Inclusion Criteria
- Patient age 13 years to adult with Pectus Excavatum requiring repair

Exclusion Criteria
- None

Anesthesia and pain management
- Standard anesthesia procedures
- Ketorolac IV at end of case
- Standard PACU orders

Infection prevention
- Double glove
- Ioban drape
- Irrigate wounds with Betadine® solution

Perioperative antibiotics
- Cefazolin
- Clindamycin if allergic
- Vancomycin if MRSA

Thrombosis prevention
- Sequential compression device (SCD) if age 16 years or older, prior to induction

Safety Precautions
- Sternal saw available and open on the field to assure proper function

Intraoperative Pain Management
- Cryoablation to 2 nerves above and below bar entry level on each side
- Bupivacaine 0.5% (2mL per nerve) 2 nerves above and below bar entry level on each side

Other
- Dictation must clearly state number of bars and which side stabilizer is placed
- Write General Surgery Pectus Repair Plan admit orders prior to patient transfer out of the O.R.

Postoperative Management

Admit to surgical floor from PACU
- Chest X-ray in PACU to assess for pneumothorax

Activity
- Showering ok on POD1
- POD1 out of bed to chair and ambulate goal is 3-4 times per day in halls, minimum of 2 times per day (bathroom does not count)

Nursing
- Temperature, heart rate, pulse oximetry, respiratory rate, pain assessment q 4 hours
- Pulse oximetry and cardiorespiratory monitoring if on continuous IV opioid infusion
- Strict I/O
- Diet: ad lib
- Incentive spirometry q 1 hour while awake
- Continue SCD (age ≥16 years) until ambulating
- Place Sternal Precaution sign above bed: Do not lift, no arm lift, 2 person assist, no log roll

Medications
- Continue perioperative antibiotics x 2 doses

Pain
- POD1 or 2: start oral pain medicines.
  - Oxycodone short acting (no long-acting), as needed
  - Acetaminophen/ibuprofen alternating, scheduled for 3 days
  - Ketorolac IV can substitute for ibuprofen, as needed, for up to 3 days

Home pain meds
- Oxycodone short acting (no long-acting), as needed
- Acetaminophen/ibuprofen alternating, as needed

Discharge Criteria
- No increased incision redness or pain
- Afebrile
- Pain adequately controlled without IV meds
- Tolerates diet without emesis
- Urine output >=0.5 mL/kg/hr
- Ambulating

Discharge Instructions
- PE540 Pectus Excavatum
- PE1453 Pain Medicine Log
- PE433 Constipation After Surgery
Intraoperative Management

**Anesthesia and pain management**
- Standard anesthesia procedures
- Standard PACU orders

**Infection prevention**
- Double glove
- Ioban drape
- Irrigate wounds with Betadine® solution
- Perioperative antibiotics
  - Cefazolin
  - Clindamycin if allergic
  - Vancomycin if MRSA

**Thrombosis prevention**
- Sequential compression device (SCD) if age 16 years or older, prior to induction

**Safety Precautions**
- Sternal saw available and open on the field to assure proper function

**Intraoperative Pain Management**
- **Cryoablation** to 2 nerves above and below bar entry level on each side
- Bupivacaine 0.5% (2mL per nerve) 2 nerves above and below bar entry level on each side

**Other**
- Dictation must clearly state number of bars and which side stabilizer is placed
- Write General Surgery Pectus Repair Plan admit orders prior to patient transfer out of the O.R.

Postoperative Checklist

1. Perioperative antibiotic given?
2. Double gloving performed?
3. Ioban drape used?
4. Povidone iodine (Betadine) washout performed?
1. The optimal timing for surgery for Pectus Excavatum repair is 13-17 years of age while the chest wall is still malleable (adults over 21 will need formal approval). However, repair at a younger age is appropriate in the setting of severe cardiac or pulmonary compression with associated signs of physiologic impairment.

2. Carefully and accurately dictate history and symptoms with regard to exercise, especially aerobic exercise intolerance:
   a. How far can youth run
   b. Can they keep up with their peers
   c. Key on aerobic events such as long distance running (more than 1 mile), soccer and basketball. Be aware that anaerobic activity (sprints, weight lifting) will usually NOT demonstrate the symptoms.

3. Referral if Marfan Syndrome suspected:
   a. Cardiology for potential ECHO
   b. Ophthalmology
   c. Genetics if Marfan Syndrome proven from either a or b above

4. If allergy suspected by history, outpatient trial with nickel

5. Pre-op testing:
   Required
   a. Chest CT scan to measure Haller index
   b. Assess for associated cardiac or pulmonary compression
      If there is cardiac and/or pulmonary compression – the patient should be referred to PASS clinic
   c. Cardiopulmonary exercise test (questionable correlation as current SCH test is an anaerobic test on treadmill with increase tilt until failure)

   Optional
   c. EKG, if symptoms consistent with ectopy. May be indicated to rule out other problems. (RAD is uniformly present: irrelevant finding.)
   d. Echocardiogram
      i. Should obtain if Marfan Syndrome (aortic root, AV)
      ii. May be indicated to rule out other anomalies
      iii. Poor correlation when performed at rest
   e. Pulmonary Function Tests have been eliminated

6. Nuss procedure is indicated for patients with a severe pectus excavatum deformity and associated physiologic impairment. Specific inclusion criteria include two or more of the following:
   a. Computed tomography (Haller) index greater than 3.25 (normal approx 2.80) with associated cardiac or pulmonary compression. An index greater than 3.25 is considered severe.
   b. Cardiology evaluation demonstrating cardiac compression, displacement, mitral valve prolapse, or murmurs.
   c. Documentation of progression of the deformity with advancing age in association with development of or worsening of physiologic symptoms (i.e. shortness of breath, lack of endurance, exercise intolerance, palpitations, and chest pain).

7. Refer to PASS clinic for any of the following:
   a. Evidence of cardiac or pulmonary compression
   b. Exercise intolerance
   c. Need for further consultation with any other subspecialties (pulm, cardiac, etc)

National and local expert opinion (Frantz 2011)
Pneumothorax

- Small pneumothorax
  - Almost universal
  - Follow-up chest x-ray unnecessary
- Large pneumothorax
  - Consider chest tube placement
  - Supplemental oxygen for O2 sats <92%
  - Repeat chest x-ray on day of discharge

Evidence [expert opinion]
Pain Management: Postoperative Day 1

- Start oral pain meds EARLY if not already on them
- Discontinue other IV pain meds
- Bowel movement not required for discharge

Evidence [expert opinion]
What is best practice for minimizing postop pain?

**Epidural**

*Using epidural postop did not lower pain scores to a clinically significant degree compared to PCA. [LOE: ☢️☢️☢️ Very low certainty due to lack of blinded outcome assessment, inclusion of young children, heterogeneity, small study size, and inconsistency of statistical significance. (Stroud 2014)]*

**Cryoablation**

*In 1 RCT and 5 non-randomized cohort studies reporting outcomes which included 196 patients who received cryoablation with a range of 1 week to 3 years follow-up, compared to controls, using cryoablation shortened LOS by around 1.1 to 3.5 days, added 20-30 minutes of surgery time, and reduced need for narcotics. Few complications or long-term pain have been reported. [LOE: ☢️☢️☢️ Very low certainty due to few patients (Graves 2019, Harbach 2018, Keller 2016, Graves 2017, Sujka 2018, Morikawa 2018)] In the RCT of 40 patients (Graves 2019), LOS was reduced by 2 days with cryoablation and all patients returned to normal sensation by 1 year. In the largest cohort study of 26 patients, none reported pain at 3 months. (Keller, 2016)*
Surgical Outcomes

What is the optimal procedure?
A meta-analysis found no randomized-controlled trials comparing Nuss to Ratvich procedures that met inclusion criteria. Eight trials were potentially eligible: 3 were prospective but not randomized, 4 compared the interventions but were retrospective and not randomized. One was a meta-analysis of retrospective studies. (De Oliveria, 2014) Johnson and Singhal (2014) conducted a systematic review of studies for adult and pediatric patients with pectus excavatum. They identified 39 cohort studies of the procedures and reported results qualitatively (a meta-analysis was not attempted). It is not possible to draw conclusions of comparative effectiveness from this paper because of its design.

In a meta-analysis of 13 quasi-experimental studies (n=1432 patients), comparing Nuss and Ratvich procedures,
- Operation time shorter for Nuss by 67 minutes (95% CI: 9 to 125 minutes), all ages
- Hospital LOS comparable (weighted mean difference -1.6, 95% CI -4.4 to 1.3)
- Analgesia and duration mean blood loss not well reported and not pooled
- In pediatric data, complications were not different between Nuss and Ratvich procedures.
[Level of Evidence (LOE): ⭐⭐⭐⭐ Very low quality (Kanagaratnam 2016), downgraded for small sample size and lack of historical control.]

In a meta-analysis of 19 quasi-experimental studies (n=1731 patients), Nuss procedure was associated with 51mL less blood loss (95% CI 33 to 70 mL) and no difference in length of stay (~0.85 days, 95% CI -0.54 to 2.22). [Level of Evidence (LOE) ⭐⭐⭐⭐ Very low quality (Mao 2017), downgraded for small sample size and significant heterogeneity]

Does surgery improve heart or lung function?
In a meta-analysis of 23 RCTs and cohort studies including 4272 patients, patients undergoing Nuss or Ratvich procedures did not experience an improvement in FEV1 from baseline at 1 or 3 years postop. [LOE ⭐⭐⭐⭐ Very low quality due to lack of historical controls and heterogeneity in outcomes at 3 years (Chen 2012)].

Jayaramakrishnan et al (2013) conducted a qualitative systematic review of 22 cohort and case-control studies that was not eligible to be GRADEd. After Nuss procedure, pulmonary function decreased in the early postop period (6-8 months) then showed a small improvement during the late postoperative period after bar removal.

In a meta-analysis of 13 studies (n=465 participants) assessing difference in pulmonary function testing results over 3 months to 3 years postop compared to baseline, changes in FEV1 (0.17, 95% CI 0.1 to 0.33) and FVC (-0.18, 95% CI -0.41 to 0.06) did not reach clinical significance. [LOE ⭐⭐⭐⭐ Very low quality due to lack of control group, small studies, and heterogeneity (Wang 2018)].
Pectus Excavatum (Nuss) v2.0: Approval & Citation

Approved by the CSW Pectus Pathway team for 7/31/19 go-live

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Operations Director: Karen Rancich Demmert, BS, MA

Retrieval Website: https://www.seattlechildrens.org/pdf/pectus-excavatum-nuss-pathway.pdf

Please cite as:
Evidence Ratings

This pathway was developed through local consensus based on published evidence and expert opinion as part of Clinical Standard Work at Seattle Children’s. Pathway teams include representatives from Medical, Subspecialty, and/or Surgical Services, Nursing, Pharmacy, Clinical Effectiveness, and other services as appropriate.

When possible, we used the GRADE method of rating evidence quality. Evidence is first assessed as to whether it is from randomized trial or cohort studies. The rating is then adjusted in the following manner (from: Guyatt G et al. J Clin Epidemiol. 2011;4:383-94, Hultcrantz M et al. J Clin Epidemiol. 2017;87:4-13.):

Quality ratings are *downgraded* if studies:
- Have serious limitations
- Have inconsistent results
- If evidence does not directly address clinical questions
- If estimates are imprecise OR
- If it is felt that there is substantial publication bias

Quality ratings are *upgraded* if it is felt that:
- The effect size is large
- If studies are designed in a way that confounding would likely underreport the magnitude of the effect OR
- If a dose-response gradient is evident

Quality of Evidence:
- 🌟🌟🌟🌟 High: The authors have a lot of confidence that the true effect is similar to the estimated effect
- 🌟🌟🌟 Moderate: The authors believe that the true effect is probably close to the estimated effect
- 🌟🌟 Low: The true effect might be markedly different from the estimated effect
- 🌟 Very low: The true effect is probably markedly different from the estimated effect

Guideline: Recommendation is from a published guideline that used methodology deemed acceptable by the team
Expert Opinion: Based on available evidence that does not meet GRADE criteria (for example, case-control studies).
Summary of Version Changes

- **Version 1.0 (5/22/2013)**: Go live
- **Version 2.0 (7/31/2019)**: Changed pain management to use cryoablation and remove soaker catheter
Medical Disclaimer

Medicine is an ever-changing science. As new research and clinical experience broaden our knowledge, changes in treatment and drug therapy are required.

The authors have checked with sources believed to be reliable in their efforts to provide information that is complete and generally in accord with the standards accepted at the time of publication.

However, in view of the possibility of human error or changes in medical sciences, neither the authors nor Seattle Children’s Healthcare System nor any other party who has been involved in the preparation or publication of this work warrants that the information contained herein is in every respect accurate or complete, and they are not responsible for any errors or omissions or for the results obtained from the use of such information.

Readers should confirm the information contained herein with other sources and are encouraged to consult with their health care provider before making any health care decision.
Literature Search Methods

For this update, we revised all our search strategies in line with current SCH Library practices. The initial literature search was conducted on June 8, 2019. The search targeted synthesized literature on all of the following concepts: funnel chest, pectus excavatum, or Nuss Ravitch and Robicsek procedures. The search was executed in Ovid Medline, Embase.com, Cochrane Database of Systematic Review, and Turning Research into Practice database (TRIP) for 2012 to current and limited to English. An expanded search was conducted on April 26, 2019 to capture any literature on the use of cryosurgery with funnel chest or pectus excavatum. The search was executed in Ovid Medline, Embase.com with no limits for language or dates.

Two reviewers screened abstracts and included guidelines and systematic reviews that addressed treatment of patients who meet pathway inclusion/exclusion criteria as well as randomized-controlled trials and cohort studies on the use of cryoablation to prevent pain. One reviewer screened full text and extracted data and a second reviewer quality checked the results. Differences were resolved by consensus.

Literature Search Results

The searches of the 4 databases (see Electronic searches) retrieved 66 records. Once duplicates had been removed, we had a total of 48 records. We excluded 18 records based on titles and abstracts. We obtained the full text of the remaining 30 records and excluded 16.

We included 14 studies. The flow diagram summarizes the study selection process.


