respiratory compromise is related to the wasted thoracic muscles.

When faced with this patient, we were unsure about the extent of contribution to the symptoms related to the diaphragm paralysis. Initially, we were keen to try noninvasive ventilation as a treatment strategy. After some deliberation, we decided to try plication as mainly a method by which the patient could be more able to recline. We were pleasantly surprised by the improvements in the patient's symptoms and by the objective improvement seen in the PFT results.

The staged approach allowed not only for stabilization of the patient but was also helpful in assessing improvement. We present this case to highlight the point that bilateral plication of paralysed diaphragm in Charcot-Marie-Tooth disease can lead to a dramatic improvement in quality of life, supported by objective evidence, and should be considered in this subgroup of patients.

References

1. Schmitt HJ, Muenster T, Schmidt J. Central neural blockade in Charcot Marie Tooth. Can J Anaesth 2004;51:1049–50.
2. Reilly MM, Murphy SM, Laurá M. Charcot-Marie-Tooth disease. J Peripher Nerv Syst 2011;16:1–14.
3. Aboussouan LS, Lewis RA, Shy ME. Disorders of pulmonary function, sleep, and the upper airway in Charcot-Marie-Tooth disease. Lung 2007;185:1–7.
4. Higgs SM, Hussain A, Jackson M, Donnelly RJ, Berrisford RG. Long term results of diaphragmatic plication for unilateral diaphragm paralysis. Eur J Cardiothorac Surg 2002;21:294–7.
5. Versteegh MI, Braun J, Voigt PG, et al. Diaphragm plication in adult patients with diaphragm paralysis leads to long term improvement of pulmonary function and level of dyspnea. Eur J Cardiothorac Surg 2007;32:449–56.

Thoracoscopy-Assisted Minimally Invasive Surgical Stabilization of the Anterolateral Flail Chest Using Nuss Bars

Sunkui Ke, MD, Hongbing Duan, MD, Yingjie Cai, MD, Jianle Kang, MD, and Zhipeng Feng, MD

Departments of Thoracic Surgery and Radiology, Zhongshan Hospital, Xiamen University, Xiamen, Fu, China

Flail chest is caused by complex fractures of multiple ribs as a result of severe chest injuries, which results in paradoxical chest movements that severely compromise respiratory function. We report our experience of thoracoscopically assisted, minimally invasive surgical stabilization of massive anterolateral flail chest using a Nuss bar in three patients. This technique offers effective stabilization while having the advantages of short surgical time, minimal blood loss, less trauma, quicker recovery, and small and inconspicuous incisions.

(Ann Thorac Surg 2014;97:2179–82)

Flail chest is caused by complex fractures of multiple ribs as a result of severe chest injuries. Because of the paradoxic movement, a flail chest can cause a significant decrease in tidal volume and an inability to clear airway secretions. These patients are prone to developing pneumonia and respiratory failure. Traditionally, patients with flail chest are treated with prolonged mechanical ventilation. In recent years, surgical fixation of the flail segment has become more accepted in selected patients. Several studies have shown that surgically treated patients have decreased ventilation and ICU requirements, a lower risk for pneumonia and mortality, less residual chest wall deformity, reduced total cost of care, and quicker return to work [1, 2]. Despite these advantages, surgical stabilization of flail chest remains underutilized because of the unfamiliarity of surgeons with stabilization techniques and the lack of effective hardware [3, 4].

We report our experience with thoracoscopically assisted, minimally invasive surgical stabilization of massive anterolateral flail chest using a Nuss bar in three patients. This technique offers effective stabilization while having the advantages of less trauma and quicker recovery.

Case Reports

Surgical Technique

Chest measurements were performed before surgery, and steel bars of appropriate length were selected. Steel bars were bent using anvil bar benders according to the three-dimensional reconstruction of their CT images. Using general anesthesia, a 1.0-cm incision was made in each uninjured chest wall on both sides of the flail segment. The pleural cavities were inspected using video-assisted thoracoscopy. Blood clots were removed and the pleural cavities were irrigated. Submuscular tunnels were made from each incision to a position lateral to the flail segment. A Nuss bar (Pectus Support Bar System; PTY Medical Device, Shanghai, China) was passed from a pre-selected uninjured intercostal incision, through the submuscular tunnel, and into the pleural cavity under thoracoscopic monitoring. The Nuss bar was passed across the mediastinum under the flail segment, and we brought out the chest wall through a preselected, uninjured intercostal incision and into a submuscular tunnel on the other side of the flail chest. The bar was rotated 180 degrees so that the convexity of the bar faced anterior to support the flail segment. The two ends of the bar rode on the uninjured ribs with the mid portion of the bar placed behind the flail chest wall. A second bar was placed as needed to support larger flail segments. The patients were observed in the intensive care unit with adequate analgesics and antibiotics. Once fracture healing was demonstrated on follow-up chest radiographs, the Nuss bars were removed in the operating room using general anesthesia.

Accepted for publication Aug 28, 2013.

Address correspondence to Dr Duan, Department of Thoracic Surgery, Zhongshan Hospital, Xiamen University, Xiamen, 361004, China; e-mail: dhb3100@sina.com.

0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2013.08.066

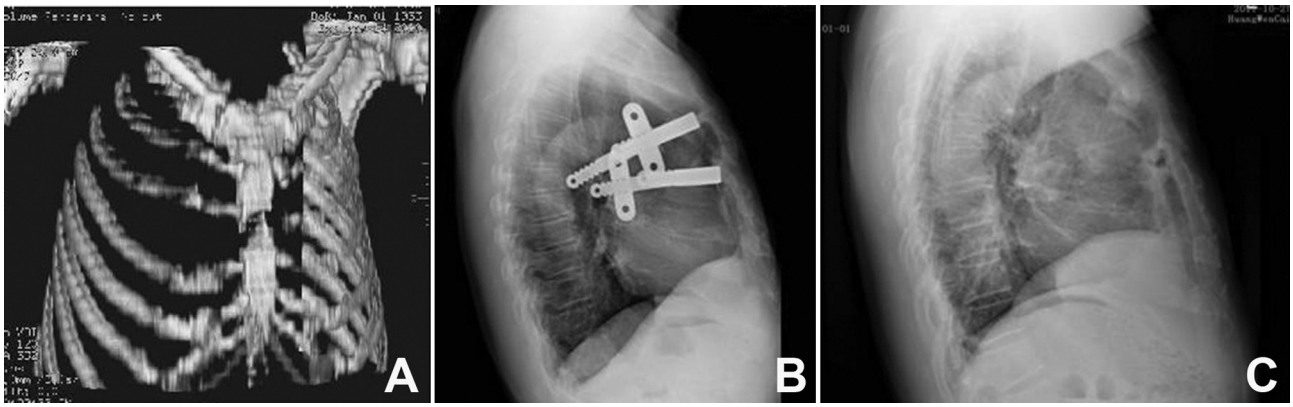

Fig 1. (A) Volume reconstruction (VR) presurgical three-dimensional computed tomographic scan. (B) Follow-up plain radiographs, 11 months after surgery. (C) Plain radiographs, 2 days after the bars were removed.

Case 1

A 58-year-old man was transferred to our emergency center 5 hours after sustaining a lorry strike to the anterior chest. Upon arrival, there was severe paradoxic movement of the chest wall. The patient had dyspnea and was unable to clear bloody secretions. His SaO_2 dropped to 80%. CT imaging with three-dimensional reconstruction revealed bilateral fractures of the second to fourth ribs, an upper sternal fracture, disruption of the costochondral junction bilaterally, bilateral hemothorax, and pulmonary contusions (Fig 1A). Surgical stabilization was performed 2 d later with the patient in the supine position. A transverse incision was made in each lateral chest wall between the anterior axillary and posterior axillary lines for thoracoscopically assisted Nuss bar placement. Surgical time was 120 min, and blood loss was 100 mL. The patient was extubated immediately after surgery and was able to breath comfortably without paradoxic movement. He was discharged home on postoperative day 12, and he resumed normal daily activities by 4 weeks. Follow-up chest radiographs showed no displacement of bars (Fig 1B). The Nuss bars were removed at 11 months after surgery without any adverse consequences (Fig 1C).

Case 2

A 30-year-old woman was transferred to our emergency center 4 days after sustaining a crush injury in a motor vehicle crash. There was severe paradoxic motion of the chest wall. Computed tomographic imaging and plain radiographs (Fig 2A) revealed multiple left anterolateral rib fractures and a left hemothorax. The patient also suffered a fracture of the pelvis, left acetabulum, and left olecranon. Nuss bar placement was performed 4 days later in a right recumbent position with two transverse incisions in the anterior axillary and scapular lines (Fig 2B). Surgical time was 80 min with minimal blood loss. Chest wall fixation prevented deterioration of her overall condition and allowed surgical stabilization of the pelvis and other fractures 6 d later. Her Nuss bar was removed 5 months later (Fig 2C).

Case 3

A 46-year-old man presented to our emergency center 2 hours after sustaining a trauma to the anterior chest

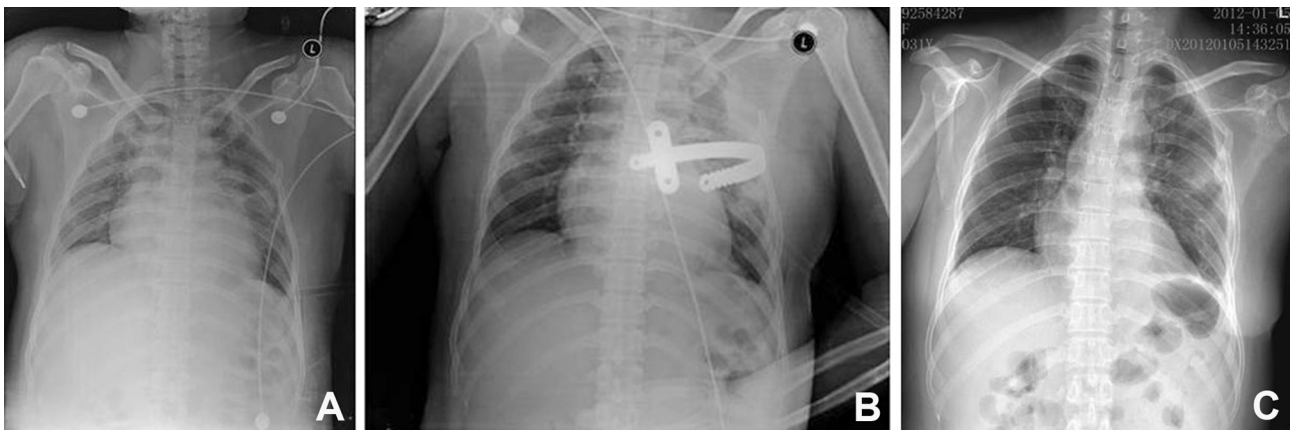

Fig 2. (A) Presurgical anteroposterior plain radiographs. (B) Follow-up plain radiographs, 4 days after surgery. (C) Two days after the bars were withdrawn.