



Using Nitinol Continuous Compression Clips in Complex Chest Wall Repair: A Case Series of a Novel Tool for Fixation

Running title: Nitinol CCC in Complex Chest Wall Repair

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Abstract

The surgical stabilization of chest wall injuries, including rib and sternal fractures, is an evolving field in trauma and critical care surgery with more complex and challenging repairs being undertaken. Nitinol continuous compression clips (CCC) have various established applications in orthopedic surgery which may have a role in certain cases of complex chest wall trauma. This case series presents four patients with complex thoracic injuries requiring repair, in which Nitinol CCC were employed as part of the operative strategy. These include cases of 1) multiple anterolateral rib fractures with concurrent sternal fracture, 2) sternomanubrial joint dislocation with prior failed fixation, 3) para-sternal cartilage fracture with nonunion 4) complex costochondral fracture with nonunion after attempted fixation. At their initial post-operative visit all patients experienced postoperative improvement in pain, with no reported wound infections. The procedure was technically straightforward, and all patients qualitatively demonstrated meaningful gains in quality-of-life following intervention. The series illustrates varied injury patterns with unique surgical challenges in which the utility of Nitinol CCC in managing sternal proved effective. While the early outcomes suggest potential benefit in selected cases, formal prospective studies with larger cohorts are needed to define optimal indications and assess long-term efficacy in thoracic trauma patients.

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Introduction

Chest wall trauma, particularly involving rib fractures, flail chest, and sternal disruption, poses significant clinical challenges. Rib fractures are present in 40% of all blunt trauma cases and lead to significant morbidity and mortality [1]. Poor outcomes are associated with older age and extent of fractures [2]. Surgical stabilization of rib fractures (SSRF) has become a well-established component of treatment for select patients with thoracic trauma; although SSRF has become increasingly common, complex patterns such as sternal flail or chronic nonunion remain difficult to treat [3]. Traditional fixation methods may be associated with complications such as hardware failure, chronic pain, or insufficient union; screw migration or loosening in particular is one of the most common mechanisms of failure of SSRF, which is more predominant in osteoporotic bone [4]. A significant gap remains in the surgical management of sternal fractures and costochondral disruptions. Little long-term prospective data regarding surgical fixation of sternal fractures exists, although some studies indicate that surgical fixation of severe fractures may result in less opioid usage and greater quality of life [5]. While technology for rib fracture fixation has rapidly advanced and evidence supporting SSRF continues to grow, similar progress has not been made in addressing injuries to the sternum and costochondral junctions—despite their frequent coexistence with severe rib fractures [6].

Nitinol, an alloy composed of nearly equal parts nickel and titanium, has been introduced for the fixation of certain skeletal fractures as well as a component of vascular stents [7,8]. Nitinol has demonstrated promising mechanical properties, including superior elasticity compared to conventional titanium [9]. There is robust literature supporting its use in foot and ankle fractures, and expanding support for use in upper extremity and pelvic fractures [10,11]. The use of nitinol in thoracic trauma remains novel, however its malleability and shape memory characteristics make it a compelling option for anatomically complex repairs, such as those present in chest wall injury.

Nitinol continuous compression clips (CCC), which offer shape memory and continuous compressive force, represent a novel adjunct in the stabilization of bony thoracic injuries [9]. There is growing evidence to support its use in some sternal reconstructions or after cardiac surgery; however, there is limited evidence demonstrating its use in chest wall reconstruction,

specifically surgical fixation of complex rib fractures [9,12,13].

Here, we describe a series of patients with complex chest wall pathology treated with Nitinol CCC as part of their surgical management. In this series, we present cases of patients with unstable sternal fractures and/or costochondral disruptions who underwent successful stabilization using Nitinol CCC implants. In reporting these cases, we aim to contribute to the body of knowledge surrounding the utility of nitinol CCC in surgical fixation of chest wall trauma.

Case Series

This manuscript is written following the CARE reporting checklist. The completed checklist is attached as supplemental material.

Case 1: Severe Chest Wall Instability

Following a motor vehicle collision (MVC), a 35-year-old female sustained anterolateral rib fractures that resulted in complete instability of the anterior chest wall (Figure 1). Although the sternal fracture was not displaced, the addition of anterolateral rib fractures produced a highly unstable chest wall with painful asynchrony with respiration. She was unable to mobilize, elevate her arm above neutral, cough effectively, or take deep breaths without experiencing debilitating pain. Her opioid requirements to achieve comfort at rest were so high that she was often unable to maintain consciousness. Physical examination revealed asynchronous motion of the right anterior chest wall with palpable crepitus and clicking during minimal movement. Muscle spasms were frequent with any positional changes.



Figure 1: Preoperative 3-Dimensional Reconstruction, Case 1

Given the severity of her symptoms and the anticipated need for upper body effort during recovery, the decision was made to surgically repair the chest wall, including

the sternum, on hospital day 2. Although stabilization of the ribs alone may have mitigated sternal instability, residual movement at the fracture site could be seen on intraoperative ultrasound following rib fracture fixation. Surgeons believed this could have significantly impeded rehabilitation and prolonged her disability and opted to perform surgical stabilization of sternal fracture (SSSF) via a small incision.

A 4 cm longitudinal incision was made over the sternal fracture, guided by preoperative ultrasound. After dissection to the anterior sternal cortex and measurement confirming a 1 cm thickness, appropriately sized Nitinol CCC were selected. Drill depth was confirmed, and a drill guide was used to span the fracture. Drill holes were placed, and clips deployed in standard fashion, achieving excellent reduction and stabilization (Figure 2). A manual pressure test confirmed construct integrity. The incision was closed in three layers.



Figure 2: Intraoperative Sternal Repair with Nitinol CCC, Case 1

Postoperative computed tomography (CT) showed appropriate placement of clips (Figure 3). She had no immediate complications following her surgery. The patient also underwent several orthopedic surgical repairs during her initial hospitalization and was discharged on hospital day 33. At last follow up 4 months later there was no reported residual disability secondary to chest wall pain.

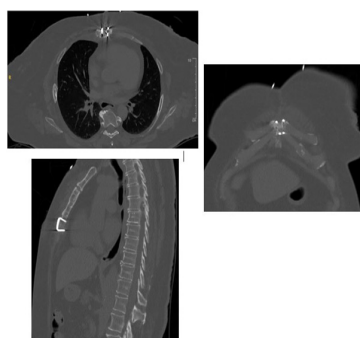


Figure 3: Postoperative Computed Tomography, Case 1

Case 2: Failed Sternal Fixation

An otherwise healthy 36-year-old female patient sustained a severe sternomanubrial fracture-dislocation along with other long bone fractures. She was initially managed with conventional SSSF. However, the fixation failed due to screw pull-through, resulting in pain and visible deformity. Upon further review, the patient was found to have a previously unnoticed series of fractures where the cartilaginous portions of lower ribs attach to the lower sternum (Figure 4). Concerned that persistent instability would lead to ongoing pain and disability, we elected to revise the repair using a combination of Nitinol CCC and anterior osteosynthesis plates one month post-operatively. This hybrid approach provided both stabilization and compression across the fracture, with satisfactory intraoperative results. At 4 month follow-up she was found to have residual sternal pain but on exam was found to have no evidence of sternal instability. Repeat CT Scan showed intact hardware in good position with callus formation across the fracture. The patient was then lost to follow-up.



Figure 4: Preoperative 3-Dimensional Reconstruction, Case 2

Case 3: Chronic Sternal Nonunion

Following a high-energy motor vehicle collision, a 61-year-old female patient sustained a severe chest injury including a sternal fracture, which was treated with standard fixation 1.5 years prior to her current presentation. One year later, she returned with persistent, intense focal pain triggered by specific movements, at the inferior sternum. Imaging and clinical assessment revealed a fracture-dislocation at the cartilage-sternum junction, previously missed (Figures 5, 6).

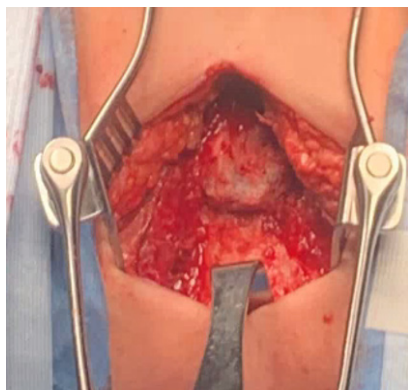


Figure 5: Intraoperative View of Sternal Chronic Nonunion, Case 3

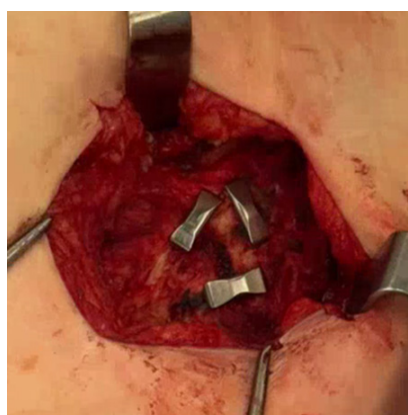


Figure 6: Intraoperative view of sternal nonunion after Nitinol CCC placement, Case 3

Due to the limited anatomical space and the cartilaginous nature of the injury, conventional fixation hardware was deemed unsuitable. Nitinol CCC were chosen to supplement the stabilization of with fracture compression using CCC. Bone marrow aspirate concentrate (BMAC) was applied to promote healing in conjunction with the mechanical stabilization. This repair was suitable for this patient and she significantly improved pain and minimal limitation in upper extremity range of motion at three month follow-up. Repeat CT scan showed good position of CCC with complete bony mineralization of callus across all fractures.

Case 4: Costochondral Disruption

A 46-year-old female patient presented with persistent pain due to nonunion of costal cartilage fractures (Figure 7), despite previous attempts at delayed fixation using plates and screws. The first attempt at repair was two months following her injury, seven years prior to this presentation in 2017. Three years post-injury she underwent hardware removal due hardware failure. The

subsequent chronic instability significantly affected her quality of life. For definitive management, Nitinol CCC were utilized to achieve multidirectional stabilization of the complex cartilaginous fracture pattern. In addition, fixation overlay bridging bar was used to stabilize the fracture line given the high degree of mobility of the costal margin at this juncture (Figure 8). This patient had mild pain post-operatively three months after surgery. She was referred to Interventional Radiology for intercostal nerve block with some improvement.



Figure 7: Preoperative 3-Dimensional Reconstruction, Case 4

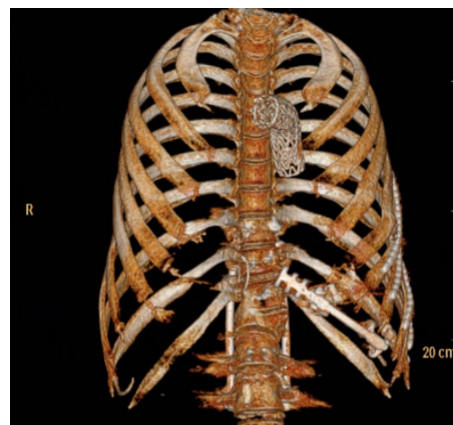


Figure 8: Postoperative 3-Dimensional Reconstruction with Nitinol CCC in place, Case 4

Discussion

This series highlights several scenarios where Nitinol CCC provided potential advantages in complex chest wall repair, including sternal flail, chronic nonunion, and revision surgeries after hardware failure. The shape-memory alloy properties of Nitinol provide continuous compression and adaptability to irregular bony surfaces, which may be particularly useful in anatomically challenging or on previously operated areas. The adjunctive use of bone

marrow aspirate in some cases suggests synergy in promoting healing at chronic nonunion sites.

We report a case series of four patients who underwent complex chest wall repair using Nitinol CCC implants at our center. All patients experienced postoperative improvement in pain, with no reported wound infections. The procedure was technically straightforward, and all followed patients demonstrated meaningful gains in quality-of-life following intervention.

While these outcomes are promising, they must be interpreted with caution. This is a small, uncontrolled series, and no direct comparisons were made with alternative techniques. Notably, all patients in this series had failed prior conservative management and/or traditional plate-and-screw fixation. This suggests that there may be a subset of patients suffering from chronic chest wall pain and instability for whom existing surgical strategies are insufficient. This smaller subset of patients would benefit from alternative approaches such as Nitinol CCC stabilization even when more classic screw and plate systems fail. The unique characteristics of Nitinol CCC, small footprint, ease of implant, continuous compression through structural memory, and versatility make it an ideal tool for stabilization of challenging anatomy.

The small number of patients and variability in clinical scenarios limit the generalizability of these findings. Additionally, long-term outcomes and comparative effectiveness against traditional fixation methods remain unknown.

The literature on Nitinol use for chest wall injuries remains limited. Hojski et al. described a series of 70 patients who underwent rib fracture fixation with nitinol-based hardware similar in construct to “Judet struts” and different from CCC described above [9]. They reported improved quality-of-life scores, no infections, and a low rate of clip fracture (n=4), which they attributed in part to improper clip contouring during placement. Similarly, Xiong et al. conducted a retrospective study of 123 patients with combined rib and sternal fractures [14]. They demonstrated improved outcomes—shorter hospital stays, reduced in-hospital complications, and better postoperative hemodynamic parameters—in patients who underwent operative fixation. However, the fixation in that study was applied to rib fractures rather than sternum or costochondral disruptions.

In the context of secondary sternal fractures, Antonic et al. presented a case series of 20 patients treated with Nitinol CCC specifically designed for this application, [15]. At six months, all patients demonstrated sternal union without wound infections, dehiscence, or instability. These findings further support the potential role of Nitinol in managing complex sternal pathology.

Further prospective studies with larger cohorts are necessary to evaluate the long-term efficacy, safety, and ideal indications for Nitinol CCC use in chest wall stabilization. This technology may offer a viable solution for select patients with complex, unstable sternal fractures and chronic nonunion patterns.

In conclusion, Nitinol CCC may represent a valuable adjunct in the surgical management of complex chest wall injuries, particularly in cases of sternal instability, costochondral disruption, or rib nonunion. This case series highlights their potential as a safe and technically feasible option with favorable early outcomes. However, larger, controlled studies are essential to determine optimal patient selection, refine surgical indications, and evaluate long-term efficacy.

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