Case Report

Costotransverse screws in repair of paraspinal rib fractures—a novel approach for rib fractures threatening the aorta

Ashley Bartscherer[1], Allan E. Stolarski[2], Claire P. Miller[1], Matthew Johnson[1], Alexa Giammarino[1], Daniel Bonville[3], John Dalfino[4], Marcel Tafen[1]

[1]Department of Surgery, Albany Medical Center, Albany, NY, USA; [2]Boston University, Boston, MA, USA; [3]Department of Surgery, Houston Methodist Hospital, Houston, TX, USA; [4]Department of Neurosurgery, Albany Medical Center, Albany, NY, USA

Correspondence to: Marcel Tafen, MD. Albany Medical College, 47 New Scotland Ave. MC-194, Albany, NY 12208, USA. Email: tafenwm@amc.edu.

Submitted May 30, 2018. Accepted for publication Dec 20, 2018.
doi: 10.21037/jtd.2018.12.107
View this article at: http://dx.doi.org/10.21037/jtd.2018.12.107

Introduction

Fragments of fractured ribs can lacerate the descending thoracic aorta and other mediastinal structures (1). The mortality associated with these aortic lacerations is extremely high. Therefore, awareness, early recognition and prevention are essential for patient survival. Currently, there is no consensus regarding the optimal strategy to prevent these penetrating aortic injuries (2). Prior techniques involved mostly eliminating the sharp rib edge threatening the great vessels (3). However, in the setting of multiple fractured ribs or an unstable chest, these techniques become problematic. Currently, threatened aorta by proximal rib fractures is not an indication for surgical stabilization of ribs (4). Additionally, plating ribs requires a landing zone on each side of the fracture for the recommended placement of three screws (5). In very proximal rib fractures, often there is not enough landing zone to accommodate three screws. We are reporting a case of open reduction internal fixation (ORIF) of paraspinal rib fractures to prevent penetrating aortic injury along with a review of the relevant literature.

Case presentation

A 21-year-old woman was struck by a train at high speed. At the scene, her blood pressure was 78/52, and pulse range was 140–160 bpm with an initial Glasgow Coma Scale of 15. She was transported to a local hospital where intubation and tube thoracostomy were performed for respiratory distress. Imaging revealed numerous left sided rib fractures and a left pneumothorax. With ongoing resuscitation, she was airlifted to our level one trauma center for further management. Further workup revealed multiple injuries (*Table 1*). Her past medical history was significant for bipolar disorder, major depressive disorder, anxiety and polysubstance abuse.

Table 1 Injuries

Skull based fractures with epidural hemorrhage
Left rib fractures 3–10 with flail segment 5–8
Right pneumothorax
Left hemopneumothorax
Left lower lobe laceration
Pneumomediastinum
Grade 5 splenic laceration
Left T1 lamina and T2 transverse process fractures
Left scapular and open humerus fracture
Right elbow, femur, and fibular fractures
Left open femur fracture

After arrival to our trauma center, she remained unstable and underwent an emergent exploratory laparotomy, splenectomy and external fixation of extremity fractures. She remained intubated and ventilated after the procedure in the surgical intensive care unit (SICU). Rib plating was initially considered given her flail chest, but this idea was quickly abandoned because of the proximity of the fractures to the spine. The distance between the closest fractured rib (left posterior 5th rib fragment) and the aorta on admission

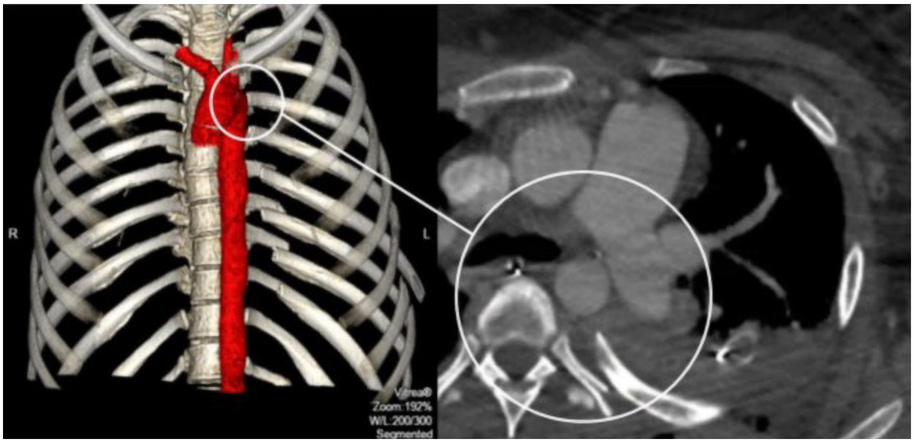

Figure 1 3D CT reconstruction of the chest on the left showing the flail pathology and paraspinal rib fractures threatening the aorta. On the right an axial CT cut is showing the proximity of the sharp fractured distal fragments of the left 5th rib to the aorta by a mere 6.5 mm.

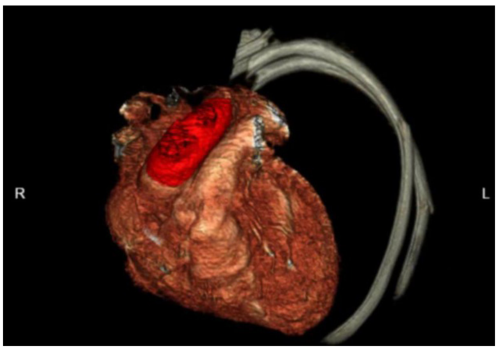

Figure 2 3D reconstruction of the chest (superior view) show in the sharp fracture ends of the left 4th and 5th ribs being very close to the descending aorta.

computed tomography (CT) scan was approximately 23.4 mm. On hospital day five, during a subsequent survey of her injuries by the SICU team, the proximity of the fractured rib fragments to the aorta was reappraised and determined to be a threat to the aorta. A repeat CT scan of the chest was performed to further assess the rib fractures (*Figures 1,2*). Immediate "do-not-turn the patient" orders were placed to minimize the risk of penetrating aortic injury. Vascular surgery was consulted the same day, and a computed tomography angiography (CTA) scan was performed to ensure that an aortic injury had not already occurred. On that CTA scan, multiple left-sided rib fragments, including the 5th were now as close as 6.5 mm from her aorta (*Figures 1,2*).

Given the proximity of the rib fragments to the aorta, flail chest and respiratory failure, she was taken to the operating room on hospital day six for rib repair. Neurosurgery was consulted to assist in the manipulation of the vertebrae. The patient was placed in right lateral decubitus position while video-assisted thoracoscopic surgery (VATS) was performed with evacuation of retained hemothorax and survey of injuries. The fractured ribs were easily visualized in the thoracic cavity and were confirmed to be near the patient's aorta, without aortic injury. A vertical paraspinal incision was then made and carried posterolaterally around the scapula. After muscle dissection, the scapula was elevated off the ribcage, exposing the rib fractures. Posterior fractures in rib 7, followed by 8, 9, and then 5 and 6 were fixed with titanium locking osteosynthesis plates using the MatrixRIB® system (5). Please note that ribs 5 and 6 each received two costotransverse screws (*Figures 3-5*) placed in the corresponding ribs and transverse processes. Anterior rib fractures in ribs 7, 8, and 9 were also plated. The patient was subsequently extubated on post-operative day one, or hospital day seven. She was transferred to the floor on post-operative day three and discharged to a rehabilitation center 23 days after presentation.

Discussion

By proactively reducing and fixing this patient's fractured ribs, we not only helped mitigate respiratory failure, but also prevented a potential aortic puncture. The patient's posterior rib fractures with sharp boney edges were an imminent threat to the descending thoracic aorta. Comparison between the patient's CT scans gave clear evidence of shifting sharp distal rib fragments towards the aorta. Movement of these fragments is larger during

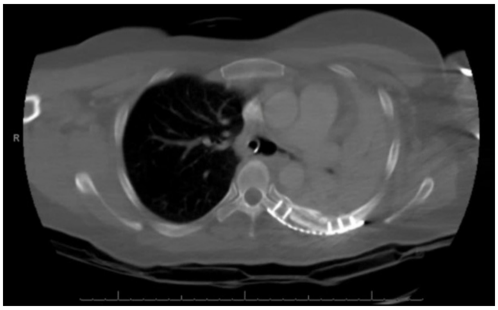

Figure 3 Axial CT of the chest illustrates the two costotransverse process screws used in surgical fixation of the 5th rib fracture. Note: this CT scan also demonstrates compressive atelectasis and hemothorax due to an unrelated trauma 19 months after initial presentation and surgical stabilization of rib fractures.

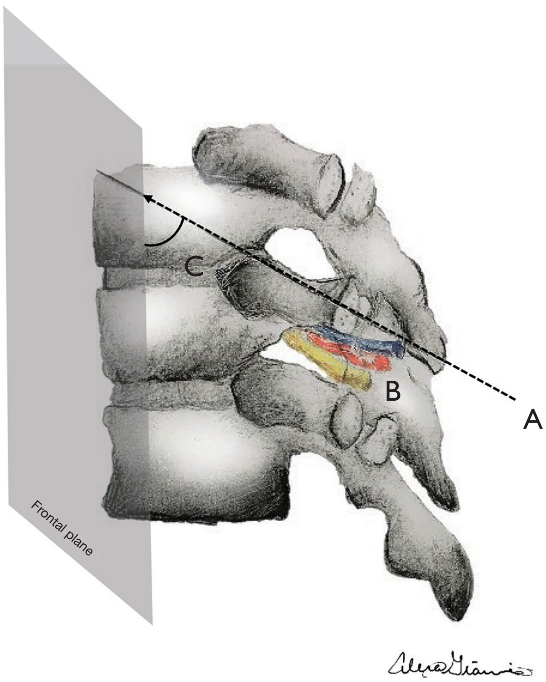

Figure 4 This schematic depicts the screw path (A) in relationship to the intercostal neurovascular bundle (B). The sagittal angle (C) is safer when maintained between 50°–70° from the frontal plane. Adapted with permission from Xu *et al.*

positional changes, such as turns or getting out of bed, putting the aorta at greater risk of injury during the abovementioned activities (1,6,7). Therefore, patients with very posterior rib fractures should be assessed for fracture patterns that could lead to impalement of nearby vital structures. Once the potential for injury is established, we

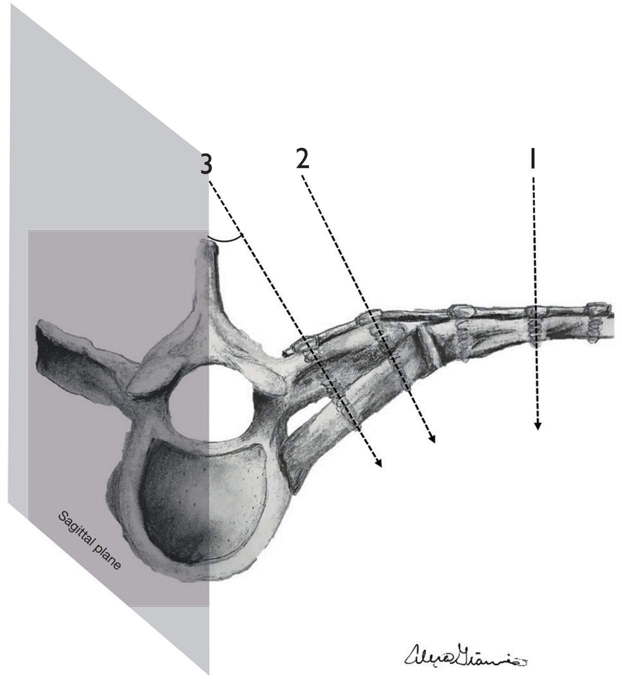

Figure 5 Relationships between the costotransverse joint, the costotransverse screws [2 and 3], the plate and the vertebral foramen. The screws are directed outward away from the vertebral body. For a safe path, an angle of 0° [1] to about 45° [3] from the sagittal plane must be maintained. Adapted with permission from Xu *et al.*

find it prudent to limit movement until surgical stabilization could be achieved. According to O'Conor *et al.*, traumatic injury to the aorta carries a 99% mortality rate without surgical intervention, and only 15% of patients will survive the first hour after injury (2).

Chest CT is an essential clinical tool that should be utilized in evaluating rib fractures and their potential for causing aortic laceration. However, it is imperative to review the CT with the injury pattern reported in mind. In one case, a patient died of a penetrating aortic injury from the sixth rib in which an improper reading of the chest CT was reported (8). Delayed presentations have been reported with similar injuries for up to fourteen days (9).

According to our literature review, the most common predisposing injuries are posterior left sided rib fractures involving ribs 4–11, most commonly 6, 7, or 8 as seen in *Table 2*. Cases of anterior right sided rib fractures have been described as well yet are less common (2). Mechanisms of injury are mostly blunt chest trauma, including falls, motor vehicle crashes, struck pedestrians, and crush injuries.

Surgical interventions have focused on a symptomatic

Table 2 Relevant literature review

Author	Year	Mechanism of injury	Fractured ribs	Rib causing injury	Aortic injury present on admission	Days post injury operation was performed	Technique of intervention	Outcome
Ashafran (10)	2005	Motorcycle accident	Not specified	Not specified	No	11	Primary repair of aorta	Survival
Boyles (3)	2013	Tractor accident	Left posterior 7–8	Left posterior 7–8	No	–	None	Death
Bruno (11)	2009	Slip and fall	8–9	8	No	6	Thoracotomy & incision	Survival
Sailhamer (12)	2007	Fall from height (5 ft)	Left 9–12	10	No	1	Thoracotomy	Death
Hsu (8)	1998	Fall from height	6	6	Yes	0	Thoracotomy	Death
Iyoda (13)	2003	Fall from height	Not specified	Not specified	Unknown	7	Thoracotomy with direct aortic closure and removal of rib fracture edge	Survival
Kano (14)	2014	Attempted suicide	3–8	7	Yes	11	Aortic replacement	Death
Kern (15)	1998	Fall from height	Not specified	Not specified	Yes	0	Aortic repair and debridement of sharp rib fractures	Survival
Kigawa (7)	1992	MVA	8	8	No	10	Aortic repair and resection of sharp rib fractures	Survival
Kitamura (16)	2012	Fall from height	5–11	7	No	2	Aortic repair and fractured rib resection	Survival
Marco (17)	1997	Motorcycle accident	5–6	6	Unknown	3	Aortic repair and rongeuring	Survival
Morimoto (18)	2014	MVA	9	9	Yes	2	Aortic repair and removal of 9th rib	Survival

approach, repairing the aorta after the injury has already occurred. Techniques have included filing, rongeuring, or resecting the jagged rib to prevent further sequelae. Operative intervention has been suggested in the literature in the setting of a left sided rib fracture threatening the aorta (12). However, only two prior case reports have focused on using surgical intervention as a preventative technique, one performed open reduction with internal fixation and the other using rib removal (12,19). We strongly suggest that an ORIF approach to rib fractures with the potential of causing aortic injury be considered in the management of these patients. This is particularly true in the setting of multiple rib fractures, flail chest, respiratory failure, and intractable pain given the mounting evidence from prospective studies. Surgical stabilization of fractured ribs is emerging as a very useful tool in thoracic trauma. These studies indicate that operative fixation of rib fractures lead to shorter intensive care unit (ICU) stays and better pulmonary outcomes compared to non-operative management (4,20,21). The outcomes and timing of ORIF for rib fractures in polytrauma patients require further study (22).

It is generally recommended to place three screws on each side of the fracture when performing ORIF (5). However, circumstances imposed us not only to place a limited number of screws but also to use an alternative structure to achieve fixation. This case demonstrates that when there is not sufficient landing zone posteriorly, the transverse process is an appropriate site for fixation. More rigid fixation is achievable by inserting the screw through the transverse process, across the costotransverse joint and into the dorsal cortex of the rib (23). This is the first case to our knowledge where posterior rib fractures were plated with screws placed through the transverse process adjacent to the rib. It has generally not been recommended to repair very posterior rib fractures due to the complex anatomy and the proximity to the spine (24). However, by their morphology, thoracic transverse processes are amenable for screw insertion (25). The costotransverse joint is a synovial joint ensheathed in a capsule and adjacent ligaments. The joint involves the thoracic vertebral body, the costal tubercle, and the transverse process. Care should be taken to avoid the neurovascular bundle which runs in the costal transverse space by directing the screws parallel to about 45 degrees to the sagittal plane and cephalad 50–70 degrees relative to the frontal plane (23) (*Figure 4*). Failure to direct the screw properly can result in injury to the neurovascular bundle and violation of parietal pleura. To further minimize risks, it is important to bear in mind that the boney purchase of the transverse process plus the dorsal cortex of the rib in the thoracic region is estimated to be around 13 mm. Loss of articulation of the costovertebral and costotransverse joints is expected, yet the effect on respiratory function is unknown.

Conclusions

Rib plating is effective in preventing a jagged edge of a fractured rib from penetrating great vessels. Costotransverse screw placement is feasible and an appropriate technique for management of paraspinal rib fractures. We propose early surgical intervention for patients who have posterior rib fractures in the left chest to prevent the development of aortic injury.

Acknowledgements

Marco Vitto, MD from Albany Medical Center Department of Radiology for technical assistance.

Footnote

Conflicts of Interest: D Bonville and M Tafen are paid consultants for DePuy Synthes. This study was presented at the 2018 Chest Wall Injury Summit of the Chest Wall Injury Society, March 2–4, 2018, in Park City, UT.

Informed Consent: Written informed consent was obtained from the patient's legal authorized representative for publication of this manuscript and any accompanying images.

References

1. Roth T, Kipfer B, Takala J, et al. Delayed heart perforation after blunt trauma. Eur J Cardiothorac Surg 2002;21:121-3.
2. O'Conor CE. Diagnosing traumatic rupture of the thoracic aorta in the emergency department. Emerg Med J 2004;21:414-9.
3. Boyles AD, Taylor BC, Ferrel JR. Posterior rib fractures as a cause of delayed aortic injury: A case series and literature review. Injury Extra 2013;44:43-5.
4. Tanaka H, Yukioka T, Yamaguti Y, et al. Surgical stabilization of internal pneumatic stabilization? A prospective randomized study of management of severe flail chest patients. J Trauma 2002;52:727-32; discussion 732.
5. DePuy Synthes Product Literature. MatrixRIBTM; Technique Guide; page 9.
6. Ashrafian H, Kumar P, Sarkar PK, et al. Delayed penetrating intrathoracic injury from multiple rib fractures. J Trauma 2005;58:858-9.
7. Kigawa I, Fukuda I, Fujii Y, et al. A sharp edge of the fractured ribs caused the aortic injury at body-position change: a case report. Nihon Kyobu Geka Gakkai Zasshi. 1992;40:1116-20.
8. Hsu YP, Chen RJ, Bullard MJ, et al. Traumatic thoracic aortic injury caused by a sharp edge of left fractured rib on body position change: case report. Changgeng Yi Xue Za Zhi 1998;21:343-6.
9. Ryu DW, Lee MK. Cardiac tamponade associated with delayed ascending aortic perforation after blunt chest trauma: a case report. BMC Surg 2017;17:70.
10. Ashrafian H, Kumar P, Sarkar PK, et al. Delayed penetrating intrathoracic injury from multiple rib fractures. J Trauma 2005;58:858-9.
11. Bruno VD, Batchelor TJ. ic injury: a rare complication of a posterior rib fracture. Ann Thorac Surg 2009;87:301-3.
12. Sailhamer E. Rib Fracture Causing Delayed Aortic Laceration. MD Magazine. 2007. Available online: http://www.mdmag.com/journals/surgical-rounds/2006/2006-10/2006-10_07, accessed January 30, 2018.
13. Iyoda A, Satoh N, Yamakawa H, et al. Rupture of the descending thoracic aorta caused by blunt chest trauma: report of a case. Surg Today 2003;33:755-7.
14. Kano M, Chikugo F, Fujimoto E. Delayed aortic injury caused by sharp rib fracture. Asian Cardiovasc Thorac Ann 2014;22:500.
15. Kern JA, Chan BB, Kron IL, et al. Successful treatment of exsanguinating aortic injury from a fractured rib. Am Surg 1998;64:1158-60.
16. Kitamura R, Colon M, Dave J. Delayed presentation of aortic laceration from seventh rib fracture: an uncommon complication. J Thorac Cardiovasc Surg 2012;144:e121-3.

17. Marco JV, Gregory JS. Posterior fracture of the left sixth rib causing late aortic laceration: case report. J Trauma 1997;42:736-7.
18. Morimoto Y, Sugimoto T, Sakahira H, et al. Successful management of threatened aortic rupture late after rib fracture caused by blunt chest trauma. Ann Vasc Surg 2014;28:1035.e11-3.
19. Sata S, Yoshida J, Nishida T, et al. Sharp rib fragment threatening to lacerate the aorta in a patient with flail chest. Gen Thorac Cardiovasc Surg 2007;55:252-4.
20. Granetzny A, Abd El-Aal M, Emam E, et al. Surgical versus conservative treatment of flail chest. Evaluation of the pulmonary status. Interact Cardiovasc Thorac Surg 2005;4:583-7.
21. Marasco SF, Davies AR, Cooper J, et al. Prospective randomized controlled trial of operative rib fixation in traumatic flail chest. J Am Coll Surg 2013;216:924-32.
22. DeFreest L, Tafen M, Bhakta A, et al. Open reduction and internal fixation of rib fractures in polytrauma patients with flail chest. Am J Surg 2016;211:761-7.
23. Xu R, Ebraheim NA, Ou Y, et al. Anatomic considerations of costotransverse screw placement in the thoracic spine. Surg Neurol 2000;53:349-54; discussion 354.
24. Pieracci FM, Rodil M, Stovall, RT, et al. Surgical stabilization of severe rib fractures. J Trauma Acute Care Surg 2015;78:883-7.
25. Cui XG, Cai JF, Sun JM, et al. Morphology study of thoracic transverse processes and its significance in pedicle-rib unit screw fixation. J Spinal Disord Tech 2015;28:E74-7.

Cite this article as: Bartscherer A, Stolarski AE, Miller CP, Johnson M, Giammarino A, Bonville D, Dalfino J, Tafen M. Costotransverse screws in repair of paraspinal rib fractures—a novel approach for rib fractures threatening the aorta. J Thorac Dis 2019;11(Suppl 8):S1090-S1095. doi: 10.21037/jtd.2018.12.107