Journal of Pediatric Surgery 51 (2016) 2033–2038

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Intercostal nerve cryoablation versus thoracic epidural catheters for postoperative analgesia following pectus excavatum repair: Preliminary outcomes in twenty-six cryoablation patients☆

Benjamin A. Keller [a,*], Sandra K. Kabagambe [a], James C. Becker [a], Y. Julia Chen [a], Laura F. Goodman [a], Julianna M. Clark-Wronski [b], Kenneth Furukawa [b], Rebecca A. Stark [a,c], Amy L. Rahm [a,c], Shinjiro Hirose [a,c], Gary W. Raff [a,c]

[a] Davis Health System, Department of Surgery, University of California, Sacramento, CA
[b] Davis Health System, Department of Anesthesia, University of California, Sacramento, CA
[c] Department of Surgery, Shriners Hospital for Children – Northern California, Sacramento, CA

ARTICLE INFO

Article history:
Received 15 August 2016
Accepted 12 September 2016

Key words:
Pectus excavatum
Nuss procedure
Cryoablation
Epidural analgesia
Pain management

ABSTRACT

Background: Multimodal pain management strategies are used for analgesia following pectus excavatum repair. However, the optimal regimen has not been identified. We describe our early experience with intercostal cryoablation for pain management in children undergoing the Nuss procedure and compare early cryoablation outcomes to our prior outcomes using thoracic epidural analgesia.
Methods: A multi-institutional, retrospective review of fifty-two patients undergoing Nuss bar placement with either intercostal cryoablation ($n = 26$) or thoracic epidural analgesia ($n = 26$) from March 2013 to January 2016 was conducted. The primary outcome was hospital length of stay. Secondary outcomes included telemetry unit monitoring time, total intravenous narcotic use, duration of intravenous narcotic use, and postoperative complications.
Results: Patients who underwent intercostal cryoablation had a significant reduction in the mean hospital length of stay, time in a monitored telemetry bed, total use of intravenous narcotics, and the duration of intravenous narcotic administration when compared to thoracic epidural patients. Cryoablation patients had a slightly higher rate of postoperative complications.
Conclusion: Intercostal cryoablation is a promising technique for postoperative pain management in children undergoing repair of pectus excavatum. This therapy results in reduced time to hospital discharge, decreased intravenous narcotic utilization, and has eliminated epidurals from our practice.
Level of evidence: Retrospective study – level III.

Pectus excavatum is the most common chest wall deformity, with an estimated occurrence of 1 in 400 to 1 in 1000 live births, and an approximate 6:1 predilection for males [1]. The deformity is characterized by a posterior curvature of the sternum and lower costal cartilage resulting in a "funnel chest" appearance. The clinical manifestations of pectus excavatum vary depending on the severity, but can include cardiopulmonary symptoms (exercise intolerance, shortness of breath), chest wall pain, poor endurance, and cosmetic concerns leading to psychosocial difficulties [2,3]. Historically, patients with pectus excavatum underwent the Ravitch procedure consisting of subperichondrial cartilage resection and sternal osteotomy [4]. In 1998, Donald Nuss introduced a minimally invasive alternative utilizing retrosternal placement of a contoured bar to produce an outward force on the sternum [5]. While the Nuss procedure minimizes the operative time and incision size, it is associated with significant postoperative pain comparable to the open repair [6,7]. Several approaches to postoperative pain management have been attempted, including using thoracic epidurals, paravertebral regional blocks, intercostal blocks, intercostal infusion catheters, patient-controlled analgesia, and multimodal anesthesia, however an optimal regimen has not yet been established [8–13]. Typically, narcotics are used as a primary modality for pain control with epidurals, anti-inflammatories, and muscle relaxants as adjuncts. Despite different techniques and the development of multifaceted pain management strategies; pain control and treatment of complications such as nausea and constipation because of around-the-clock narcotic use remain a significant challenge after the Nuss procedure.

Cryotherapy has been used for decades to treat pain syndromes including facial neuralgias, peripheral neuropathies and facet joint pain [14]. In the 1970s, this technique was expanded to patients who

☆ Disclosure: Gary W. Raff is a consultant for Atricure® (Mason, OH).

* Corresponding author at: Davis Health System, Department of Surgery, University of California, 2315 Stockton Blvd, OP512, Sacramento, CA 95817. Tel.: +1 916 734 2724.
E-mail address: bakeller@ucdavis.edu (B.A. Keller).

http://dx.doi.org/10.1016/j.jpedsurg.2016.09.034
0022-3468/

underwent a thoracotomy for postoperative pain control [15]. The use of cryotherapy in these patients has been shown to decrease postoperative opioid usage and improve pulmonary mechanics [16–18]. Despite these promising findings, cryoablative analgesia was not adopted for use in the Nuss procedure until recently. In early 2015, the Food and Drug Administration (FDA) approved the first commercially available cryoablation probe (CryoICE®, AtriCure, Mason, OH) for temporary ablation of peripheral nerves, generating renewed interest in applying this technique to managing postoperative pain [19].

Given the prior success of cryoanalgesia in adult patients undergoing thoracic surgery and the challenges associated with pain control in children undergoing the Nuss procedure, we began using cryoablation as the foundation of our postoperative pain management strategy. The purpose of this study is to describe our method of intercostal nerve cryoablation and report the results of our early experience with it as a novel technique for pain management in children undergoing the Nuss procedure. These results are compared to a historical control group of patients that were managed with thoracic epidural catheters.

1. Methods

1.1. Retrospective review and data collection

After obtaining institutional review board (IRB) approval, a multi-institution, retrospective review of all patients who underwent Nuss bar placement for pectus excavatum repair between March 1, 2013 and January 31, 2016 was conducted. No patients were excluded from analysis. The patient's age, gender, Haller index, American Society of Anesthesiologists (ASA) physical status classification, and the indication for pectus repair were recorded. Operative, hospital, and outpatient follow-up data were collected. The primary outcome was hospital length of stay (LOS) after surgery. Secondary outcomes included operative time, telemetry unit monitoring time, total amount of intravenous (IV) narcotic use, and the duration of IV narcotic use. Narcotic use at the first follow-up appointment, subjective chest wall complaints at the three-month follow-up appointment and any procedure related complications were reviewed.

1.2. Thoracic epidural management

Patients in the thoracic epidural group were brought to the operating room and following premedication with fentanyl and midazolam, underwent thoracic epidural placement prior to the induction of anesthesia. Postoperatively, hydromorphone with or without bupivacaine was used for the epidural infusion. Epidural infusions, including changes to the infusion rate and epidural boluses were managed by anesthesiologists with input from the surgical team until the time of removal. Epidural catheters were removed between postoperative days two and three.

1.3. Intercostal nerve cryoablation

Early in our experience with cryoablation, the procedure was performed after the Nuss bar was placed. We altered our approach midway through the study period and began performing cryoablation prior to Nuss bar placement. To perform the cryoablation, a 5-mm 30-degree thoracoscope is placed in the thoracic cavity for direct visualization of the thoracic wall and to monitor ice crystal formation (Fig. 1). Utilizing the same incisions used for the Nuss bar placement, a subcutaneous tunnel is bluntly created up to the third intercostal space. The Atricure CryoICE® cryoablation probe (Mason, OH) is inserted through the subcutaneous tunnel, and its position confirmed by thoracoscopy. The probe is cooled to −60 degrees Celsius for two minutes. Proper position of the probe is confirmed by observing muscle fasciculations in the intercostal space. After the ablation cycle is complete, the probe is warmed to ambient temperature and allowed to release from the nerve without traction. Care is taken to avoid any other injury to the intercostal nerves and to only dissect bluntly in the region of the nerve to avoid disturbing the epineurium. This procedure is repeated in the fourth, fifth, sixth, and seventh intercostal spaces bilaterally.

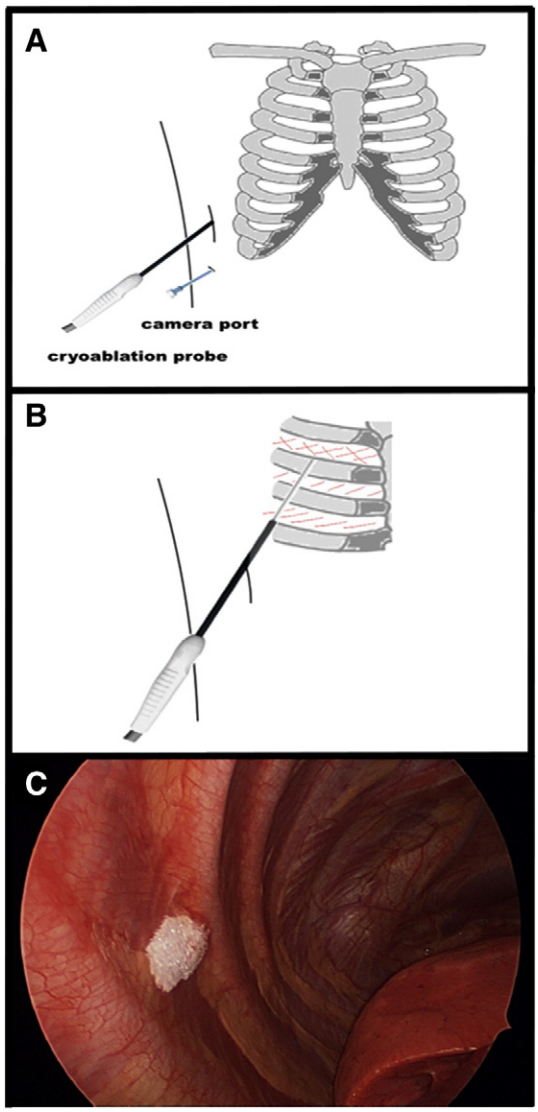

Fig. 1. The Atricure CryoICE probe is tunneled subcutaneously to the third intercostal space and cryoablation is performed. The procedure is repeated in the fourth, fifth, sixth, and seventh intercostal spaces bilaterally (A&B). A 5-mm 30-degree scope is placed in the thoracic cavity to monitor ice crystal formation during cryoablation (C).

1.4. Postoperative pain management

In both the thoracic epidural and the cryoablation groups, patients were managed with similar multi-modal pain management strategies. All children were started on patient controlled IV narcotic analgesics and 48 to 72 h of scheduled IV non-steroidal anti-inflammatories (ketorolac) immediately postoperatively. In addition to narcotics and anti-inflammatory medications, benzodiazepines (diazepam) were utilized for muscle spasms as needed. In the cryoablation group, gabapentin was started on postoperative day two to prevent the development of neuropathic chest wall pain. As pain improved and patients had adequate oral intake, children were transitioned to