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Original Research Article

First rib fractures as indicators of serious intra and extra-thoracic injury in polytrauma and their impact on the morbidity and mortality

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ABSTRACT

Background: First-rib fractures are relatively rare compared with fractures of other ribs because of the broad structure deeply placed and protected location of the first rib. A high amount of energy is needed to cause a first-rib fracture; violent trauma, such as that involving motor vehicle accident, is a frequent cause of these fractures, as well as other serious intra-thoracic, head, cervical spine, and intra-abdominal injuries. First-rib fractures have traditionally been considered indicators of increased injury severity and mortality in major trauma patients. The aim was to study the significance of first-rib fractures as indicators of serious intra-thoracic and extra-thoracic injury in polytrauma and their impact on the morbidity and mortality in a high-altitude area in Al-Taif, Saudi Arabia.
Methods: This is a retrospective study conducted in King Abdul-Aziz Specialist Hospital (KASH), Taif City, KSA. Patients with chest injuries who presented to the emergency department and were admitted to the hospital between November 2013 and March 2016 were included in the study. Data regarding first-rib fracture were collected, and the relationship between first-rib injuries and associated intra-thoracic and extra-thoracic injuries was analyzed.
Results: There was a high incidence of first-rib fracture (23.45%), and 35.8% were bilateral. The most common associated chest injury was a pulmonary contusion (58.5%), followed by pneumothorax (32.1%), hemopneumothorax (20.7%), and surgical emphysema (20.7%). The most common associated extra-thoracic injuries in our study were skeletal injuries (47.4%), cervical spine injuries (11.3%), and head trauma (24.5%).
Conclusions: Fractures of the first-rib are associated with serious thoracic and extra-thoracic injuries; they are associated only with increased morbidity in patients with polytrauma and have no independent impact on mortality.

Keywords: First-rib, Chest injuries, Rib fracture, Trauma, Multiple trauma, Saudi Arabia

INTRODUCTION

Chest injury is associated with significant life-threatening injuries, and severe chest trauma should be a red flag for trauma care providers not only because of the possible associated intra-thoracic injuries but also because of potential extra-thoracic injuries.[1]

Because of its broad structure and deeply placed and protected location in the upper thoracic cavity, protected by the shoulder girdle and muscles, first-rib fractures are relatively rare compared with fractures of the other ribs.[2] Thus great force is required to fracture the first-rib, and an isolated fracture of this rib is unusual.[3]

This led researchers to postulate that the high amount of energy causing first-rib fracture could also lead to fractures in several other ribs, subclavian artery and aortic injuries, multisystem injuries, and, consequently, greater mortality and morbidity.[4]

The proposed mechanisms that result in these fractures include direct causes, which typically involve high-energy trauma to the chest wall, or indirect causes, which

include excessive neck extension movements or excessive use of accessory muscles of respiration, resulting in “traction-type "injuries.[5]

Of the five reported injury mechanisms leading to first-rib fractures, only three are related to high-impact trauma’. The three mechanisms include posterior directed trauma to the upper thorax or shoulder girdle, a direct blow to the sternum/anterior chest wall, and a direct blow fracturing the clavicle. The other mechanisms of first-rib fracture include a strong sudden contraction of the scalenus anterior muscle (considered a low-energy mechanism) and fractures associated with no identifiable mechanical trauma (thought to be stress fractures).[4]

Violent traumas, such as motor vehicle accidents, are frequent causes of these fractures. The circumstances under which patients survive polytrauma are important to note, as it is possible that other serious intra-thoracic, head, cervical spine, and intra-abdominal injuries may have been missed, necessitating extra vigilance in the initial assessment.[6]

High-energy traumas that cause first-rib fractures also lead to fatal complications of the neighboring structures, such as subclavian vasculature, brachial plexus, and mediastinal contents. Early complications of first-rib fractures are pneumothorax, rupture of the apex of the lung, Horner’s syndrome, injury of the brachial plexus, injury of the subclavian artery, pleurisy, trachea-esophageal fistula formation, aneurysm of the aortic arch, and abscess formation in the clavicular neighborhood. Thus, these cases require immediate medical attention to evaluate the accompanying intra-thoracic life-threatening injuries.[7]

First-rib fractures have traditionally been considered indicators of increased injury severity and mortality in major trauma patients. However, these relationships are not definitively proven. Some reviews mention this association in the context of polytrauma; however, the medical literature also includes several studies and case reports that describe isolated first-rib fractures resulting from relatively minor trauma, without serious complications.[8,9]

Objectives of the study

Until now, there have been no large multicenter studies on the association between first-rib fractures and severe or life-threatening injuries. This study is aimed at shedding light on the significance of first-rib fractures as indicators of serious injury (intra-thoracic and extra-thoracic) in polytrauma patientsand their impact on morbidity and mortality in a high-altitude area in Saudi Arabia.

METHODS

This is a retrospective study conducted in King Abdul-Aziz Specialist Hospital (KASH), which is a tertiary hospital in Taif city in the Makkah Province of Saudi Arabia.

All patients with chest injuries who presented to the emergency department and were admitted to the hospital from November 2013 to March 2016 were included in this study. Data regarding demographics, causes, mechanisms and patterns of the injury, whether there were any associated injuries, management, and outcome including complications and mortality were collected and entered into predesigned proforma. Data regarding first-rib fracture were collected, and the relationship between first-rib injuries and associated intra-thoracic and extra-thoracic injuries was analyzed in comparison with other cases of chest trauma without first rib injury.

Ethical approval

Ethical approval was obtained from the Research Ethics Committee of KASH. The confidentiality of patients was preserved by not including the names or identifying personal details.

Statistical analysis

Data were entered into a computer and analyzed using SPSS software version 20 with the help of a medical statistician. Categorical variables were summarized as proportions and frequencies and analyzed using the Chi-square test. Continuous variables were expressed as mean and standard deviation. Significance was defined as a $p \leq 0.05$.

RESULTS

Patient records for the 2.5 year period were reviewed, and first-rib fractures were identified in 53 (23.4%) of 226 patients who presented to the hospital with thoracic trauma. Forty-six patients were male (86.8%) and seven were female (13.2%), ranging in age from 12 to 81 years (mean 39±9). All cases were of blunt trauma: 48 (90.5%) cases of motor vehicle road traffic accidents, one (1.8%) of a pedestrian road traffic accident, and 4 (7.5%) of falls from heights (Table 1).

Table 1: Distribution of patients with first-rib fractures according to age group.

Age (in years)	No. of patients	%
11–20	8	15.1
21–30	17	32.1
31–40	15	28.3
41–50	4	7.5
51–60	4	7.5
61–70	3	5.7
71–80	1	1.9
81–90	1	1.9

Of the 53 cases of first rib fracture, 19 (35.8%) were bilateral, 15 (28.3%) were right-side unilateral and 19

(35.8%) were left-side unilateral. Isolated first-rib fractures without fractures in the other ribs were diagnosed in 12 (22.6%) cases during hospital admission (9 unilateral and 3bilateral). The distribution of first-rib fractures along with fractures of other ribs is shown in Table 2.

First-rib fractures were detected using chest radiography in 15 (28.3%) cases and computed tomography in 38 (7.1%) cases. The locations of first-rib fractures were as follows: 23 (43.3%) posterior, 18 (33.9%) lateral, and 12 (22.6%) anterior.

Forty-seven (88.6%) cases included other thoracic injuries: 17 (32.1%) cases had pneumothorax, 8 (15.1%) cases had hemothorax, 11 (20.7%) cases had hemopneumothorax, 31 (58.5%) cases had lung contusion, 2 cases (3.7%) had flail chest, 2 cases had hem pericardium, 2 cases had hemomediastinum, and11 (20.7%) cases had surgical emphysema. None of the cases had associated diaphragmatic injuries or vascular injuries, and only 6 (11.3%) cases had isolated rib fractures without any thoracic injuries (Tables 3 and 4).

Table 2: Distribution of first-rib fracture along with fractures of other ribs.

Rib fracture	No. of patients	%
Without fractures in other rib	12	22.6
With fractures in 1-2 other ribs	14	26.4
With fractures in 3-5 other ribs	15	28.3
With fractures in >5 other ribs	12	22.6

Table 3: First-rib fractures in association with lung injuries.

Type of injury		First rib		P value
		No (n=173)	Yes (n=53)	
		N (%)	N (%)	
Pneumothorax	No	133 (76.8)	36 (67.9)	0.189
	Yes	40 (23.1)	17 (32.1)	
Hemothorax	No	150 (86.7)	45 (84.9)	0.739
	Yes	23 (13.2)	8 (15.1)	
Hemopneumothorax	No	147 (84.9)	42 (79.2)	0.324
	Yes	26 (15)	11 (20.7)	
Lung contusion	No	71 (41)	22 (41.5)	0.952
	Yes	102 (58.9)	31 (58.5)	
Diaphragmatic injury	No	168 (97.1)	53 (100)	0.211
	Yes	5 (2.8)	0 (0)	
Hemopericardium	No	172 (99.4)	51 (96.2)	0.075
	Yes	1 (0.6)	2 (3.7)	
Hemomediastinum	No	168 (97.1)	51 (96.2)	0.745
	Yes	5 (2.8)	2 (3.7)	
Surgical emphysema	No	152 (87.8)	42 (79.2)	0.115
	Yes	21 (12.1)	11 (20.7)	
Flail chest	No	172 (99.4)	51 (96.2)	0.075
	Yes	1 (0.6)	2 (3.7)	

Table 4: Patients with first-rib fractures in association with thoracic fractures.

Type of injury		First rib		P value
		No (n=173)	Yes (n=53)	
		N (%)	N (%)	
Sternum fracture	No	165 (95.3)	49 (92.4)	0.406
	Yes	8 (4.6)	4 (7.5)	
Scapular fracture	No	159 (91.9)	43 (81.1)	0.026*
	Yes	14 (8.1)	10 (18.8)	
Clavicle fracture	No	166 95.9)	46 (86.7)	0.015*
	Yes	7 (4)	7 (13.2)	
Thoracic spine fracture	No	150 (86.7)	45 (84.9)	0.49
	Yes	23 (13.3)	8 (15.1)	
Flail chest	No	172 (99.4)	51 (96.2)	0.075
	Yes	1 (0.6)	2 (3.7)	

Table 5: First rib fracture patients and associated extra-thoracic injuries.

Site of injury		First-rib fracture		P value
		No (n=173)	Yes (n=53)	
		N (%)	N (%)	
Head	No	105 (60.6)	40 (75.4)	0.050
	Yes	68 (39.3)	13 (24.5)	
Facial	No	156 (90.1)	44 (83.1)	0.153
	Yes	17 (9.8)	9 (16.9)	
Spleen	No	150 (86.7)	50 (94.3)	0.128
	Yes	23 (13.2)	3 (5.6)	
Liver	No	156 (90.1)	49 (92.4)	0.780
	Yes	15 (8.6)	4 (7.5)	
Kidney	No	172 (99.4)	53 (100)	0.579
	Yes	1 (0.6)	0 (0)	
Bladder	No	172 (99.4)	53 (100)	0.579
	Yes	1 (0.6)	0 (0)	
Pelvis	No	158 (91.3)	47 (88.6)	0.561
	Yes	15 (8.6)	6 (11.3)	
Extremities– upper limb	No	155 (89.6)	44 (83.1)	0.197
	Yes	18 (10.4)	9 (16.9)	
Extremities– lower limb	No	149 (86.1)	46 (86.7)	0.902
	Yes	24 (13.8)	7 (13.2)	
Extra-thoracic spine cervical spine	No	162 (93.6)	47 (88.6)	0.390
	Yes	11 (15.1)	6 (11.3)	
Extra-thoracic spine lumbar spine	No	151 (87.3)	50 (94.3)	0.466
	Yes	22 (12.7)	3 (5.6)	

Table 6: Distribution of patients with first-rib fracture according to the management of associated injuries.

Management		No. of patients		P value
		No (n=173)	Yes (n=53)	
		N (%)	N (%)	
Tube thoracotomy	No	141 (81.5)	28 (52.8)	0.0001*
	Yes	32 (18.5)	25 (47.2)	
Thoracotomy	No	170 (98.2)	52 (98.1)	0.659
	Yes	3 (1.7)	1 (1.8)	
Intubation	No	132 (76.3)	49 (92.4)	0.006
	Yes	41 (23.6)	4 (7.5)	
Tracheostomy	No	165 (95.4)	52 (98.1)	0.334
	Yes	8 (4.6)	1 (1.8)	
Laparotomy	No	159 (91.9)	51 (96.2)	0.229
	Yes	14 (8.1)	2 (3.7)	
Orthopedic interventions	No	134 (77.4)	39 (73.5)	0.341
	Yes	39 (22.5)	14 (26.4)	

Associated extra-thoracic injuries were observed in 22 (41.5%) cases with head and face injury, 9 (16.9%) cases with extra-thoracic spine fracture, 16 (30.2%) cases with extremity fracture, and 6 (11.3%) cases with pelvic fracture. Four cases (7.5%) had associated abdominal injuries (of which three cases had combined liver and splenic injuries and one case had isolated liver injuries (Table 5)).

Conservative management was performed in 22 patients (41.5%), tube thoracostomy in 25 (47.2%) patients who had associated chest injury, intubation in 4 (7.5%) patients, with the duration of intubation varying from 3 to 6 days, tracheostomy in one (1.8%) patient, and thoracotomy in one (1.8%) patient. For the management of extra-thoracic injuries, laparotomies were performed in 2 (3.8%) patients and orthopedic interventions in 14 (26.4%) patients. All patients treated with non-conservative management were primarily followed up in the intensive care unit with an average stay of 3-5 days (Table 6).

Comorbidities on admission were found in 19 patients: 9 had hypertension, 9 had diabetes, and 3 had bronchial asthma.

In all, 50% of patients had a hospital stay of less than one week, 19 (35.8%) patients had a hospital stay of less than two weeks, and 5 (9.4%) patients had a hospital stay of 3 weeks (Table 7).

Table 7: Distribution of first rib fracture patients according to length of hospital stay.

Duration/days	No. of patients	%
1–7	27	50.9
8–14	19	35.8
15–21	5	9.4
22–28	1	1.9
≥29	1	1.9

Table 8: Distribution of first rib fracture patients according to morbidity and mortality rates.

		No. of patients		P value
		No (n=173)	Yes (n=53)	
		N (%)	**N (%)**	
Survival	Death	8 (4.6)	1 (1.8)	0.373
	Survive	165 (95.4)	52 (98.1)	
Complications	No	165 (95.4)	49 (92.4)	0.482
	Yes	8 (4.6)	4 (7.5)	

Of the 53 patients, one died, with a mortality rate of 1.9%. The overall mortality rate in patients with first rib fracture was 7.5%; two (3.7%) patients developed total atelectasis, one patient (1.9%) developed acute respiratory distress syndrome, and one patient (1.9%) had paraplegia, which was related to the associated extra-thoracic injuries (Table 8).

DISCUSSION

Chest injuries are usually life threatening, either on their own or in conjunction with other system injuries. Fractures of the upper ribs are usually rare and signify a severe trauma whereby concomitant great vessel injuries are commonplace. On the other hand, fracture of the 4-9 ribs are the most common fractures. Fractures of the 9-12 ribs may result in laceration of the abdominal organ.[10]

Our hospital is a referral center in the field of thoracic surgery. Therefore, many patients with thoracic traumas are referred to our hospital from other hospitals in the Al-Taif province.

According to medical literature, traumatic fracture of the first rib is quite rare, and the bilateral condition is especially rare. First-rib fracture is the rarest form of rib fracture as it is kept relatively rigid with attachments posteriorly to the first thoracic vertebra and anteriorly to the sternum. It is broad and flat with a groove for the subclavian artery at its upper surface, which is a weak point and most fractures occur at this point. The symptoms include pain in the shoulder, chest, and base of the cervical spine, as well as neurological sequelae.[3]

A high incidence of first-rib fractures (23.45%) was found in our study, which described in many other studies by its rarity. In all, 86.8% of patients were male and 13.2% were female, and a maximum number of patients with first-rib fractures were in the age group of 21–30 (32.1%) and 31–40 (28.3%) years, which is the most productive phase of life. The common mode of trauma was RTA, accounting for 92.5% of traumas, followed by falls from a heightin7.5% of the cases studied, which is nearly similar to that in a study by Kochar et al, where in RTA was found to account for70% of traumas, whereas falls from a height accounted for15% of trauma cases.[11]

In this study, of the 53 cases with first-rib fracture, 19 (35.8%) were bilateral, whereas the study by Ismail et al concluded that bilateral first-rib fracture was a rare entity.[6] In our study, 28.3% of cases were right-side unilateral side and 35.8% were left-side unilateral.

First-rib fracture is commonly associated with multiple rib fractures, which could lead to morbidity and mortality due to atelectasis, pneumonia, or vascular intra-thoracic lesions.[12] Their findings are similar to those of our study, in which first-rib fractures along with fractures in other ribs were diagnosed in 41 (77.3%) cases.

In cases involving direct trauma, theoretically, a considerable amount of force must be transmitted through the surrounding structures to result in these fractures. Considering the fact that transmission of a high magnitude of force occurs in both direct and indirect causes of fractures of the first rib (and usually the clavicles and scapulae as well), these injuries should be considered as major injuries.[6] In our study, 18.8% of cases had scapular fracture, 15.1% had thoracic spine fracture, and 13.2% had clavicle fracture. Therefore, these fractures should serve as indicators to draw attention to other severe injuries associated with high-energy trauma.

In cases of first-rib fractures caused by a high-energy trauma, fatal complications of the neighboring structures were observed. Early complications are pneumothorax and rupture of the apex of the lung, Horner's syndrome, injury of the brachial plexus, injury of the subclavian artery, pleurisy, tracheoesophageal fistula formation, and aneurysm of the aortic arch.[7] In our study, 11.3% of cases with first rib fracture had isolated rib fracture without any thoracic injuries and 88.6% of cases with first rib fracture had other thoracic injuries: the most common injury was a pulmonary contusion (58.5%), similar to the result of other studies, followed by associated pneumothorax

(32.1%), hemopneumothorax (20.7%), surgical emphysema (20.7%), and hemothorax (15.1%) in our study.[13,14] Only 3.7% of cases had flail chest, hemopericardium, and hemomediastinum, and none of the cases had associated diaphragmatic injuries. Thus, their presence should alert the clinician to necessitate long-term follow-up for late-developing squeal.

The mortality associated with this injury is high. Neurologic lesions account for the majority of deaths; however, unrecognized abdominal injuries and pulmonary complications are also significant causes of mortality.[3]

The other most common associated extra-thoracic injuries in our study were skeletal injuries (47.4%): extra-thoracic spine fracture in 16.9% of cases, extremity fracture in 30.2%, and pelvic fracture in11.3%.This percentage is higher than that in a study by Yazkan, in which skeletal injuries were detected in 27.3% of cases.[15]

In all, 7.5% of our cases had associated abdominal injuries (three cases had combined liver and splenic injuries and one case had isolated liver injury).This percentage is lower than that in the study by Yazkan (36.3%) and Phillips et al (55%).[15,16]

Neurologic injuries were also frequent, with an overall incidence of 37% (20-40%).[13] In our study, the percentage of patients with first-rib fractures who had severe head trauma was24.5%, which is similar to that in previous study by Sammy et al, who reported a prevalence of 28.9%.[4]

In the study by Yazkan, 63.6%of cases had head injuries and vertebral injuries.[15] The proportion of patients with first-rib fractures who had cervical spine injuries in our study was 11.3%, which was similar to the previously reported rate of 9.7% by Poole et al.[17] This relatively high incidence of serious head and cervical spine injuries in our study indicates the need for more attention to patients with first-rib fractures.

Ismail et al concluded that in patients with radio-graphically detected first bilateral rib fractures it would be prudent to proceed with imaging of the cervical spine or vice versa to detect these fractures, considering their high degree of association.[6] Brachial plexus injury and Horner's syndrome may occur in survivors. Injury of the subclavian artery has also been reported and the importance of this association is stressed.[3] In our study, brachial plexus and vascular injuries were not recorded in patients with first-rib fractures, which is similar to the results obtained in the study by Yazkan.[15] However, the incidence rates of brachial plexus injuries and vascular injuries were1.1% and 2.3%, respectively, for vascular injuries in the study by Sammy et al.[4]

In all, 50% of patients had a hospital stay of less than one week, whereas 35.8% had a hospital stay of less than two weeks, which was mainly because of associated head trauma and intra-thoracic injuries. Additionally, 9.4% of patients had a long hospital stay of 3 weeks mainly owing to operative interference for the skeletal injuries.

The mortality rate of first-rib fracture is associated with other organ injuries such as vascular, neurological, cardiac, and pulmonary injuries, and the rates range from 0 to 48%.[13] In our study, only one patient died, with a mortality rate of 1.8%. This patient had a head trauma; left first rib, left multiple rib, and upper limb fractures; and diabetes mellitus as a comorbidity and underwent management with intubation, thoracotomy, and ORIF. This is similar to that in a study by Yazkan, in which no mortality was detected.[15]

A high incidence of traumatic first-rib fractures and bilateral first-rib fracture was found, which are often associated with serious intra-thoracic, neurological head and cervical spine injuries, and skeletal injuries that might affect the patient's survival.

This study confirmed the view of the previous study that first-rib fractures are associated with high-energy trauma and more severe injuries in patients with major polytrauma and clarified the increased mortality associated with these life-threatening injuries wither intra-thoracic orextra-thoracicinjuries. Thus, first-rib fracture cases require immediate medical attention to recognize these associated life-threatening injuries.

These findings could be useful in the development of a management protocol for patients presenting with first-rib fractures following major trauma.

CONCLUSION

In conclusion, fractures of the first rib are associated with serious intra-thoracic and extra-thoracic injuries but not always with vascular and neurological injuries, and they are only associated with increased morbidity in patients with polytrauma and have no independent impact on mortality. The thoracic trauma team must be aware of those serious injuries to ensure early diagnosis and appropriate treatment and for appropriate observation in the intensive care unit to prevent or reduce morbidity and mortality.

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