Anesthetic Management of Acute Subcutaneous Emphysema and Pneumothorax Following a Nuss Procedure: A Case Report

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The minimally invasive Nuss procedure has become the standard of care for surgical correction of pectus excavatum. Pectus excavatum is the most common congenital deformity of the chest wall. Historically, surgical correction was limited to the Ravitch procedure, an invasive procedure associated with significant drawbacks, where abnormal cartilage was removed and the sternum elevated and stabilized. Patients typically experienced a prolonged recovery period, from 6 to 9 months and significant postoperative pain.

The Nuss procedure, invented in 1998, is much less invasive and has a success rate of 90% compared with the Ravitch procedure with a success rate of 70% to 80%. This more recent procedure normally has an exceedingly low complication rate, reported to be 8% to 11%. Postoperative analgesia ranges from patient controlled analgesia to a thoracic epidural depending on the surgeon's preference. This case report details an immediate postoperative complication that occurred with its subsequent anesthetic management.

Keywords: Nuss procedure, patient controlled analgesia, pectus excavatum, Ravitch procedure, subcutaneous emphysema.

Pectus excavatum (PE) is the most common deformity of the chest wall occurring in 1/700 live births.[1] It is a congenital deformity characterized by a concavity of the sternum. At birth, there is a mild deformity of the chest wall producing an inward displacement of the sternum that progresses as the child ages. This inward displacement of the sternum, if left untreated, can contribute to shortness of breath, pain, and cardiopulmonary growth restriction.

Indications for surgical repair include the extent of the deformity and resultant impact on cardiopulmonary function. A chest x-ray and or echocardiogram may be done preoperatively to assess pulmonary and cardiac function to determine the degree of compromise. Cosmesis is also a factor that will affect most adolescents, as body image is a major concern. A pectus index of greater than 3.25, compared to the normal 2.56, is a primary indication for surgery. This index is derived by dividing the transverse dimension of the chest by the sternovertebral dimension.[2]

Before 1998, PE was surgically treated with the Ravitch procedure. This involved a mobilization of the sternum by resecting the costal cartilages bilaterally and performing a sternal osteotomy. This invasive procedure involved longer intraoperative time, greater blood loss, more postoperative pain, and longer length of stay compared to the Nuss procedure.[3]

A minimally invasive approach using the Lorenz pectus bar was developed by Donald Nuss, MD, in 1998. The bar is placed under the sternum, which, over the next 2 years, enables the malleable sternum and flexible cartilages to assume a more anatomic conformation. The Figure illustrates the 3 stages of surgical correction. The benefits of this technique include sparing cartilaginous incision and resection, avoiding chest wall incision, raising pectoralis muscle flaps, and resecting rib cartilage. Other benefits include shorter operative time, less blood loss, decreased postoperative pain, decreased length of stay, and earlier return to normal activity.[4]

Complications associated with the Nuss procedure include pectus bar migration, pneumonia, atelectasis, local infection, and pleural and pericardial effusion, which contributed to an overall complication rate of 11.1% that included pneumothorax, atelectasis, and subcutaneous emphysema.[3]

The following case report describes the perioperative course of a young patient undergoing the Nuss procedure.

Case Summary

A 14-year-old male (159.8 cm, 50.6 kg), ASA I classification, who presented for a pectus repair with a pectus index of 4.2. Medical history was unremarkable, and he denied a history of exercise tolerance or discomfort. He was not taking any over-the-counter herbal medications or prescribed medication and had no known drug allergies or sensitivities to latex or food allergies. A physical examination was performed preoperatively by the pediatric nurse practitioner that revealed a healthy male in no acute distress. Lung sounds were clear to auscultation, and heart sounds revealed no murmurs or gallops and was in a regular cardiac rhythm. No preoperative testing or imaging was ordered.

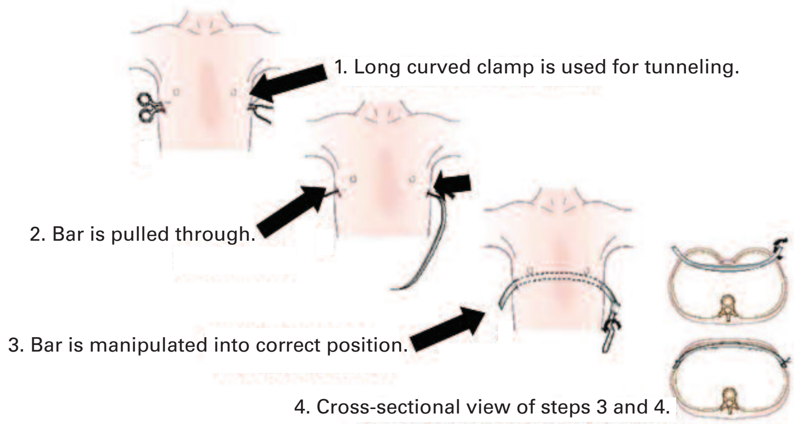

Figure. The Nuss Procedure for Pectus Deformity

On the day of surgery, no change from the preoperative visit was noted. Preoperative vital signs were: temperature, 36.2°C; heart rate, 72 beats/min; respiratory rate, 18 breaths/min in an unlabored pattern; blood pressure, 115/67 mm Hg; and SaO_2, 100% on room air (FIO_2, 21%). After discussion with the patient, the patient's family, and the surgeon, the anesthetic plan was developed that included an inhalational induction, establishment of intravenous access, general anesthesia with insertion of an endotracheal tube (ETT), and subsequent extubation in the operating room. The decision to perform an inhalational induction rather than an intravenous induction was based on the anesthesia care team's choice to observe the patient's ventilatory pattern under anesthesia to identify any potential problems with ventilation that may arise because of the pectus deformity. Postoperative care would include transfer to postanesthesia care unit and then to an inpatient unit where postoperative patient controlled analgesia would be ordered for postoperative analgesia. This particular surgeon prefers patient controlled analgesia as opposed to a thoracic epidural for postoperative pain management.

Preoperative medication included midazolam, 10 mg orally, and acetaminophen, 650 mg orally. The patient was transferred to the operating room where standard monitors were applied, which included a pulse oximeter, noninvasive blood pressure cuff, and a 3-lead electrocardiogram placed posteriorly to avoid the surgical field.

An inhalational induction was started with 7 L nitrous oxide (N_2O) and 3 L oxygen (O_2), followed by incrementally adding sevoflurane at 2%, 4%, 6%, and 8%. Spontaneous ventilation occurred without difficulty. An 18-gauge intravenous catheter was placed in his left wrist. Vecuronium, 6 mg, was given, and after ensuring the patient could be easily manually ventilated, direct laryngoscopy was performed with a MacIntosh blade 3 that yielded a grade I view. Intubation was easily and atraumatically accomplished with a 6.0-mm cuffed ETT. Positive $ETCO_2$ revealed a normal waveform and breath sounds were equal bilaterally. The cuffed ETT was taped at 18 cm at the lip and inflated with 1 mL of air to ensure an adequate seal. An orogastric tube was then placed along with an oropharyngeal airway. Cefazolin, 1 g, was administered intravenously after discussion with the surgeon to decrease the incidence of a postoperative surgical infection. After sterile prep/drape by the surgical team, the procedure started uneventfully. The pain service was consulted during the case for postoperative analgesia, in this case intravenous patient controlled analgesia.

Maintenance of the anesthetic involved an FIO_2 of 50%; O_2 and N_2O, 1.5 L/min; and desflurane at an expired concentration of 6%. Our decision to use N_2O was based on this procedure being minimally invasive and extrathoracic in nature.

At the end of the procedure, the surgeon requested reinflation of the lungs. The patient was manually ventilated with a sustained sigh breath with 100% O_2 reaching a peak inspiratory pressure of approximately 30 cm H_2O. An occlusive dressing was then placed over the pectus bar insertion sites.

The patient was given 4 mg of ondansetron for postoperative nausea and vomiting prophylaxis. Reversal of neuromuscular blockade was achieved with 0.6 mg glycopyrolate and 3 mg of neostigmine after observing spontaneous recovery of 1 out of 4 twitches on the train of 4 using the peripheral nerve stimulator. Before emergence, a postprocedure anterior posterior chest radiograph was obtained, and the patient was catheterized for 50 mL of urine. High peak inspiratory pressures occurred within 5 minutes of application of the occlusive dressing. Lung sounds upon auscultation revealed decreased breaths sounds throughout all lung fields. A diagnosis of bronchospasm was made, 3 metered puffs of albuterol 90 µg/puff was administered via the elbow between the ETT and the circuit, and the patient was manually ventilated with 100% O_2.

Additional auscultation revealed significantly decreased right side lung sounds with progressive difficult manual ventilation with a decreased pulse oximeter reading to 60%. The chest radiograph simultaneously revealed the following: ETT placement in midthoracic area, moderate right-sided pneumothorax with bilateral subcutaneous emphysema, and minimal atelectasis in the left base. The surgeons estimated a 20% right pneumothorax, and a decision was made to perform a needle decompression at the intersection of the midclavicular line and second rib. Approximately 100 mL of air was aspirated, which resulted in a rise in SaO_2 to 100%. Postneedle decompression chest radiograph revealed a slight decrease in the right pneumothorax based on the surgeons' estimation, persistent bilateral subcutaneous emphysema, and unchanged left lower lobe atelectasis. After discussion with the attending surgeon, the decision was made to awaken and extubate the patient.

After meeting the extubation criteria of spontaneous regular respiration, following commands, an SaO_2 of 99% to 100%, and exhibiting good sustained strength, the patient was suctioned and then extubated with positive pressure. Within 5 minutes after extubation, the patient was emergently reintubated after exhibiting signs of respiratory distress: SaO_2 in the 80s and shortness of breath. No tracheal deviation was noted. He received 50 μg of fentanyl, 100 mg of propofol, and 100 mg of succinylcholine. A direct laryngoscopy was performed and a 7.0-mm ETT was placed. A larger ETT was used in the event of prolonged mechanical ventilation in the pediatric intensive care unit (PICU). End-tidal carbon dioxide was present along with positive and equal breath sounds. Midazolam, 1 mg, was given for anterograde amnesia.

The third portable chest radiograph revealed a further decrease in the right pneumothorax, increased right-sided subcutaneous emphysema, and left lower lobe atelectasis. The decision was made to transfer the patient to the PICU after placement of a 20-gauge left radial arterial line. The transport to the PICU was uneventful.

The patient's postoperative course was stable. He was ventilated in the PICU with pressure support ventilation with a pressure of 10 cm H_2O, a rate of 5 breaths/min with 5 cm H_2O of positive end expiratory pressure. Initial arterial blood gases were pH, 7.36; PCO_2, 39.1; PaO_2, 101.7; HCO_3, 21.6; base excess, 3.4; and SaO_2, 97.5%. Initial PICU laboratory reports were unremarkable with the exception of a serum lactate level of 3.0 (0.5-2.0). Subsequent chest radiographs revealed no pneumothorax with decreasing subcutaneous emphysema.

The patient had an uneventful PICU course, was extubated at 5:30 AM on the first postoperative day. The postextubation chest x-ray revealed residual bilateral apical pneumathoraces with bilateral subcutaneous emphysema. He was transferred from the PICU to the medical/surgical floor, then subsequently discharged on the third postoperative day without further sequelae.

Discussion

Subcutaneous emphysema occurs when there is a compromise in the normal integrity of the skin leading to entrainment and entrapment of air. A pneumothorax occurs when air enters the thoracic cavity and is unable to escape. This diminishes lung expansion that can lead to a mediastinal shift.

In the case study presented, an occlusive dressing was applied that theoretically would have decreased the likelihood of entraining air into the thorax. The combination of positive pressure ventilation, the intrathoracic disruption due to the surgery, and the time period before the application of an occlusive dressing likely contributed to the entrainment of air. The patient did exhibit signs of subcutaneous emphysema but had no mediastinal shift on chest radiographs.

The incidence of complications concerning the minimally invasive Nuss procedure ranges from 8% to 11%.[5] There is further stratification into minor and major complications. The minor complication rate averaged about 8% and included self-resolving pneumothorax, atelactasis, and subcutaneous emphysema.[3] Major complications were identified as pectus bar dislocation, local infection, pleural and pericardial effusion, and hepatic injury with an overall incidence of 11.1%.[5] A Korean study that involved 322 patients yielded a total complication rate of 18.9%, of which 7.5% (24 patients) developed a pneumothorax. The treatment included spontaneous resolution (11 patients), needle aspiration (4 patients), chest tube insertion (1 patient) and percutaneous catheter placement (8 patients).[5]

After review of this case, the following issues were raised as factors that could have mitigated the progression of this complication: avoiding the use of N_2O for anesthetic maintenance, earlier application of an occlusive dressing, and ensuring the attending surgeon is present for the reading of the initial postoperative chest film. In this case, the pulmonary injury caused by the Lorenz bar placement was the causative factor in developing a pneumothorax with subcutaneous emphysema. The attending surgeon allowed the surgical fellow to "close" and review the initial postoperative radiograph, which contributed to the late detection of pneumothorax and the subsequent development of subcutaneous emphysema.

In conclusion, the incidence of acute respiratory distress requiring emergency reintubation and an unexpected PICU admission was unusual.

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