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Surgical stabilization of flail chest injuries with MatrixRIB implants: A prospective observational study

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ABSTRACT

Background: Surgical stabilization of flail chest injury with generic osteosynthesis implants remains challenging. A novel implant system comprising anatomic rib plates and intramedullary splints may improve surgical stabilization of flail chest injuries. This observational study evaluated our early clinical experience with this novel implant system to document if it can simplify the surgical procedure while providing reliable stabilization.

Methods: Twenty consecutive patients that underwent stabilization of flail chest injury with anatomic plates and intramedullary splints were prospectively enrolled at two Level I trauma centres. Data collection included patient demographics, injury characterization, surgical procedure details and post-operative recovery. Follow-up was performed at three and six months to assess pulmonary function, durability of implants and fixation and patient health.

Results: Patients had an Injury Severity Score of 28 ± 10, a chest Abbreviated Injury Score of 4.2 ± 0.4 and 8.5 ± 2.9 fractured ribs. Surgical stabilization was achieved on average with five plates and one splint. Intra-operative contouring was required in 14% of plates. Post-operative duration of ventilation was 6.4 ± 8.6 days. Total hospitalization was 15 ± 10 days. At three months, patients had regained 84% of their expected forced vital capacity (%FVC). At six months, 7 of 15 patients that completed follow-up had returned to work. There was no mortality. Among the 91 rib plates, 15 splints and 605 screws in this study there was no hardware failure and no loss of initial fixation. There was one incidence of wound infection. Implants were removed in one patient after fractures had healed.

Conclusions: Anatomic plates eliminated the need for extensive intraoperative plate contouring. Intramedullary rib splints provided a less-invasive fixation alternative for single, non-comminuted fractures. These early clinical results indicate that the novel implant system provides reliable fixation and accommodates the wide range of fractures encountered in flail chest injury.

Introduction

Flail chest injury is diagnosed by paradoxical motion of an incompetent chest wall segment, comprised of three or more consecutive ribs that are fractured in at least two places. Flail chest is present in 6–15% of patients that have sustained blunt chest wall trauma.[1–3] Surgical stabilization of a flail chest injury in select patients can shorten the duration of ventilator support to reduce the morbidity and mortality associated with prolonged mechanical ventilation.[4–9] Moreover, surgical stabilization can decrease long-term pain and disability of flail chest injury due to mal-unions, non-unions and progressive collapse of the flail segment.[10–14] Recent guidelines published by the National Institute for Health and Clinical Excellence (NICE) recommend surgical stabilization of a flail chest based on consistent evidence of its efficacy and lack of major safety concerns.[15]

Fixation of rib fractures with generic implants is challenging for several reasons: first, the cortex of ribs is on average less than 1 mm thick,[16] providing little interface for reliable fixation of osteosynthesis implants, particularly in osteopenic bone.[1] Second, ribs are highly flexible[17,18] due to their ovoid cross-section with a typical width of 6–8 mm.[16] Standard osteosynthesis implants that do not restore the high flexibility of the native rib induce stress risers, are prone to fixation failure, and can lead to chest wall tightness.[19,20] Third, the geometry of the rib surface is conical and twisted, making intraoperative contouring of generic plates time-consuming and difficult.[16,21]

In case of flail chest injury, surgical stabilization of rib fractures is particularly difficult due to the number and complexity of fractures encountered and due to limited accessibility of posterior

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rib fractures. While not all fractures of a flail chest require fixation to stabilize a flail segment, the surgical procedure remains complex and typically requires a cooperative approach between orthopaedic, trauma or thoracic surgeons.[2,22] This complexity may explain in part the finding of a recent survey among 238 surgeons, whereby 76% agreed that rib fracture fixation was indicated in select patients, but only 26% had ever performed or assisted in rib fracture repair.[23] Surgical stabilization of flail chest injury has furthermore been complicated by a lack of implants that accommodate the unique form and function of ribs.[19] For the past three decades, surgical stabilization of flail chest injury has primarily been performed with generic osteosynthesis plates and intramedullary Kirschner wires.[24] The majority of reported complications were implant-related, including screw pull-out, implant breakage, wire migration and cut-out, pain related to prone hardware and chest wall rigidity attributed to stiff implants.[4,25–30]

In order to reduce implant-related complications and to simplify the surgical technique, a dedicated implant system for rib fracture fixation (MatrixRIB, Synthes CMF, West Chester, PA) has recently been developed based on a biometric study of human ribs.[16,17] This implant system entails anatomically contoured rib plates to reduce the need for intra-operative contouring, and intramedullary splints to enable less-invasive fixation of isolated or posterior fractures.[17,21] Biomechanical studies demonstrated that anatomic plate constructs restored the stiffness and strength of native ribs[17] and that intramedullary splint constructs were significantly stronger than Kirschner wire constructs while preventing cut-out failure.[31,32] However, these bench-top studies can only predict clinical performance within the limited test parameters of the experimental setup.

This prospective observational study documented our clinical experience with MatrixRIB implants for stabilization of flail chest injury in 20 consecutive patients. Next to patient outcomes, this study assessed implant performance in terms of the amount of intra-operative implant contouring, the durability of implants, implant fixation and flail chest stabilization and the incidence of implant-related discomfort or chest tightness that would require implant removal.

Patients and methods

From January 2009 to January 2011, 20 consecutive patients that required surgical stabilization of flail chest injury were enrolled at the Level I Trauma Centres of (Legacy Health System in Portland, OR, and the University Medical Center Brackenridge, Austin, TX). Indications for surgical stabilization were flail chest injury with three or more consecutive ribs fractures in at least two locations. Exclusion criteria were age <21 years or >80 years, pregnancy, severe closed head injury, severe spinal cord injury and associated extra-thoracic injuries that made survival during the follow-up period unlikely. The study protocol was approved by the Internal Review Boards of both institutions.

Patient demographics and injury information was obtained from pertinent medical records. The number and location of rib fractures was extracted from three-dimensional computed tomography (CT) reconstructions (Fig. 1A). These pre-operative CT reconstructions were deemed essential to plan the surgical approach and stabilization. They were also used to quantitatively assess the amount of lung contusion.[33] Areas corresponding to the healthy lung, contusion, haemothorax and pneumothorax were defined using a region segmentation tool (Amira 5.3, Visage Imaging GmbH, Berlin, Germany), and the contused volume was calculated as a percentage of the total long volume.

Flail chest stabilization was performed through a standard thoracotomy overlaying the flail location (Fig. 1B). Rib fractures were exposed and care was taken to preserve the periosteum (Fig. 1C). Fractures were stabilized with anatomic plates and intramedullary rib splints (Fig. 1D). For plate fixation, anatomically pre-contoured plates (MatrixRIB, Synthes) were cut to the desired

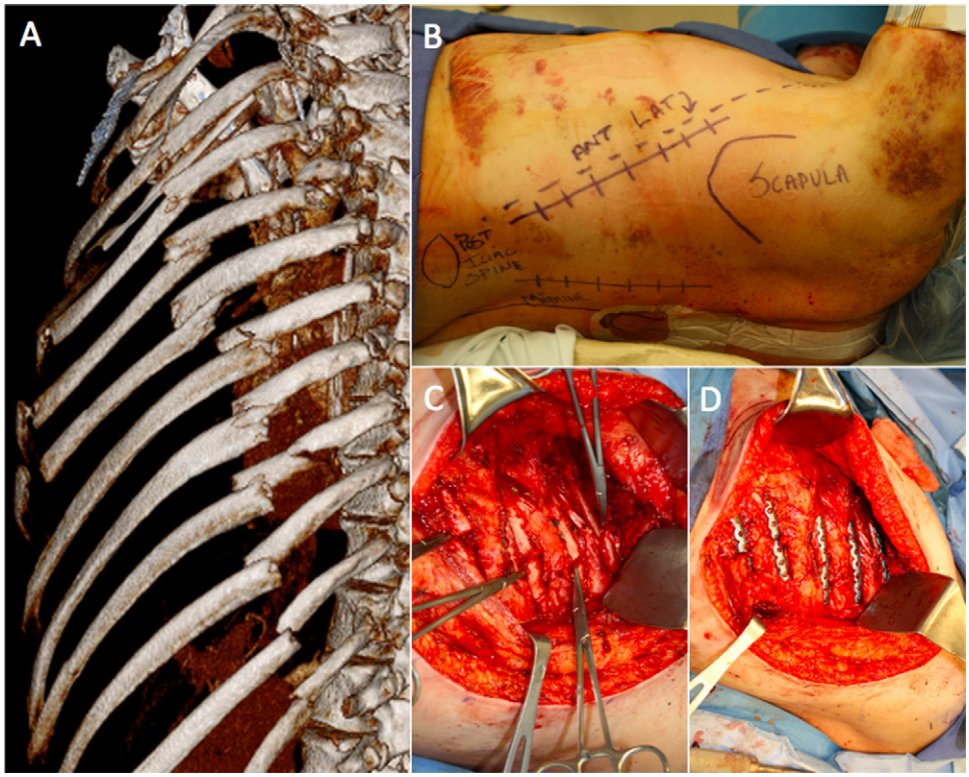

Fig. 1. (A) CT reconstruction is crucial for fracture visualization. (B) Intra-operative planning of left thoracotomy overlying the flail segment with latissimus sparing exposure. (C) Exposure of rib fracture with preservation of periosteum. (D) Surgical stabilization with anatomic plates.