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## Original Article

# Correlation of rib fracture patterns with abdominal solid organ injury: A retrospective observational cohort study

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## ABSTRACT

**Purpose:** Rib fractures are one of the most common causes of morbidity and mortality and are associated with abdominal solid organ injury (ASOI). The purpose of this study was to investigate the correlation of ASOI with the number, location, and involved segments of rib fracture(s) in blunt chest trauma.

**Methods:** This retrospective cohort study was conducted on patients with blunt chest trauma over the age of 15 years, who were hospitalized with the diagnosis of rib fractures from July 2015 to September 2020. After ethic committee approval, a retrospective chart review was designed and patients with a diagnosis of rib fractures were selected. Patients who had chest and abdominopelvic CT scan were included in the study and additional data including age, gender, injury severity score, trauma mechanism, number and sides of the fractured ribs (left/right/bilateral), rib fracture segments (upper, middle, lower zone) and results of chest and abdominal spiral CT scan were recorded. The correlation between ASOI and the sides, segments and number of rib fracture(s) was assessed by Pearson's correlation coefficient.

**Results:** Altogether 1056 patients with rib fracture(s) were included. The mean age was (42.76 ± 13.35) years and 85.4% were male. The most common mechanism of trauma was car accident (34.6%). Most fractures occurred in the middle rib zone (60.44%) and the most commonly involved ribs were the 6th and 7th ones (15.7% and 16.4%, respectively). Concurrent abdominal injuries were observed in 103 patients (34.91%) and were significantly associated with middle zone rib fractures.

**Conclusion:** There is a significant relationship between middle zone rib fractures and ASOI. Intra-abdominal injuries are not restricted to fractures of the lower ribs and thus should always be kept in mind during management of blunt trauma patients with rib fractures.

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## Introduction

Chest trauma is a major cause of morbidity and mortality, especially in the younger population, accounting for the third cause, after head and extremity injuries.<sup>1</sup> Rib fractures are frequently seen in blunt trauma (reported in 40% of patients).<sup>2</sup> Besides, rib fractures are often accompanied with injuries in other body regions and thus have a high mortality rate.<sup>3,4</sup> The

increase in the number of fractures correlates with the severity of injuries and presence of other injuries in the head and neck, abdomen, extremities, etc.<sup>5,6</sup> Up to 26% of rib fractures are accompanied with abdominal solid organ injury (ASOI), typically the liver and the spleen.<sup>7</sup> Several studies have reported the correlation between the segments involved and ASOI in rib fractures. It is indicated that fractures of the lower ribs (9th–12th ribs) are more often associated with ASOI.<sup>7,8</sup> But since the liver, spleen, and kidneys are positioned above the point that partitions the inferior ribs, our hypothesis is that ASOI is more likely to occur in fractures at a higher level of the ribs. Additionally, the trauma energy that is required to break the upper and middle ribs is usually higher than that for lower ribs, and thus is more likely to be associated with

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ASOI. This correlation is important because rib fractures may raise the surgeon's suspicion to investigate and promptly diagnose internal organ injuries which may otherwise be easily overlooked.

The aim of this study was to investigate the correlation of rib fractures and their patterns and locations with ASOI and identify the patients at risk.

**Methods**

*Inclusion and exclusion criteria & variables evaluated*

This retrospective cohort study, based on medical records and radiologic data, was carried out on patients who were hospitalized for sustaining rib fracture(s) due to blunt chest trauma from July 2015 to September 2020. The inclusion criteria were aged over 15 years and high energy blunt trauma (car-pedestrian accidents, motor vehicle collisions, motorcycle collisions and fall from a height >3 m); while the exclusion criteria were patient's age less than 15 years, pregnant women, incomplete data in medical records, penetrating trauma, and ASOI without chest trauma.

This study has been approved by the Ethics Committee of Kashan University of Medical Sciences (approval number: MEDN-PREC.1398.008). The researchers adhered to the Helsinki Declaration.

Demographic data, trauma mechanism, injury severity score (ISS) and abbreviated injury scale for different body regions, findings of physical examination, results of chest and abdominopelvic imaging, number and location of the rib fractures, associated ASOI and patient outcomes were extracted from the database. Injuries to the chest wall and lung parenchyma as well as extra chest wall injuries (diaphragm, intracranial, abdominal, pelvic, spinal and extremity injuries) were recorded. Patients were managed in the hospital according to the standard care and in line with the advanced trauma life support guidelines.

*Patient management*

According to our trauma research center protocol, a chest X-ray exam was ordered for all the stable patients that were suspected to have rib fractures. Unstable patients with any ASOI by abdominal CT scan were referred to the operation room after initial resuscitation. Rib fractures were initially diagnosed by means of simple radiography. Chest and abdominal CT scan was performed if the patient had documented rib fractures with previous chest X-ray.

To assess the correlation between rib fractures and intra-abdominal injuries, rib fractures were classified according to their location sides (left, right, and bilateral) and zone (upper zone: ribs 1–4, middle zone: ribs 5–8, and lower zone: ribs 9–12). All the overlapped levels were checked. The number of fractures was studied based on the reading of the radiology expert. The correlation between ASOI and the location, level, and number of rib fractures was statistically compared and analyzed based on the researched data.

Liver injuries were managed with suturing, gel foam application, packing and reoperation after 48 h. Spleen injuries were managed with splenectomy or splenorrhaphy. Hemodynamically stable patients with subcapsular haematoma (about 20%–30% of surface area) or parenchymal laceration (depth of less than 3 cm) were considered grade I and grade II injuries of spleen or per American association for the surgery of trauma classification. These patients were managed conservatively in the intensive care unit. Mild to moderate nonexpanding sub-capsular hematoma or contusion were also managed non-surgically.

Pain control was achieved with Acetaminophen and intravenous opioids. Intercostal or epidural nerve block was done on patients with more than 3 fractures, underlying disease or elderly patients.

*Follow-up*

Patients were followed up from the time presented to the emergency department until 4 months after discharge for possible complications.

*Data analysis*

All data were analyzed using SPSS 16. Results were expressed as means ± SD or percentage. Independent sample *t*-test, Chi-square test, Fisher's exact test or nonparametric test was used for comparisons, depending on statistical hypothesis and the nature of variables. Pearson's correlation coefficient was used to determine the correlation of ASOI with the number of fractured ribs. A *p* value < 0.05 was considered statistically significant.

**Results**

*Demographic data*

In this study, 1056 blunt chest trauma patients with 1608 rib fractures were analyzed. The mean age was (42.76 ± 13.35) years (range, 16–71 years); 901 (85.3%) was male the rest was female (14.7%). The mean ISS was 21.60 ± 4.18. The most common mechanism of trauma was car accidents (365 cases, 34.6%), followed by motorcycle driver collisions (214 cases, 20.3%), fall from a height >3 m (193 cases, 18.3%), car to pedestrian (147 cases, 13.9%) and others (136 cases, 12.9%).

Most fractures occurred in the middle zone of 6th and 7th ribs (15.7% and 16.4%, respectively). The injuries to the 12th rib were the least frequent (3.3%). Meantime, the highest quantity of fractured ribs belonged to the middle rib zone (60.4%), followed by the lower zone (23.6%) (Table 1).

Regarding the rib fractures, 190 cases (18.0%) were isolated fracture without associated injuries; 133 cases (12.6%) was bilaterally, 445 (43.1%) was right side only and 478 (45.3%) left side only, revealing no significant difference between the two sides. For all the cases, 761 (72.06%) had 1 or 2 ribs fractured with normal chest and abdominal CT scan, and were managed in the outpatient unit.

**Table 1**  
Frequency of 1608 rib fractures in each segment.

Rib fracture location	Frequency (n)	Percent (%)
Upper zone	256	15.9
1	32	2.0
2	36	2.2
3	84	5.2
4	104	6.5
Middle zone	972	60.4
5	224	13.9
6	252	15.7
7	264	16.4
8	232	14.4
Lower zone	380	23.6
9	204	12.7
10	88	5.5
11	68	4.2
12	20	1.2

**Incidence of ASOIs**

In this series, 295 cases (27.9%) had associated injuries. Of these, ASOIs were observed in 103 cases (9.8%): the most commonly injured organs were the liver (42, 40.8%), followed by the spleen (37, 35.9%), and the kidney (24, 23.3%). These patients underwent abdominal laparotomy. For liver injuries, tissue repair was done. Spleen injuries were treated with splenectomy or splenorrhaphy. The majority of kidney injuries included perirenal hematoma confined within the perirenal fascia, subcapsular hematoma or contusion without laceration. One kidney was partially resected. The distribution of ASOIs according to the sides and segments of the fractured ribs is shown in Table 2 and Table 3.

**Other injuries**

Other associated injuries included hemo-pneumo thorax in 68 cases (6.4%) which was managed with simple chest tube, pelvic and long bone fractures in 61 cases (5.8%), head injuries in 49 cases (4.6%), and spinal injuries in 37 cases (3.5%). There were some cases of small intestine perforation and mesenteric injury without sufficient informative data in the pre-operative abdominal CT scan (31 cases, 2.9%). We also had 3 cases of diaphragmatic hernia which was repaired at the same operation. Organ injury scaling for multiple injuries was Grade 3 and 4 in our patients (serious to severe). The mean ISS was 21.60 ± 4.18 which was calculated based on the abbreviated injury scale.

**Outcomes**

In this study series, 81 patients (7.7%) had pulmonary contusion, 24 were intubated due to respiratory insufficiency. Of the 295 cases with associated injuries, the mortality rate was 4.3% (12 cases). The major causes of mortality were severe bilateral lung contusion, more than 5 ribs fractured, flail chest, and also severe injuries of the liver, coagulopathy, hypothermia and irreversible shock.

**Discussion**

In our study, males were of the majority of trauma cases and the result is consistent with previous studies. The overall mortality rate

**Table 2**  
Incidence of 103 cases of concomitant abdominal solid organ injuries based on the rib fracture side, n (%).

Injured organ	Rib fracture side		Total	p value
	Right (n = 56)	Left (n = 47)		
Liver	38 (90.5)	4 (9.5)	42 (100)	<0.001 <sup>a</sup>
Spleen	7 (18.9)	30 (81.1)	37 (100)	<0.001 <sup>a</sup>
Right kidney	8 (72.7)	3 (27.3)	11 (100)	<0.001 <sup>b</sup>
Left kidney	3 (23.1)	10 (76.9)	13 (100)	<0.001 <sup>b</sup>

<sup>a</sup> Chi-square test.  
<sup>b</sup> Fisher's exact test.

**Table 3**  
Incidence of the 103 cases of abdominal solid organ injuries based on the rib fracture regions, n (%).

Injured organ	Rib fracture zone			Total	p value
	Upper (n = 6)	Middle (n = 80)	Lower (n = 17)		
Liver	2 (4.8)	35 (83.3)	5 (11.9)	42 (100)	<0.001
Spleen	1 (2.7)	32 (86.5)	4 (10.8)	37 (100)	<0.001
Right kidney	2 (18.2)	6 (54.5)	3 (27.3)	11 (100)	0.030
Left kidney	1 (7.7)	7 (53.8)	5 (38.5)	13 (100)	0.023

in our research was 4.3%, less than that in other groups of study population.<sup>9,10</sup>

Rib fractures are often associated with concomitant injuries to other organs and the mortality is reported to be 4%–12%.<sup>3,4,6</sup> Intra-abdominal injuries at the early phase of trauma are particularly important as the abdominal signs are not clear, and such injuries can be easily neglected. As a result, early detection and treatment of intra-abdominal bleeding is crucial for the management of multiple injury patients. The incidence of concomitant ASOI in patients sustaining rib fractures is reported to be about 10%–26%.<sup>7</sup> The rate in this study is also somewhat lower (9.7%), which is probably attributable to the not selective manner of patients who had no abdominal symptoms but abdominopelvic CT scans.

The most commonly injured intra-abdominal organs in rib fracture patients is the liver, which comprises about 40% of intra-abdominal injuries.<sup>7</sup> Similarly, in our study, 40.8% of ASOIs were liver injuries. Liver injuries are reported to be associated with right rib fractures, younger age and higher ISS.<sup>8</sup> The spleen is the second solid organ prone to be affected in rib fractures, mostly associated with left rib fractures and a high ISS.<sup>8</sup> Although liver injuries are more often encountered with right rib cage fractures, they are also seen after left sided acceleration/deceleration impacts. Liver injuries were associated with left rib fractures in 9.5% of our patients and the spleen was injured in 9% of those with right rib fractures. Therefore, the possibility of contra-lateral injuries should be kept in mind.

Generally, it is thought that ASOIs are encountered in lower rib fractures. Park et al.<sup>7</sup> reported concomitant intra-abdominal injuries in 57% of patients sustaining lower rib fractures, in comparison to only 32% in middle rib fractures. Also, Schweiki et al.<sup>8</sup> observed a higher probability of liver and spleen injuries in lower rib fractures. This study verified a high possibility of ASOIs in the middle segment (ribs 4–8). This discordance can be explained by the higher prevalence of middle segment fractures in comparison to lower rib fractures in our study. The liver and spleen can rise to the 5th intercostal space during expiration. In addition, fractures of the middle and upper thorax are usually associated with a greater trauma impact than lower rib fractures, increasing the possibility of ASOIs. Therefore, the possibility of dominancy ASOI in middle rib fractures should not be neglected.

This study has some limitations. It is a single-center study and the sample size is not very large and patient outcomes are restricted to this specific study population and cannot be generalized to all patients with rib fractures.

In conclusion, rib fractures have significant association with solid organ injuries, especially fractured ribs of the 6th and 7th, which are located in the middle segment of the thorax. Intra-abdominal injuries are not restricted to fractures of the lower ribs and should always be kept in mind during rib fracture management. Fractures of ribs in the middle segments can be as a possible abdominal screening, which will significantly improve the sensitivity for identification of ASOIs.

In the end, we would like to highlight that:

- (1) Rib fractures of the middle segment (ribs 4–8) are closely associated with ASOI in blunt trauma.
- (2) Right sided rib fractures are closely associated with liver injuries.
- (3) Left sided rib fractures are closely associated with splenic injuries.
- (4) Advanced trauma life support guidelines should consider middle segment rib fractures also for solid organ injury.

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Nil.

## Ethical statement

This study has been approved by the Ethics Committee of Kashan University of Medical Sciences (approval number: MEDN-PREC.1395.082). The researchers adhered to the Helsinki Declaration.

## Declaration of competing interest

The authors declare that they have no conflicts of interest.

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## Author contributions

Abdoulhossein Davoodabadi and Esmail Abdorrahim Kashi supervised the study, Mohammad Mashayekhili collected patient data, Hamidreza Gilasi provided the statistical support, Abdoulhossein Davoodabadi, Mohammad Mashayekhili and Noshin Mosaviabioki participated in drafting of the manuscript and final scientific review. All authors read and approved the manuscript and state that this study represents honest work.

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