Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.JournalofSurgicalResearch.com

Association for Academic Surgery

Comparing outcomes with thoracic epidural and intercostal nerve cryoablation after Nuss procedure

Calista M. Harbaugh, MD,[a,*] *Kevin N. Johnson, MD,*[b] *Courtney E. Kein, BA,*[a] *Marcus D. Jarboe, MD,*[b] *Ronald B. Hirschl, MD,*[b] *James D. Geiger, MD,*[b] *and Samir K. Gadepalli, MD, MBA*[b]

[a] *Department of Surgery, University of Michigan Medical School, Ann Arbor, Michigan*
[b] *Section of Pediatric Surgery, C.S. Mott Children's Hospital, University of Michigan Medical School, Ann Arbor, Michigan*

ARTICLE INFO

Article history:
Received 1 March 2018
Received in revised form
18 May 2018
Accepted 24 May 2018
Available online xxx

Keywords:
Pectus
Cryoablation
Epidural
Pain management
Pediatric surgery

ABSTRACT

Background: This study aimed to evaluate postoperative outcomes after minimally invasive repair of pectus excavatum (Nuss procedure) using video-assisted intercostal nerve cryoablation (INC) compared to thoracic epidural (TE).

Materials and methods: We performed a single center retrospective review of pediatric patients who underwent Nuss procedure with INC ($n = 19$) or TE ($n = 13$) from April 2015 to August 2017. Preoperative, intraoperative, and postoperative characteristics were collected. The primary outcome was length of stay (LOS) and secondary outcomes were intravenous and oral opioid use, pain scores, and complications. Opioids were converted to oral morphine milligram equivalents per kilogram (oral morphine equivalent [OME]/kg). Mann–Whitney U test was used for continuous and chi-squared analysis for categorical variables.

Results: There were no significant differences in patient characteristics, except Haller Index (INC: median [interquartile range] 4.3 [3.6-4.9]; TE: 3.2 [2.8-4.0]; $P = 0.03$). LOS was shorter with INC (INC: 3 [3-4] days; TE: 6 [5-7] days; $P < 0.001$). Opioid use was higher intraoperatively (INC: 1.08 [0.87-1.37] OME/kg; TE: 0.46 [0.37-0.67] OME/kg; $P = 0.002$) and unchanged postoperatively (INC: 1.78 [1.26-3.77] OME/kg; TE: 1.82 [1.05-3.37] OME/kg; $P = 0.80$), and prescription doses were lower at discharge in INC (INC: 30 [30-40] doses; TE: 42 [40-60] doses; $P = 0.005$). There was no significant difference in postoperative complications (INC: 42.1%; TE: 53.9%; $P = 0.51$).

Conclusions: INC during Nuss procedure reduced LOS, shifting postoperative opioid use earlier during admission. This may reflect the need for improved early pain control until INC takes effect. Prospective evaluation after INC is needed to characterize long-term pain medication requirements.

* *Corresponding author*. Department of Surgery, University of Michigan Medical School, 1620 E Medical Ctr Dr 2110 TC, Ann Arbor, MI 48109-5346. Tel.: (734) 936-5732; fax: (734) 998-2523.
E-mail address: calistah@med.umich.edu (C.M. Harbaugh).
0022-4804/$ – see front matter © 2018 Elsevier Inc. All rights reserved.
https://doi.org/10.1016/j.jss.2018.05.048

Introduction

Pectus excavatum repair is commonly associated with significant postoperative pain,[1] yet lack of consensus remains as to optimal management of pain following repair. Pectus excavatum, an abnormal growth of the sternum and ribs resulting in a concave appearance of the chest, is typically repaired in adolescence secondary to reduced cardiopulmonary reserve or social exclusion and psychological sequelae related to an abnormal appearance.[2] In the minimally invasive Nuss procedure, a retrosternal, contoured bar is placed, exerting outward force on the depressed sternum.[2] While the Nuss procedure has been associated with reduced scarring, operative time, and blood loss as compared to the open Ravitch repair,[3] pain remains a prominent issue.[1,4] A number of approaches to pain management have been compared, including thoracic epidural (TE),[4,5] intercostal nerve block,[6,7] continuous paravertebral blockade,[8-10] and multimodal enhanced recovery protocols,[11-13] though all are self-limited and the mainstay of postoperative pain management remains opioid pain medications.[2] Postoperative opioid therapy has been shown to increase risk of persistent opioid use among adolescents and young adults[14]; thus in the context of the current opioid epidemic, alternative nonopioid solutions to treating postoperative pain are urgently needed.

Video-assisted intercostal nerve cryoablation (INC) may be one solution to improve postoperative pain control after pectus excavatum repair in pediatric patients, reduce postoperative opioid use, and shorten length of stay (LOS).[15,16] INC has previously been used among adults to prevent or treat post-thoractomy pain.[17,18] There have been two recent reports of INC following Nuss procedure in pediatric patients[15,16]; however, the studies are limited by sample size, concurrent use of multimodal locoregional pain control, and financial conflicts of interest. Although pectus excavatum is the most common chest wall deformity, the overall number of procedures performed at a given center remains small, highlighting the need for additional reporting of postoperative outcomes after INC at the time of the Nuss procedure.

With this study, we performed a retrospective review of 31 patients undergoing the Nuss procedure with TE as compared to INC at a single institution. Our primary outcome of interest was postoperative LOS and secondary outcomes included intravenous and oral opioid use, pain scores, and complication rates. We hypothesized that patients treated with INC during the Nuss procedure would have decreased LOS, postoperative opioid use, and postoperative pain scores without an increase in complication rates as compared to patients with TE.

Methods

Study population

This study was approved by the University of Michigan Institutional Review Board (HUM00135404) and informed consent was waived due to the retrospective nature of this study. A departmental practice change was instituted in the section of Pediatric Surgery at C.S. Mott Children's Hospital (Ann Arbor, MI) based on literature review and expert consensus to use INC for all patients undergoing the Nuss procedure as of July 2016. All pediatric surgery partners were trained in the use of INC by an adult cardiothoracic surgeon currently using this technique through observation, and a previously trained surgeon and company representative were present in the operating room for the first time a faculty surgeon applied the technique. A retrospective review was performed of all patients undergoing the Nuss procedure with INC (July 2016-August 2017, $n = 19$ patients) compared to historical controls undergoing the Nuss procedure with TE (April 2015-July 2016, $n = 13$ patients). The Nuss procedure was performed in the standard fashion under direct thoracoscopic visualization in all patients. For severe defects, either a hybrid Nuss procedure in which subperichondrial resections of 1-3 ribs via an additional incision was preoperatively planned and performed or a second bar was placed if necessary.

TE management

All epidurals were placed before pectus repair by the dedicated Pediatric Acute Pain Service, composed of anesthesiology clinicians. Epidurals were tested in the postoperative area for appropriate level. Epidurals contained hydromorphone 5 mcg/mL and bupivacaine 0.0625% or 0.125%. If the epidural did not provide adequate pain management, hydromorphone was removed from the epidural and patient controlled analgesia (PCA) was started with intravenous morphine or hydromorphone. For all patients, a working epidural was removed when the patient tolerated adequate oral intake and the patient was transitioned to oral medications.

Intercostal nerve cryoablation

INC was performed thoracoscopically under direct visualization using a 30° thoracoscope (Storz) before placement of the Nuss bar at the time of surgery using the AtriCure cryoICE (Mason, OH) through the existing ports.[15] Performance of INC before bar placement (and before connection of the hemithoraces across the mediastinum) allows isolated insufflation of each chest, which enhances visualization during INC. The probe was applied at the neurovascular bundle along the inferior aspect of the ribs. A cooling temperature of −60°C was applied for 2 min for 4-5 intercostal spaces (two intercostal spaces above and below the bar), taking care not to go above the third rib space or below the ninth (Fig. 1). Following application, the probe was allowed to warm before removing it from the tissues to minimize trauma.

Postoperative management

Postoperatively, all patients were managed according to a standardized pectus protocol. All patients received nonsteroidal anti-inflammatories (ketorolac or ibuprofen) on a scheduled basis and diazepam or cyclobenzaprine for muscle spasm as needed. The protocol was modified only with regard to epidural management after initiation of INC. No patients