

Sternal plating for traumatic sternal non-union

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Abstract

Introduction

Sternal non-union is a rare complication of sternal fracture but one which may impact patients symptomatically or cosmetically. Should conservative measures fail, the indications for operative intervention have become more defined in recent years and new techniques have been developed to restore sternal position and thus correct chest wall shape and function.

Cases

We present two cases of aseptic sternal non-union. Case 1 involved a young patient with a protracted history of sternal pain owing to an injury induced by repeated low-grade stress. Case 2 refers to another young individual who presented with persistent pain 1 year after suffering a fractured sternum in a motor bike accident.

Outcome

Despite polarising inciting events, both were found to have non-union injuries to the sternum with evidence of pseudoarthrosis. We examine their management with parallel locking compression plate sternal fixation.

Discussion

We also evaluate the current literature with respect to sternal plating, novel operative and non-operative alternatives, including recombinant human parathyroid hormone, and peri-operative considerations, such as closed incision negative pressure therapy. With ever improving access to axial imaging, particularly in the setting of trauma, these injuries are likely to increase in prevalence.

Introduction

Sternal fractures, most frequently of the sternal body¹, are not an uncommon occurrence in the trauma setting, with an incidence of 8% in blunt thoracic trauma and 18% in polytrauma,

with the most common mechanism being motor vehicle accidents, accounting for 68% of injuries^{1,2}. Whilst the majority of sternal fractures are managed conservatively initially, evidence suggests that operative intervention in the acute phase may reduce morbidity and mortality in select patients^{2,3}. However, indications for such early surgical intervention remain poorly defined and there persists a clinical spectrum of opinion with respect to the optimum time to proceed to operative management. In contrast, there is gathering consensus regarding the appropriate intervention for sternal malunion or non-union – a rare complication of sternal fractures, occurring in 1% of patients⁴.

Sternal non-union can be defined as a persistent sternal fracture without evidence of healing for greater than three months^{2,4} and malunion whereby the sternal fracture heals in an abnormal position². Operative intervention in this setting aims to restore the sternal fragments to the correct position, neutralising shearing forces to the sternum and thereby correcting the anterior chest wall shape and function⁵. Indications for surgery include the presence of a sternal deformity, the loss of sternal continuity for greater than six weeks and the persistence of chest pain for two to eight weeks following trauma⁶. Nevertheless, the absolute necessity for operative intervention remains challenging to identify, as it is widely accepted that pain can last for up to 12 weeks, even in a healing sternum⁷.

Over the past several decades, materials used for sternal fixation have included stainless steel wires, absorbable plates, non-absorbable plates and internal cemented screws². However, given the sparsity of cases, the optimal method of intervention has yet to be defined.

We present two cases of sternal non-union following polarising thoracic insults, describe our experience with locking compression sternal plating and provide a narrative literature review of sternal plating for sternal pseudoarthrosis.

Case one

A 22-year-old, otherwise healthy, gentleman presented to the cardiothoracic surgery outpatient department with a protracted two-year history of central chest discomfort in the absence of other concerning cardiorespiratory symptoms. Examination was significant for a small area of tenderness at the midpoint of his sternal body. After extensive workup by various other specialities, he underwent magnetic resonance imaging (MRI) of his sternum and was found to have non-fusion of the first and second parts of the body of sternum with evidence of discontinuous new bone formation suggestive of pseudo-arthrosis (Figure 1a). On further questioning, he recalled no specific history of trauma but detailed being involved in heavy lifting as part of his employment in his teenage years. This low-grade repetitive stress was felt to be the likely inciting event. He underwent an elective procedure under general anaesthetic to debride a bony prominence in the affected region. A soft tissue defect was found beneath the bone which was consistent with radiologically diagnosed pseudo-arthrosis. Following this, sternal plating was performed with two vertical, parallel, five hole Depuy

Synthes reconstruction, 3.5mm, locking compression plates (LCP) fixed to sternum either side of midline with 4x 14mm and 6x 10mm screws using depth limited drilling (Figure 1b). This was covered with bilateral pectoral flaps which were raised during the procedure, with a one eighth inch drain inserted and negative pressure dressing applied (Prevena[®]). Post-operatively, he was fitted with a sternal binder and recovered well. X-rays (Figure 1c) displayed stable positioning of the plates without complications. He was discharged uneventfully day three post-operatively with a satisfactory initial improvement in symptoms, which persisted at his six-week post-operative review.

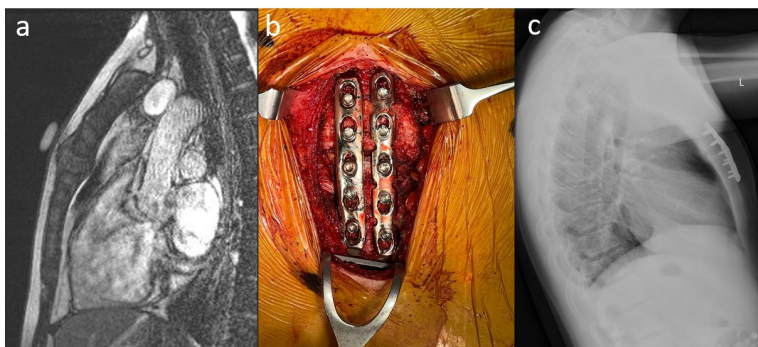


Figure 1: a) Coronal section of pre-operative MRI with skin marker over point of maximal discomfort, b) Intra-operative imaging of sternal plates c) Lateral chest x-ray post-operatively

Case two

A 37-year-old gentleman, who was involved in a high-speed motor bike incident and suffered a minimally displaced fracture to sternum, presented to the cardiothoracic surgery department six months later with persistent sternal pain resulting in limitation of physical activities and a grinding sensation within the chest wall on movement. His symptoms failed to resolve with conservative measures and outpatient follow up. MRI displayed a persistent transverse fracture of the mid body of sternum with mild anterior displacement of the distal fragment, which displayed partial non-union. Computed Tomography (CT) findings (Figure 2a) were consistent with MRI and, following multi-disciplinary discussion, proceeding to surgical intervention was deemed appropriate 11 months following the initial injury. He underwent elective sternal plating with two vertical, parallel, eight hole, DePuy Synthes MatrixRib 2.8mm, sternal plates fixated to either side of the sternal midline using depth limited drilling with 6x 8mm, 6x 10mm, 1x 12mm and 1x 16mm screws (Figure 2b). The plates required considerable moulding to approximate the sternal shape given the anterior displacement of the distal sternum. The pectoral flaps were once again closed, an eighth inch drain inserted and Prevena[®] dressing applied. His post operative X-Rays were also satisfactory (Figure 2c)

and he was discharged day 5 post-operatively with relief of symptoms. Unfortunately, his pain had recurred, albeit to a lesser degree, at his six-week outpatient follow up appointment.

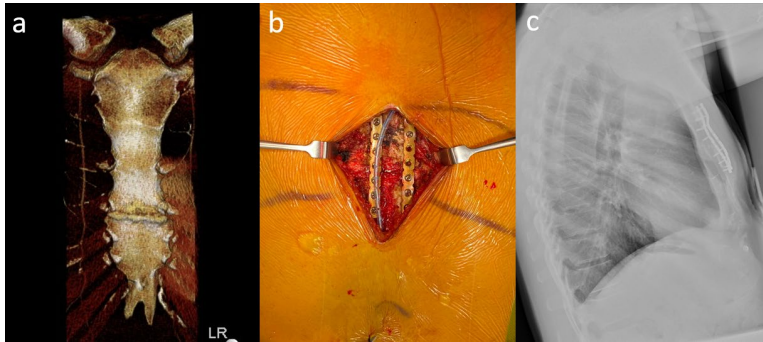


Figure 2: a) Pre-operative computed tomography of sternum, b) Intra-operative imaging of sternal plates, c) Lateral chest x-ray post-operatively

Discussion

Here we present two cases of sternal fixation with locking compression plates in patients with sternal non-union following contrasting inciting events. The motor vehicle incident resulting in case two's injury is typical of that resulting in sternal fracture but the repeated non-traumatic stress resulting in non-union in case one is quite unusual, albeit not unheard of. A case described by Bar-Haim et al⁶, involving a body builder with severe persistent chest pain despite no obvious inciting event and normal routine imaging, highlighted the importance of careful history taking and maintaining a high index of suspicion, as dynamic ultrasound imaging was ultimately required to make the diagnosis in that case. Much in the same way as case one, repeat low level trauma to the sternum from weightlifting resulted in non-union, which was successfully managed with sternal plating⁶.

Sternal pseudarthrosis is defined as a defect of bony consolidation following trauma with no sign of healing and is characterized by sternal instability⁸. The incidence of both sternal non-union and sternal pseudoarthrosis following sternal fractures is poorly estimated, likely due to the undefined follow up of what is a relatively benign inciting insult but it is more commonly observed following midline sternotomy⁸. However, with the dawn of routine axial imaging for blunt force trauma, it is a complication that is likely to represent an increasing burden on healthcare systems, as CT imaging detects over 94% of sternal fractures that would previously have been missed on conventional chest x-ray⁹. In this way, more advanced imaging techniques, including 3-D CT reconstruction, have been advocated for to identify those likely to benefit from surgery¹⁰.

Whilst written in relation to the acute setting of sternal fractures, Richardson et al¹¹ propose that sternal fixation with plating is an underappreciated resource after utilising it in 35 patients to stabilise the sternum with outstanding results. Similar results were achieved in the 64 patients examined by Zhao et al¹². Metanalysis of 191 patients undergoing sternal fixation of any kind displayed a 98% healing rate and a mere 2% morbidity rate², albeit acknowledged by the authors that the interpretation of this data is limited given the heterogeneity of these studies and the inconsistent nature of case reports and series. Further systematic review by Klei et al¹ reaffirmed these findings, with a 100% effectiveness in inducing sternal healing in the 187 subjects studied, 42 of whom were operated on for non-union post trauma. Although not quite parallel, these findings may promote the theory that plating is an underutilised resource in the chronic sternal pain setting post sternal trauma.

Plates of various sizes and materials have been proposed in the management of these patients. Byun et al¹³ suggest the use of T shaped plates but this small cohort study is overwhelmed by the general consensus that leans toward the use of longitudinal titanium plates, with minimal exposure of the sternal fracture, reducing the risk of iatrogenic injury to vessels¹². This facilitates ease of reshaping the plates in the event of an uneven sternum¹², which was proven true in our second case. The use of locking screws, especially in thin bone affected by pseudoarthrosis⁶, is recommended as they allow rigid fixation that resists multidirectional tension¹² whilst minimizing plate-bone contact which preserves periosteal blood flow⁵. Reported experience of operative management of sternal pseudoarthrosis is largely following midline sternotomy rather than sternal fractures. Whilst sternal plating has been successful in this setting^{14,15}, patients have also been managed successfully with CT guided percutaneous cementoplasty⁸, but trials will be required to assess this intervention following trauma. Interestingly, Plass et al¹⁵ report three cases whose sternal pain persisted immediately after plating but in whom, following a period to allow sternal healing, the pain resolved following removal of the plates once their function was complete. This may indeed prove relevant to our second patient in longer term follow up.

However, novel operative and non-operative techniques continue to be developed. For example, Imanishi et al¹⁶ described a 2019 case whereby two pairs of bioresorbable plates were inserted anterior to and posterior to the sternum via a video assisted thoracoscopic surgical approach in order to enhance sternal strength. Minimally invasive plate osteosynthesis techniques also continue to be developed via a tissue incision made remote to the fractured bone, reducing exposure of and further damage to the fractured component of the sternum¹⁷. Whilst the use of autogenic bone transplant has been a long-recognised adjunct to operative management of sternal fractures^{18,19}, the harvest of bone, generally from the iliac crest, is a challenge. Recent experience from Kalab et al²⁰ promotes the use of femoral allogeneous bone grafting, which induces a 42% increase in osteoblast activity in the area of non-union. Sternal reconstruction using adipose-derived stromal vascular fraction stem cells

as an adjunct to surgery in lieu of bone transplant has demonstrated impressive success and with ease of access to adipose tissue via liposuction²¹. This innovation may represent the next globally accepted progression in the management of these patients.

For those whom operative intervention is not feasible, two case reports have proven the utility of teriparatide, a recombinant fragment of human parathyroid hormone, in promoting healing of sternal non-union within three months of initiation with a significant improvement in pain severity^{22,23}. This may be particularly useful in those with underlying osteoporosis and may yet prove useful as an adjunct to surgical intervention.

Finally, of note, both of our patient's wounds were managed post-operatively with Prevena[®] negative pressure dressings. This closed incision negative pressure therapy has been proven to reduce surgical site infections not only following a sternotomy²⁴, but specifically in the setting of rib and sternal fixation²⁵. Thus, negative pressure wound therapy should be considered the standard of care when plating in an attempt to alleviate the risk of prosthetic contamination.

Discussion

Sternal non-union with pseudoarthrosis is a rare presentation to cardiothoracic surgery departments and one which may require a high degree of clinical suspicion given the variability of inciting events. We have presented our experience with two DePuy locking compression plate products used for patients with aseptic post-traumatic sternal non-union and have found them to promise adequate initial effects. Future developments will undoubtedly lie in the creation of further devices to stabilise the sternum and ancillary knowledge regarding negative pressure dressings and stem cell therapy will continue to improve outcomes. However, what is desperately required is a comprehensive multi-centre study to accurately define, not only the indications for and optimal operative technique of surgical intervention, but the expected success rates, average durations of stay and complications involved. Post-traumatic sternal pseudoarthrosis may not only be an injury of concern in the future, but perhaps is one that the surgical community ought to be more cognisant of currently, with encouragement to promptly investigate persistent sternal pain following trauma.

Declarations of Conflicts of Interest:

None declared.

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