage leading to paralysis, infection, and respiratory depression [3,6]. Moreover, the use of epidural analgesia is limited to the first two to three postoperative days; thereafter, the patient is usually transitioned to oral regimens [7]. The ability to adequately control postoperative pain is the primary determinant of hospital stay following the Nuss procedure and often necessitates a prolonged hospitalization [4].

We recently began performing intraoperative cryoanalgesia during the Nuss procedure as a new pain control strategy and published the method of this technique [8]. In this retrospective review, we further describe the thoracoscopic intrathoracic cryoanalgesia technique, report our experience from treating our first 10 patients, and discuss lessons learned thus far.

1. Materials and methods

With approval from institutional review boards at two UCSF Benioff Children's Hospital campuses (IRB #16-19217 and IRB #150914), we conducted a retrospective chart review of patients who underwent the Nuss procedure with cryoanalgesia between June 1, 2015 and April 30, 2016 at our institutions. All procedures were performed by one of two attending pediatric surgeons. The first six cases were performed with single lumen endotracheal intubation, and the remaining four cases were performed with double lumen endotracheal tubes. All skin incisions made on the chest during the course of the operations were injected with 0.25% bupivacaine prior to incision. The technical details of the Nuss procedure we utilized have been described previously [9].

1.1. Cryoanalgesia application

Cryoanalgesia of the intercostal nerves was performed prior to Nuss bar placement through a thoracoscopic approach under direct visualization with a cryoprobe (cryoICE: AtriCure, Inc., West Chester, OH, USA) in all patients. After bilateral thoracoscopic port placements, the patient's

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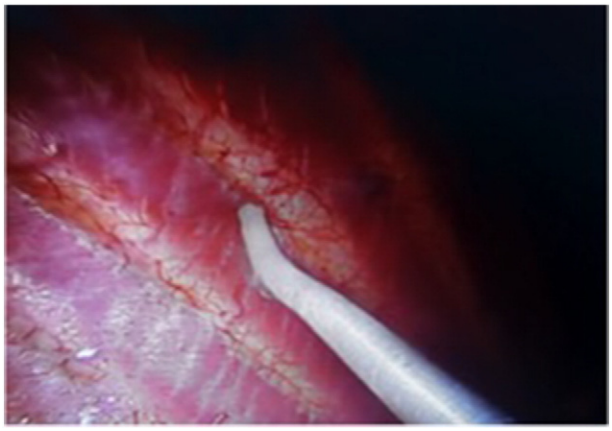

Fig. 1. Cryoprobe Application: The cryoprobe is placed at 90 degrees to the intercostal nerve under direct thoracoscopic vision.

anterior sunken chest wall was elevated using the T-fastener suture technique [9]. The retrosternal space was dissected under direct camera visualization from the left chest toward the right chest to create a communicating channel between the two sides. Once this retrosternal channel was created, the cryoprobe was placed through the skin incision that had already been made for inserting the Nuss bar. Next, a rigid 30° thoracoscope and the cryoprobe were passed together across the anterior mediastinum to gain access to the contralateral chest wall [8]. The mediastinal tissue is protected from injury by the insulating plastic sheath, which covers the shaft of the probe. In the few cases where the patient's chest was too wide for the cryoprobe to reach the contralateral chest wall, the cryoprobe was passed through the ipsilateral Nuss bar incision site and angled posteriorly in order to access the intercostal nerves.

In all patients, 4–5 nerves on each side were treated, proximal (posterior–lateral) to the chest incision site: the intercostal nerve at the level of the bar insertion, the 2 nerves above, and 2 nerves below. At each level, the probe was placed in direct contact with the nerve at each rib space and continuously treated at −60 °C for 2 min (Fig. 1). After the freeze cycle, the probe was thawed and allowed to fall off the pleural lining without traction; the thaw cycle was completed within a few seconds.

1.2. Postoperative care

Postoperatively, patients were admitted to the postanalgesia care unit, then to a regular hospital room. No epidurals were placed. Patients were allowed to have intravenous morphine or oral narcotic (acetaminophen/hydrocodone) as needed. Verbal pain scores were collected by nurses and physicians and recorded in the electronic medical record. After hospital discharge, patients presented for postoperative clinic visits 1–2 weeks after surgery, then 2–3 months after surgery, according to patient and physician preference. Further in-person follow-up depended on patient need; otherwise patients were contacted via phone or e-mail at time of manuscript preparation.

1.3. Data analysis

All data were recorded using Microsoft Excel for Mac 2011 (Microsoft Corporation, Redmond, WA) and analyzed with GraphPad Prism 7 (GraphPad Software, La Jolla, CA). Basic patient characteristics were summarized and described. Postoperative length of hospital stay of the 10 patients who had cryoanalgesia was compared to the length of stay of the cohort of previous 15 Nuss procedure patients at our institution using the unpaired t test. Verbal pain scores were summarized and described. When more than one pain score was collected from a patient over a single hospital day, that day's scores were averaged.

Table 1
Characteristics of Patients who Received Intraoperative Cryoanalgesia During the Nuss Procedure for Pectus Excavatum.

Patient	*Age (years)*	*Sex*	*Haller Index*	*Postoperative. Length of Stay (days)*	*Length of follow-up (months)*
1	18	M	4	2	12
2	23	F	5.2	3	9
3	31	M	3.3	2	8
4	14	M	5	2	8
5	13	M	3.4	1	8
6	16	M	8	2	8
7	13	M	4.1	2	8
8	16	F	4.3	3	5
9	9	M	6.2	1	6
10	15	M	4	1	4

2. Results

Patient information is summarized in Table 1. Eight male and two female patients underwent the Nuss procedure with cryoanalgesia. The mean age was 16.8 years (range 9–31 years). The mean Haller Index was 4.39 (range 3.2–8). The mean postoperative length of stay (LOS) was 2 days (range 1–3). Compared to the preceding 15 Nuss patients at our institution, who were treated with a thoracic epidural, mean LOS was significantly shorter with cryoanalgesia, 2.0 ± 0.82 vs. 6.3 ± 1.3 days, $P < 0.001$ (Fig. 2).

Using a verbal pain scale of 0–10, average pain score on postoperative day (POD) 1 was 3.4 (range 1–7). Three patients were discharged on POD 1. Average pain score of the remaining 7 patients on POD 2 was 3.2 (range 1–5), and of the two patients who stayed until POD 3, the average pain score was 4.6 (4 and 5.2). Numerical pain scores were collected for 6 patients at their 1-week postoperative visit, and mean pain score was 1.1 (range 0–2) (Fig. 3). Length of follow-up ranged from 4 to 12 months (average 8 months). At the 2-week postoperative visit, patient 2, a 23 year-old female, was found to have symptomatic pleural effusions, which required bilateral pigtail placement for drainage. She also reported a stinging sensation in the anterior chest one month following the Nuss procedure, which resolved with gabapentin medication. There were no other immediate postoperative complications.

Sensation returned gradually in all patients, progressing from lateral to medial. Normal sensation returned to 5 patients by 2 months after surgery, 1 patient by 3 months, and 2 patients by 4 months. Two patients had some persistent numbness at 8 and 9 months, respectively —

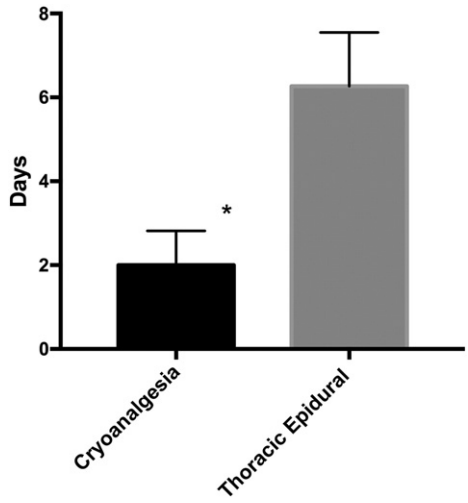

Fig. 2. Postoperative Length of Stay: Mean postoperative length of stay was significantly shorter in patients with cryoanalgesia (N = 10) than in a previous cohort treated with thoracic epidural (N = 15), 2.0 ± 0.82 vs. 6.3 ± 1.3 days, $P < 0.001$ (unpaired t test; error bars indicate standard deviation).