



Case report

Bilateral first rib fractures with multi-organ complications: A case report and literature review

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ABSTRACT

Background: Bilateral first rib fractures are rare. This article presented the diagnosis and treatment of a case of bilateral first rib fractures with multi-organ complications and discussed the injury mechanism.

Case presentation: A 15-year-old girl fell off a motorcycle. She complained of right neck root pain and right upper limb weakness. The myodynamia of the right upper limb was grade 0, and the sensation disappeared below the level of the elbow joint. The computed tomography (CT) showed bilateral first rib fractures and transverse process fracture of the 6th cervical vertebra. Chest CT revealed a massive hemothorax in the right thoracic cavity, and head magnetic resonance imaging showed bilateral cerebellar infarction. Cervical computed tomography angiography (CTA) revealed a lumen occlusion at the origin of the right subclavian artery. The patient underwent an emergency thoracoscopy, and a re-examination of chest CT indicated that no obvious pleural effusion was found after the hemothorax was cleared. The patient underwent right subclavian arteriography and interventional endovascular thrombolysis, and the right subclavicular artery was patency postoperative. Bilateral first rib fractures and cerebellar infarction were treated conservatively. The brachial plexus injury did not show any signs of recovery after conservative treatment, and she was recommended to be transferred to a superior hospital for surgical treatment.

Conclusions: The injury mechanism of bilateral first rib fractures with multi-organ complications was closely related to the initial factor of the right neck root colliding with a bulge on the ground. We believe that the fractures occur as a result of a combination including a high energy trauma from direct impact and a low-energy mechanism from violent muscle contraction caused by neck hyperextension. This case report was helpful for clinicians to understand bilateral first rib fractures and their complications.

1. Introduction

First rib fracture is extremely rare, and bilateral rib fractures are even less common whatever the etiology might be [1]. Rib

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fractures are presented in about 10 % of trauma patients, and 90 % of patients with rib fractures are associated with injury [2]. First rib fracture has been a challenge for doctors since it was first described in 1869 [3].

It is well known that traumatic fractures usually involve not only the first rib but also the surrounding structures such as the clavicle and scapula [4]. Severe thoracic trauma is closely associated with fracture of the first rib and commonly predisposes patients to injury of the subclavian vessels, brachial plexus, and other mediastinal structures [1]. We herein reported a traumatic bilateral first rib fracture with multi-organ complications involving the chest, vascular, brachial plexus, and brain, and discussed the mechanism of injury.

2. Case presentation

A 15-year-old female of Chinese descent was involved in a motorcycle accident where she fell off the vehicle while riding as a passenger, then she was admitted to our hospital. The patient had a history of good health before this. She described the motorcycle tipped to the left due to excessive speed when turned left. The right neck root collided with a bulge on the ground as she fell off the back of the motorcycle. The patient complained of right neck root pain right upper limb weakness, and no chest pain or dyspnea. The patient's vital signs remained stable following admission. Multiple abrasions and swelling were found on the surface of the face, forehead, and right neck root, and wounds of about 5cm and 8cm were presented on the left face and the right neck respectively. The physical examination conducted one-hour post-injury indicated diminished sensory perception in the right upper extremity. The myodynamia of the right upper limb was grade 0/5, and the myodynamia of the right deltoid, biceps brachii, and forearm extensor was grade 0/5 respectively. The sensation of the right upper arm was reduced, and the sensation disappeared below the level of the elbow joint. The pulsation of the right radial artery was weak. Electromyography showed that the motor conduction of the median, ulnar, radial, musculocutaneous, and axillary nerves of the right upper limb failed to elicit positive waveforms. The right deltoid, biceps brachii, abductor pollicis brevis, and dorsal interossei showed a large amount of abnormal spontaneous electrical activity at rest. The preliminary diagnosis was root avulsion of the right brachial plexus. The initial head, neck, and chest CT following admission showed bilateral first rib fractures (Fig. 1A and B), and transverse process fracture of the 6th cervical vertebra (Fig. 1C). The soft tissue at the right neck and entrance of the thorax was contused, and the hematoma was formed. Bilateral mild pneumothorax was found without head abnormalities. The wound was repaired with a suture. 2 hours after the patient was shifted to the intensive care unit (ICU), and the blood routine examination revealed a significant decrease in hemoglobin levels by 20g/L. The subsequent re-examination of chest CT revealed a massive hemothorax in the right thoracic cavity (Fig. 2A) the afternoon following the admission. Head magnetic resonance imaging (MRI) showed bilateral cerebellar infarction (Fig. 2B), and abdominal CT showed no abnormality on the following

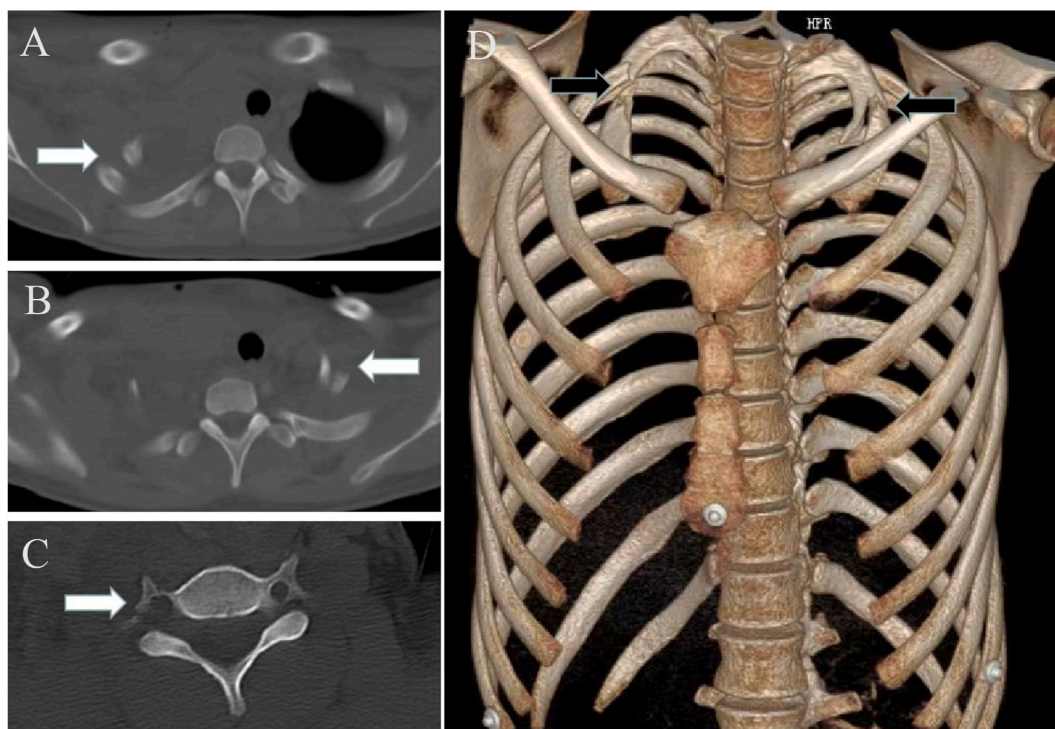


Fig. 1. Images of bilateral first rib fractures and transverse process fracture of the 6th cervical vertebra. A and B. The neck and chest CT showed fractures of the right and left first rib respectively (white arrow). C. The neck CT showed a transverse process fracture of the 6th cervical vertebra (white arrow). D. Three-dimensional CT of the neck and chest confirmed bilateral first rib fractures (black arrow) and the displaced fractures of the right first rib with a jagged edge.

day of admission. Cervical CTA revealed a lumen occlusion at the origin of the right subclavian artery (Fig. 3A).

The patient underwent emergency right subclavian arteriography on the night of admission. Intraoperatively, the occlusion of the right subclavian artery was observed, and the occlusion length was 3.8cm (Fig. 3B). The blood supply of the distal upper limb can be supplied by collateral vessels, and no vertebral artery occlusion or vessel rupture was found. A thoracoscopy was performed after arteriography, The patient was placed in the left slope position. The skin was incised 1.5cm at the intersection of the right midaxillary line and the 6th intercostal space, followed by the insertion of a 10mm trocar as an observation port. The procedure of thoracoscopy was conducted, revealing a substantial volume of hemothorax. The skin was incised 3cm at the intersection of the right anterior axillary line and the 4th intercostal space as a surgical access point. The suction device effectively removed all the blood and clots from the chest. The parietal pleura at the apex of the chest exhibited hematoma and bleeding. The technique of electrocoagulation was employed for hemostasis, Subsequently, the chest cavity was irrigated with saline solution, and the procedure concluded with the insertion of a closed thoracic drainage tube. On the 7th day after admission, the patient underwent right subclavian arteriography and interventional endovascular thrombolysis. The right subclavicular artery was patency and the pulsation of the right radial artery was normal postoperative (Fig. 3C). The right closed thoracic drainage tube was removed on the 9th day postoperatively, and repeat chest CT showed no obvious pleural effusion was found. Bilateral first rib fractures and cerebellar infarction were treated conservatively. The right upper limb was placed on an arm sling, and the joints were subjected to passive movement. The muscles were stimulated with electric currents, and massage and acupuncture were performed on the patient for a month. However, the patient did not show any recovery signs of sensory and motor function in the right upper limb. The patient continued to complain about right upper limb weakness and no sensation below the level of the elbow. Our hospital could not provide a more effective treatment plan due to the difficulty and complexity of the treatment of brachial plexus root avulsion, and the patient was recommended to be transferred to a superior hospital for nerve reconstruction surgery.

3. Discussion

The first rib fracture is relatively rare due to its anatomical features. It is short and thick, parallel to the transverse plane of the body, and protected by the scapula, clavicle, and adjacent muscles. Therefore, less forceful impacts often result in fractures of ribs located more superficially [5]. It has been believed that high-energy injury mechanisms, such as high-speed motor vehicle collision, are necessary conditions to cause the first rib fracture [6]. Among the five reported injury mechanisms leading to fracture of the first rib, only three are associated with high-energy trauma [7]. The three mechanisms include direct posterior trauma to the upper chest or shoulder girdle, direct blow to the sternum/anterior chest wall, and direct blow fracturing the clavicle [8]. The other mechanisms of first rib fracture include intense sudden contraction of the scalenus anterior muscle and stress fracture, and these are considered to be low -energy mechanisms [9]. Bilateral first rib fractures, regardless of the different mechanism, can be divided into one of the three categories [10]: (1) because direct chest injury, is often associated with road traffic accidents; (2) In sports, especially in rowing and weight lifting where excessive muscle contraction of the neck must occur immediately; (3) Medical cases of respiratory problems requiring excessive contraction of accessory breathing muscles such as asthma and pertussis in children. Connolly reported that first rib fractures can be combined with cervical traumatic lesions, and the 6th and 7th cervical vertebrae were injured in more than one-third of the cases [11].

However, it was interesting that the bilateral first rib fractures in our case could not be explained by the previously reported mechanism [5,10,12–29] (Table 1), it had a different mechanism of occurrence. The right neck root collided with a bulge on the

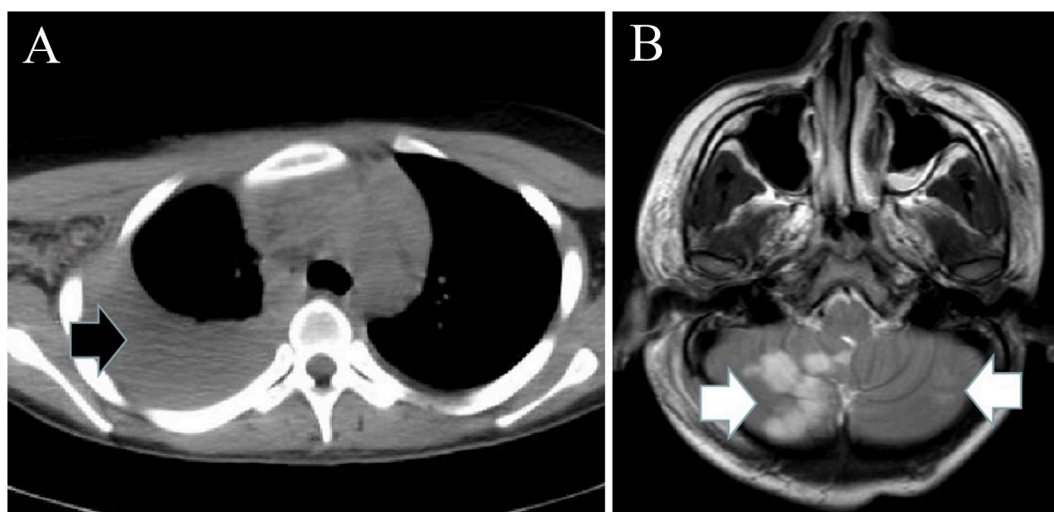


Fig. 2. Images of hemothorax and cerebellar infarction. A. Chest CT showed massive right hemothorax (black arrow). B. Head MRI revealed bilateral cerebellar infarction (white arrow), and the right lesions were more severe than those of the left.

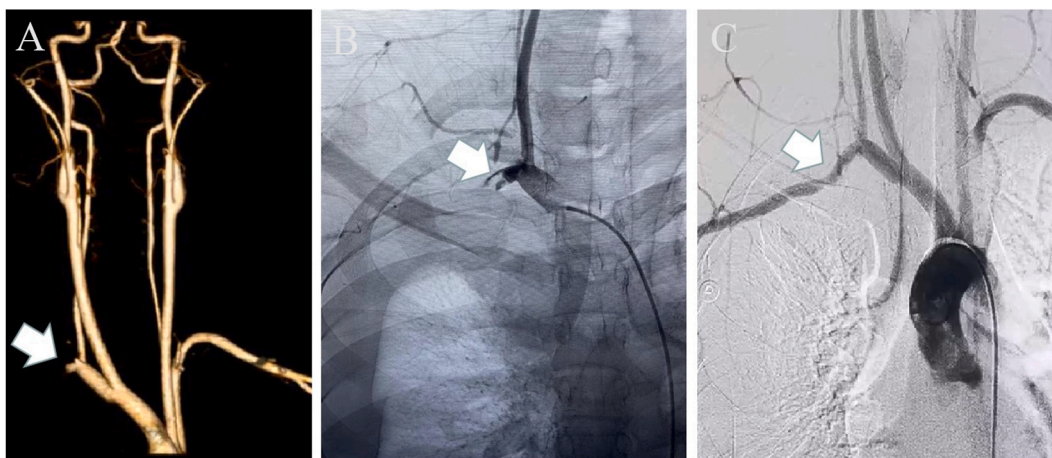


Fig. 3. Preoperative and postoperative images of right subclavian artery occlusion. **A** and **B.** Cervical CTA and arteriography showed lumen occlusion of the initial segment of the right subclavian artery respectively (white arrow). **C.** Arteriography revealed that the right subclavian artery was patency after interventional endovascular thrombolysis (white arrow).

ground when the patient fell off the motorcycle. On the one hand, due to the excessive impact force which directly led to the fracture of the right first rib and the transverse process fracture of the 6th cervical vertebra (displaced fractures); on the other hand, the patient also hyperextended her neck as she fell, which might cause the scalenus anterior and sternocleidomastoid muscles to contract forcefully resulting in the bilateral first rib fractures. Our patient had an abraded wound over the forehead during her fall which indicated a hyperextension moment at the neck.

In addition to its usefulness as an indicator of severe trauma, the first rib fracture may also produce injuries [30]. The three-dimensional CT showed that the right first rib was completely displaced, with a jagged edge of the fracture line (Fig. 1D), and the jagged rib edges damaged the cupula of the pleura by respiratory movement. The impact of the fall caused the rupture of the right neck or intercostal blood vessels, and blood flowed into the pleural cavity through the rupture of the right cupula of the pleura. No active bleeding was found with thoracoscopy after the right hemothorax was cleared, which confirmed that the pleural hemorrhage was not the result of substantive organ injury in the thorax.

Tellechea suggested that the occurrence of bilateral first rib fractures should rule out the possibility of injury to the major vessels [31]. Vascular injuries in patients with first rib fractures range from 5.5 % to 48 %, and the aorta is the most common injury, followed by the subclavian artery [7]. Previous studies suggested that subclavian artery injury may be related to first rib fracture [32]. The manifestations of subclavian artery injury include subclavian artery laceration, rupture, aneurysm, and delayed rupture [15]. Under such circumstances, early angiography should be considered promptly. Yee suggested that the indications of arterial angiography in first rib fractures should be limited to patients with (1) obvious displacement of the fragments, (2) hemothorax, (3) alteration in blood pressure or pulse of the affected extremity, (4) brachial plexus injury, and (5) subclavian groove fracture [33]. The arteriography of our patient revealed right subclavian artery occlusion without significant tear or rupture of the artery wall, which was different from previous reports. We thought that the patient's head swung to the left followed by neck hyperextension and rotation as she fell to the ground. The sudden and intense contraction of the neck muscles exerted a shear force on the right subclavian artery, and this shear force resulted in damage to the right subclavian artery intima, in addition, the hematoma of the neck compressed the right subclavian artery, which leads to right subclavian artery thrombosis and arterial occlusion.

First rib fractures with neurologic injuries were frequent, with an overall incidence of 37 %. The most common head injury was concussion [7]. Sammy pointed out that the relatively high incidence of severe cervical vertebra and head injuries reinforced the need for greater vigilance in the management of patients with first rib fractures [34]. In our case, the patient was conscious with a rolling gait because the head MRI showed bilateral cerebellar infarction, and the right lesions were more severe than that of the left. We considered the mechanism as follows: The thrombus entered the right vertebral artery after it partially detached from the right subclavian artery and resulted in right cerebellar infarction. The partial thrombus reached the contralateral side by the anastomotic branch of the cerebellar artery and resulted in a left cerebellar infarction.

The brachial plexus injuries were described in 1 % of the polytrauma and in 4–5% of the public way accidents [35]. The lesions of the brachial plexus were associated 72 % with a cerebral injury, 13 % with a cervical fracture, and 52 % with a neurapraxia [36]. The patient presented with right brachial plexus root avulsion, and the mechanism of injury was similar to that of vascular injury. The sudden and intense contraction of the neck muscles exerted shear forces on the root of the brachial plexus, and shear force resulted in the root avulsion of the right brachial plexus.

The limitation of our study was that the patient's brachial plexus injury did not show any signs of recovery, and she was recommended to be transferred to a superior hospital for surgical treatment.

Table 1
A review of injury mechanism of first rib fracture cases reported.

Sex	Age (years)	Department	Symptoms	Unilateral or Bilateral fractures	Neurovascular abnormality or Cerebellar infarction	Injury mechanism	Reference
Male	17	Orthopedics	Shoulder pain and arm paresthesia	Unilateral	Neurologic injury	Stress fractures: Winging a bat	Kawashima et al. (2020)/[12]
Male	13	Orthopedics	Shoulder pain and arm paresthesia	Unilateral	NA	Stress fractures: Basketball rebounding	Kawashima et al. (2020)/[12]
Male	18	Emergency Department	Right supraclavicular fossa pain	Unilateral	NA	Falling on his flexed right elbow	Breen et al. (2011)/[5]
Male	33	Emergency Department	Severe hness	Unilateral	Neurologic injury : Horner's syndrome	Indirect traumatic force from the sternum	Lin et al.(2015)/[13]
Male	18	Emergency Department	Right shoulder pain	Unilateral	NA	Stress fractures: weight training	Vikramaditya et al. (2001)/[14]
Female	12	Emergency Department	Left shoulder pain	Unilateral	NA	Stress fractures: play rugby	Vikramaditya et al. (2001)/[14]
Male	55	Emergency and ICU	Severe dyspnea	Bilateral	The left subclavian artery rupture	Blunt trauma: he was struck by a car while riding a motorcycle	Yonezawa et al. (2017)/[15]
Male	49	Orthopedics	Paresthesia of the left superior member	Unilateral	The left brachial plexus injury	Public way crash	Legaye et al. (2006)/[16]
Male	19	Orthopedics	Dyspnea and paresthesia of the superior member	Bilateral	The left Horner's syndrome and the left brachial plexus injury	Motor vehicle accident	Mcadam et al. (1986)/[17]
Female	28	Emergency Department	Acute pain behind the clavicles	Bilateral	NA	A hoarding fell from height on her head and shoulders	Chatterjee et al. (2011)/[10]
Male	17	Orthopedics	Right shoulder and neck pain	Unilateral	NA	Collision injury: a direct blow to the right shoulder/neck area	Colosimo et al. (2004)/[18]
Male	19	Orthopedics	Left lower limb and right-hand pain	Bilateral	NA	Driver's airbags inflation	Stoneham et al. (1995)/[19]
Male	28	Cardiothoracic surgery	Chest pain	Bilateral	NA	The thorax was run over by a motor vehicle	Moodley et al. (2007)/[20]
Male	24	Center for Spine Pain	Medial scapula, upper thoracic, and sternal pain	Unilateral	NA	Fatigue of the bone	Nguyen et al. (2006)/[21]
Male	18	Sports medicine and orthopaedic Center	The posterior scapula pain	Unilateral	NA	Suffered a blow over the posterior scapula while playing football	Barrett et al. (1988)/[22]
Male	17	Sports medicine and orthopaedic center	The scapula and axilla pain	Unilateral	NA	The sternum was struck by a helmet	Barrett et al. (1988)/[22]
Female	48	Orthopedics	Left shoulder pain	Unilateral	NA	shoveling snow	Chan et al. (1994)/[23]
Male	51	Trauma Department	Chest pain and dyspnea	Bilateral	Neurologic injury : Horner's syndrome	A car drove over his chest at low speed	Ofri et al. (2017)/[24]
Male	63	Orthopedics	The neck and both shoulders pain	Bilateral	NA	Presented following a fall on outstretched hand	Karuppal et al. (2013)/[25]
Male	13	Emergency Department	The left shoulder and neck pain	Unilateral	NA	Stretching with a yawn	Lee et al. (2012)/[26]
Male	15	Orthopedics	The left shoulder and clavicle pain	Unilateral	Compression of the left subclavian artery and numbness in the left upper extremity	Jumping for a basketball rebound	Terabayashi et al. (2010)/[27]
Female	17	Orthopedics	Right shoulder and periscapular pain	Unilateral	The right upper extremity numbness along the ulnar nerve distribution	Stress fracture: pitching	Young et al. (2016)/[28]
Male	18	Rehabilitation and Sports Therapy Center	Left neck and shoulder pain	Unilateral	NA	Involved in a facemask-to-facemask collision	Sclafani et al. (2014)/[29]

ICU, intensive care unit; NA, not available.

4. Conclusion

Bilateral first rib fractures are rare entities that are associated with severe trauma. Different injury mechanisms can lead to different complications and clinical manifestations. Our case presented a different mechanism of injury that was not reported previously, and it should not be ignored for this mechanism. We advocated that an active, multidisciplinary approach should be adopted to identify and treat associated life-threatening injuries.

Ethics approval and consent to participate

The present case report was approved by the Ethics Committees of Yichang Central People's Hospital.

Consent for publication

A copy of the written consent is available for review by the editor of this journal. The patient's father provided written informed consent for the publication of the information.

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Data availability statement

All data generated or analyzed during this study are included in this published article.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Ling Yao: Writing – original draft, Data curation, Conceptualization. **Xun Gong:** Data curation, Conceptualization. **Wanqiang Li:** Writing – review & editing, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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