ISSN- O: 2458 - 868X, ISSN–P: 2458 – 8687
Index Copernicus Value: 68 . 16
PubMed - National Library of Medicine - ID: 101731606

International Journal of Medical Science and Innovative Research (IJMSIR)
IJMSIR : A Medical Publication Hub
Available Online at: www.ijmsir.com
Volume – 5, Issue – 5, October - 2020, Page No. : 167 - 178

Comprehensive Analysis of Rib Fracture Patterns in Blunt Trauma Chest/ Abdomen

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Citation this Article: Dr Harvinder Singh Chhabra, Dr Ashwini Kumar, Dr Navdeep Kaur, Dr Darshpreet Singh Chhabra, "Comprehensive Analysis of Rib Fracture Patterns In Blunt Trauma Chest/ Abdomen", IJMSIR- October - 2020, Vol – 5, Issue - 5, P. No. 167– 178

Type of Publication: Original Research Paper

Conflicts of Interest: Nil

Abstract

Blunt thoracic trauma is routinely a cause of trauma related deaths and when associated with rib fractures, makes the mechanism and pattern of rib fractures an important area of consideration, both because of associated mortality as well as, clues that it can provide to help an expert to opine regarding the manner of injury. This study aimed to determine rib fracture patterns and associated injuries in cases of blunt trauma to chest and abdomen. We studied a hundred cases of blunt trauma to chest and abdomen that presented in the trauma emergency and met our predetermined inclusion and exclusion criteria.

Keywords: blunt trauma chest, road traffic accidents, assault, fall, blunt trauma abdomen, rib fractures.

Introduction

Trauma is an insult to body, mind, or both. All trauma is not due to road traffic accidents. Only 22.8 % of all trauma cases are transport-related injuries, the rest 77.2 % being other trauma like falls, agriculture-related trauma, firearm injuries, intentional self-harm, assault, fall of objects, etc. [1]. The thorax is susceptible to all kinds of injuries especially blunt and penetrating thoracic trauma. Blunt thoracic trauma is routinely encountered in an emergency and is sometimes associated with trauma-related deaths. One of the most common sequelae of blunt thoracic trauma is rib fractures [2, 3]. The detection of rib fractures is important to detect an associated injury -pneumothorax, haemothorax pulmonary contusion, flail chest, pneumonia, vascular and nerve damage, abdominal organ injury, to prevent complications such as atelectasis and acute respiratory failure, to document the injury for medical-legal purposes and to detect pathologic fractures [4]. The available literature acknowledges that the force acting on a body differs according to the circumstance of injury: for example, the force acting in a fall from height or a motor vehicle accident is considerable as compared to that in a

physical assault and so are the outcomes of the incident i.e. the injury sustained, fatality, etc.

The energy possessed by a body in motion is referred to as "Kinetic Energy". Kinetic energy depends upon the mass and velocity of the body. So, in the case of a moving object, with mass remaining constant, any change in velocity thus results in four times the increase in kinetic energy. Also, as the mass increases, with mass remaining constant, the kinetic energy possessed by the body will increase linearly [5]. In other words, if a massive object and a light object have the same momentum, the light one will have a lot more kinetic energy and if a light object and a heavy one has the same velocity, the heavy object will have more kinetic energy. This forms the basis of the hypotheses that the pattern of injuries should be different in different scenarios depending upon the amount of force being applied. Also, the direction of impact and the reaction of victims differ in different scenarios. So, a pattern can be deduced by studying the various parameters involved which may also be useful to build upon the present knowledge of forensic medicine.

This research study investigated the relation between rib fracture patterns and the manner of injury, the rib fracture patterns that exist in correlation with soft tissue organ injury, and also evaluates rib fracture patterns in relation to the age of the individual.

Methods

Study subjects included a hundred consecutive cases of blunt trauma to chest and abdomen that presented in the surgery emergency with known and complete history of blunt trauma chest/abdomen involving fracture of ribs in which a minimum of X-ray and USG had been done. All unknown cases without any proper history of illness/medication were excluded. Complete history, detailing the manner and circumstance of injury was noted.

Statistical Analysis

Statistical analysis was performed on the data of all the recorded cases of rib fractures. The chi square test was employed for the statistical analysis of the variables. All statistical results were significant when $p < 0.05$. The relationship between the total number of rib fractures and various associated injuries were statistically analysed using chi square tests. Fisher exact test was applied wherever the groups had less than 5 cases. Wherever necessary the Pearson correlation and McNemar-Bowker Test were applied. ANOVA testing was done to determine if there was any significant difference in the means of hospital stay for each manner of injury and on finding significant difference, the data subjected to Post HOC Turkey HSD to determine groups among all exhibited this significant difference. Statistical analysis was performed using SPSS statistical package.

Results

Of the total number of 100 cases, males (96 cases) outnumbered females, who constituted only 4 percent of all the cases. The minimum age of 21 years and a maximum of 85 years was recorded. The mean age was 47.6 years with a standard deviation of ±14.2 years. Road traffic accidents accounted for most of the cases at 64 % of the total, followed by fall from height and physical assault. Physical assault and fall from height cases constituted 17 % and 19 % cases of the total respectively. When age was extrapolated against the manner of injury, the overall maximum cases lay in the 41 – 50 age group (n = 30). Maximum RTA cases lay in the 41-50 age group (n = 20). Maximum physical assault cases lay in the 41- 50 age group (n =5) and

maximum cases of fall from height lay in the 51-60 age group (n=7) (Fig 1).

Maximum victims were two-wheeler riders in 45 % of the RTA cases, followed by pedestrians (28 %) and four-wheeler occupants (16%). In around 55 % of cases, the victims were the drivers, followed by pillion riders in 38 % cases. In 2 cases (6.9%), the position of the victim could not be ascertained. From among the pillion riders, 3 victims were riding cross-legged and 3 were sitting sideways at the time of the incident. In 5 cases sitting posture of the victim could not be ascertained. A total of 10 cases were recorded of victims in four-wheelers. In 80% of cases, the victim was driving the vehicle. The front passenger and back right passenger sustained rib fractures in one case each. However, no pattern of rib fractures could be ascertained from the recorded data. Four-wheeler and heavy vehicles were jointly the most common culprits followed by two-wheelers. In 5 cases, the patients had either hit some stray cow or a stationary object/vehicle. In one case, the offending vehicle could not be ascertained.

Cumulatively, four-wheeler, and heavy vehicles were the offending vehicles in 44 cases, which constituted almost two-thirds of the total RTA cases. A collision between a two-wheeler- four-wheeler was the most common type of RTA followed by Pedestrian – Four-wheeler, and Two-wheeler – Heavy vehicle. A collision between a two-wheeler- four-wheeler was the most common type of RTA followed by Pedestrian – Four-wheeler, and Two-wheeler – Heavy vehicle. Maximum cases were of a frontal impact, followed by the right-sided impact.

Assault cases constituted 17 cases of the total and were analysed according to the alleged kind of weapon used. For this, the weapons were divided into light blunt weapons and heavy blunt weapons. Use of heavy blunt weapons was recorded in 47 % cases, followed by light blunt in 35 % cases and least was the use of a combination of heavy blunt and light blunt weapons in 18 % cases. The total number of ribs fractured in assault cases was 28. One case of multiple rib fractures to the same rib was recorded. There were no cases of multiple rib fractures to the same rib.

Patients with an alleged history of fall from height were 19 in number. The floor number or the height of the fall from the ground was recorded. In the cases where only the floor number was recorded and not the height of fall, the height of each floor was taken as 13 ft. as per the Indian standards. The height of fall ranged from 0 to 39 ft. The sample group was divided into 5 groups of increasing height. The height of the fall was not available in 3 cases. Maximum cases fell in the 14-26 ft. group. All cases were attributed to the workplace or accidental injuries. No mortality was recorded in this group.

RTA cases had a maximum incidence of the same ribs with multiple fractures followed by cases of fall from height and physical assault. In all 17 cases having multiple fractures of the same rib were noted sharing among them a total number of 41 ribs with such fractures. However, no association with the manner of injury could be established from the recorded data. (Fig 2,3 & 4)

Frequencies for rib fracture by location for each rib were recorded. For each rib, frequencies for no fracture, costochondral junction (CC), midclavicular line (MC), midaxillary line (MA), mid scapular line (MS), costovertebral junction (CV), or combination of the above were recorded. The frequencies thus obtained are shown in Table 2 for the left ribcage and Table 3 for the right ribcage.

Overall, 63 % of cases had complications of pneumothorax, haemothorax, or a combination of the two. Of these incidences of haemothorax was recorded in 47 % cases followed by a combination of the in 10 % cases and isolated pneumothorax in 6 % cases. As expected, lungs were maximally involved in 15 cases, followed by liver (8 cases), spleen (5 cases), and kidneys (3 cases) in that order. However, no cases of injury to Heart or the great vessels were recorded. When this data was subjected to chi-square tests to find an association between the side of rib fractures and injury to soft tissue organs no association could be construed.

RTA cases were associated with maximum hospital stay with a mean of 12.03 days and a standard deviation of ± 9.9. Physical assault cases were associated with the least days of hospital stay with a mean of 4.41 days and a standard deviation of ± 4.4. The hospital stay in Fall cases was intermediate of the above two, with a mean of 8.9 and a standard deviation of ± 4.4 (Table 3). When these values of the mean of hospital stay in different manners of injury were plotted in a line diagram a visible dip was noted in cases of physical assault indicating an association. These values were then subjected to the ANOVA test to test whether a significant difference of mean was there between the groups. A significant difference between means is seen with $p = 0.004$ ($p < 0.05$). Now, these values were subjected to Post HOC Turkey HSD test to determine which mean among the set of means differed from the rest, which showed us a statistically significant difference between RTA and Physical assaults. Of the above 100 clinical cases of rib fractures, mortality was recorded in 3 cases (3%).

Discussion

Males are probably more exposed to the impulses of life, which explains the more predominance of rib fractures in males. People of middle age are more predisposed to rib fractures. The frequency of rib fractures is less at either extreme of age as children and old people are less likely to drive vehicles or be involved in a workplace injury or be involved in violent assaults, which decrease their chances of sustaining rib fractures. These are aptly mirrored by the results of our study as well as some other studies.

RTA and falls can both result in high impact injuries. Karadayi, et al, in their study, encountered 64 % cases of traffic accidents, 24.3 % fall from height, and 3.3 % assault cases [6]. Similar findings have been reported by other studies. In our study, the physical assault cases were more. The reason for this may be that majority of such patients gave proper history, and thus fulfilled our pre-defined inclusion criteria. On the other hand, many cases of RTA and Fall from height were at times reluctant to get a medico-legal case registered and gave insufficient history, thus not fulfilling the inclusion criteria.

In a study, the author encountered 77.1 % drivers, followed by 11.4 % front passengers and 3.81 % back seat passengers. He suggested that it was because every car involved in an accident has a driver and may not necessarily have co-passengers [7]. In a study on cadavers, frontal impact in the presence of a torso belt resulted in fractures located primarily on the upper left and lower right aspects, along the path of the belt [8]. The profile in our study was similar but due to the small sample size, no association could be construed between the sitting position in 4 wheelers and the pattern of rib fractures.

In a study, the author concluded that the presence of some injuries can exclude a circumstance (i.e. cardio-vascular injuries associated with pulmonary contusion can exclude an assault). The same author further opines that the findings of more than 3 rib fractures (including first and second rib) on a posterior line, associated with pulmonary contusion and cardiac or vascular injuries will exclude an assault, directing the investigation towards a fall from height (in the presence of associated pulmonary artery injury), or a motor vehicle accident. Also, the presence of more than one fracture on the same rib (double/multiple fractures) wasn't noted in assault cases with the authors reasoning that this type of injury resulted from an intense force of impact and that the number of ribs fractured provided an index as to the relative force of the injury [9]. In our study, when the manner of injury was extrapolated against the side of rib fractures, we found bilateral rib fractures to be strongly associated with RTA and no association with physical assault. Multiple rib fractures of the same rib had the highest incidence in RTA followed by fall from height and physical assault. The number of ribs fractured provides an index as to the relative force of the injury.

Data also suggests that in trauma, due to the close proximity, the clavicle is the first one to get fractured and provides relative protection to the underlying first rib and less so to the second rib. The study by Kochar et.al also reported similar findings, however, the authors suggest that the first rib in the majority of recorded cases was fractured as a result of indirect trauma due to hyperextension of the neck combined with violent contraction of sternocleidomastoid and scalene muscle [10].

In the study done by Subedi, et al, the presence of liver injuries was significantly increased in all rib fractures and right-sided only or bilateral ribs fractures, whereas, splenic injuries were significantly associated with left-sided only or bilateral rib fractures [11]. Thus, they suggested that the presence of rib fractures is a good indicator of underlying liver and spleen injuries. The same could not be reproduced in our study, which exhibited only 8% and 5% of cases of liver and spleen injuries, respectively. This difference was because the above-mentioned study focused only on the fatal cases of rib fractures while our study included non-fatal cases and which constituted a majority of our cases. However, in the light of our findings, the presence of rib fractures is a good indicator of organ injury, at autopsy, i.e., in potentially fatal cases and of uncertain predictability, when all cases are taken into account. However, the presence of rib fractures should always alert the treating doctor to be vigilant in ruling out associated injuries to the abdominal organs. The findings by Karadayi, et al, support our findings, as after retrospectively analysing 214 cases they found spleen and liver injuries in only 4.7 % and 1.7 % of cases [6].

The cases of RTA had a longer stay in hospital when compared with the cases of physical assaults which was expected as RTA's involve high energy impact on the chest and abdomen, thus resulting in more injuries when compared with assaults. However, no significant difference between physical assault and fall from height and RTA and fall from a height could be construed [Table 4].

Conclusions

Injury as discussed earlier is any harm caused to any person, on body, mind, reputation or property. It may be intentional or unintentional and thus has varied

mechanism of occurrence. Accordingly, the extent, pattern, mortality/ morbidity may not be the same. Influenced from the results of similar studies in other parts of the world, we intended to replicate the same in our sample. We conclude by endorsing the views of various authors cited in this study that the patterns do exist which may be indicative of the manner of injury but are not exclusive. Similar -studies with a multicentric approach and a greater sample size need to be carried in order to decipher more of such patterns. Afterall, recognizing patterns is the template of Forensic Medicine.

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Legends Figure and Table

Table 1 – Distribution of cases as per side of rib fracture (includes bilateral rib fractures on each side) for each manner of injury

Manner of injury	Cases	Mean of number of left ribs with fractures	Mean of number of right ribs with fractures
Road traffic accident	64	3.2	2.8
Physical assault	17	0.8	0.7
Fall from height	19	3	1.4
Total	100	2.8	2.2

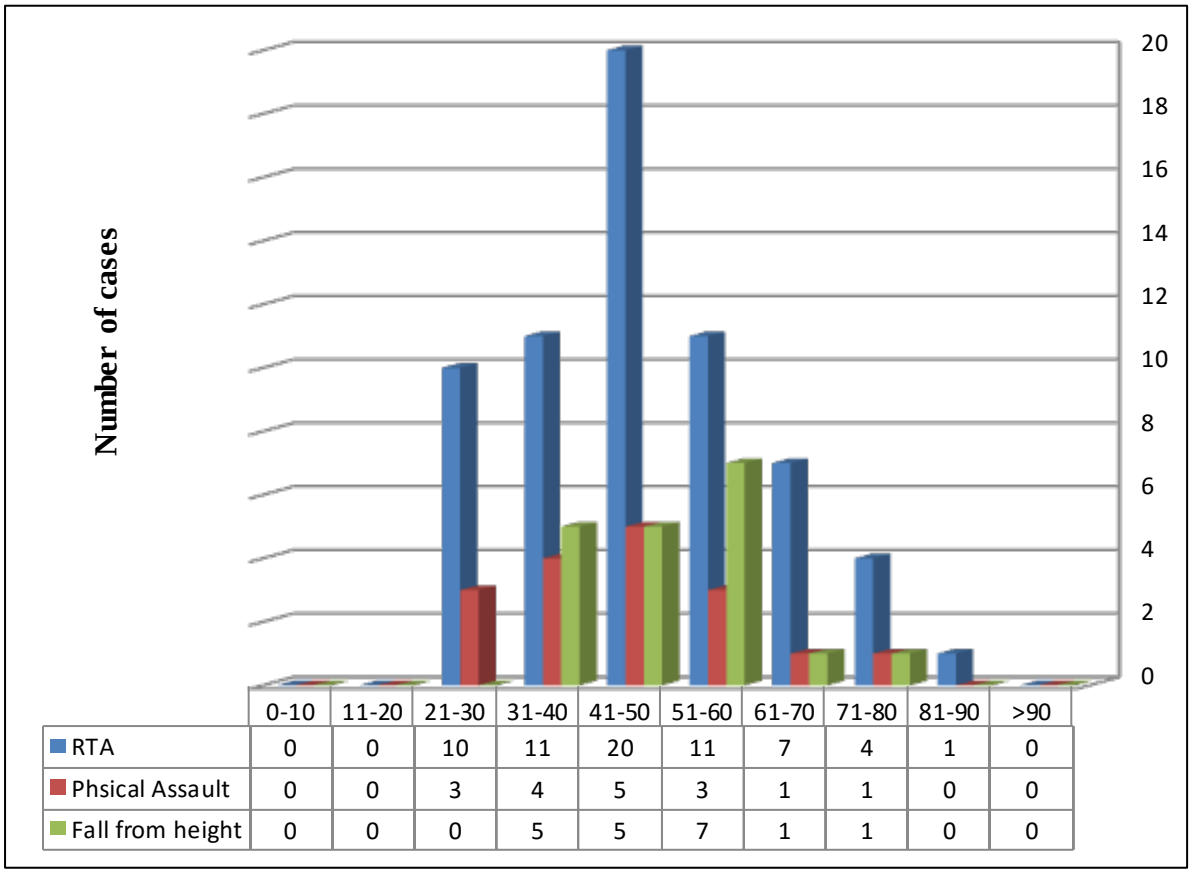
Table 2 – Left rib fracture frequencies by location

	No Fracture	Costo chondra junction (CC)	Mid clavicular (MC)	Mid axillary (MA)	Mid scapular (MS)	Costo vertebra junction (CV)	Combination
LR 1	95	0	2	2	0	1	0
LR 2	81	0	6	9	4	0	0
LR 3	66	1	6	17	8	1	1(MC+MS)
LR 4	65	1	6	16	9	1	1(MC+MA) 1(MC+MS)
LR 5	59	1	10	19	5	2	2(MC+MA) 1(MC+MS) 1(MS+CV)
LR 6	63	1	7	16	5	3	1(MC+MC) 2(MC+MA) 1(MA+MA) 1(MS+CV)
LR 7	59	0	8	21	7	3	2(MC+MA)
LR 8	68	0	8	19	4	1	0
LR 9	83	0	2	9	4	1	1(MC+MA)
LR 10	89	0	1	4	5	1	0
LR 11	99	0	0	0	0	1	0
LR 12	100	0	0	0	1	1	0

Table 3 – Right rib fracture frequencies by location							
	No Fracture	Costo chondra junction (CC)	Mid clavicular (MC)	Mid axillary (MA)	Mid scapular ((MS)	Costo vertebra junction (CV)	Combination
RR 1	96	0	2	2	0	0	0
RR 2	80	1	8	7	2	1	1(MA+CV)
RR 3	74	1	4	8	6	1	2(MA+MC) 3(MA+MS) 1(MA+CV)
RR 4	68	1	6	9	9	0	3(MA+MC) 3(MA+MS) 1(MA+CV)
RR 5	67	1	7	9	9	0	2(MA+MC) 1(MA+MA) 3(MA+MS) 1(MS+CV)
RR 6	69	1	5	14	6	1	2(MA+MC) 1(MA+MS) 1(MA+CV)
RR 7	66	0	5	19	3	4	2(MA+MC) 1(MA+MS)
RR 8	78	0	1	13	5	3	0
RR 9	87	0	0	7	6	0	0
RR 10	97	0	0	1	2	0	0
RR 11	97	0	0	0	2	1	0
RR 12	100	0	0	0	0	0	0

Table 4 – Duration of hospital stay vs Manner of injury

		N	Mean	Std. Deviation	Minimum	Maximum
Hospital Stay	Road traffic accident	64	12.03	± 9.895	3	67
	Physical assault	17	4.41	± 4.360	1	18
	Fall from height	19	8.89	± 4.446	4	17
	Total	100	10.14	± 8.787	1	67



	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
RTA	0	0	10	11	20	11	7	4	1	0
Phsical Assault	0	0	3	4	5	3	1	1	0	0
Fall from height	0	0	0	5	5	7	1	1	0	0

Figure 1: Age and Sex wise distribution of cases.

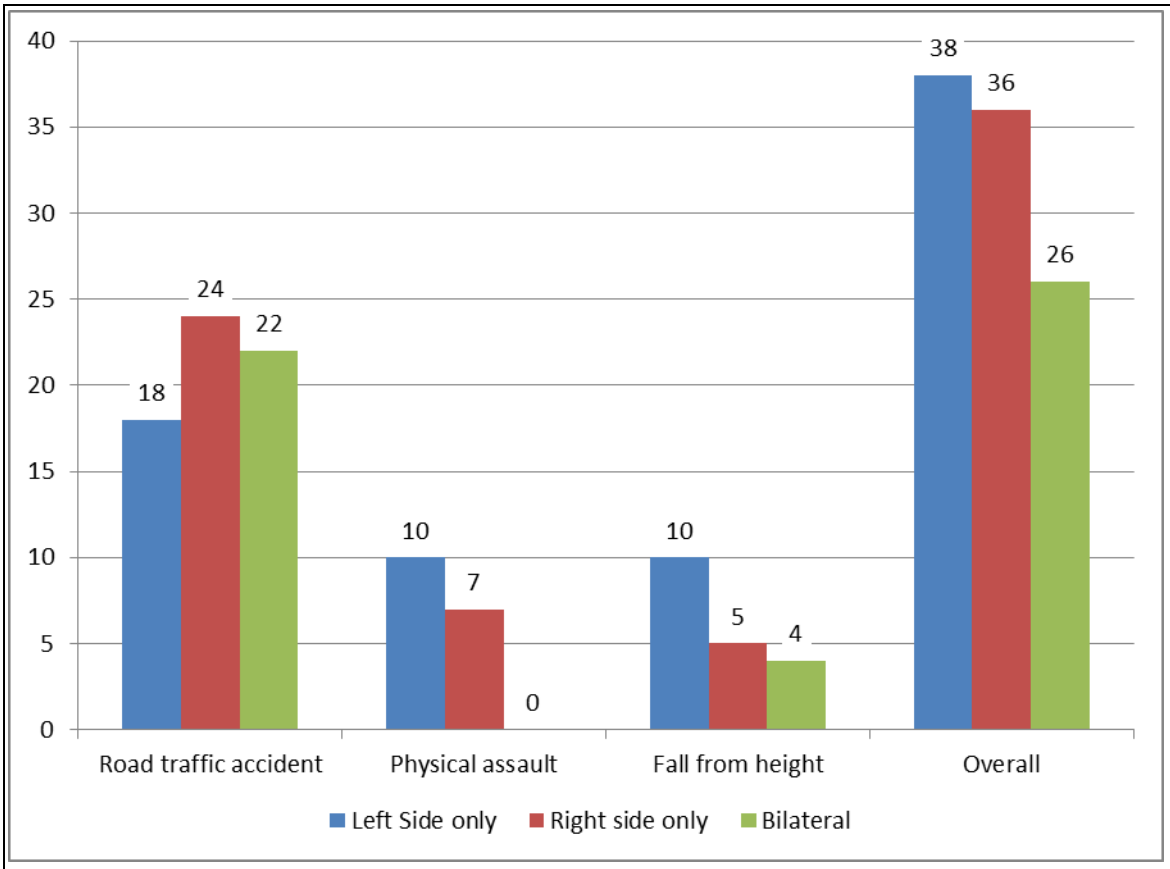


Figure 2 – Manner of injury vs side of rib fractures cross tabulation

Chi-Square Tests

	p value
Pearson Chi-Square	.020
Mc Nemar- Bowker Test	.002

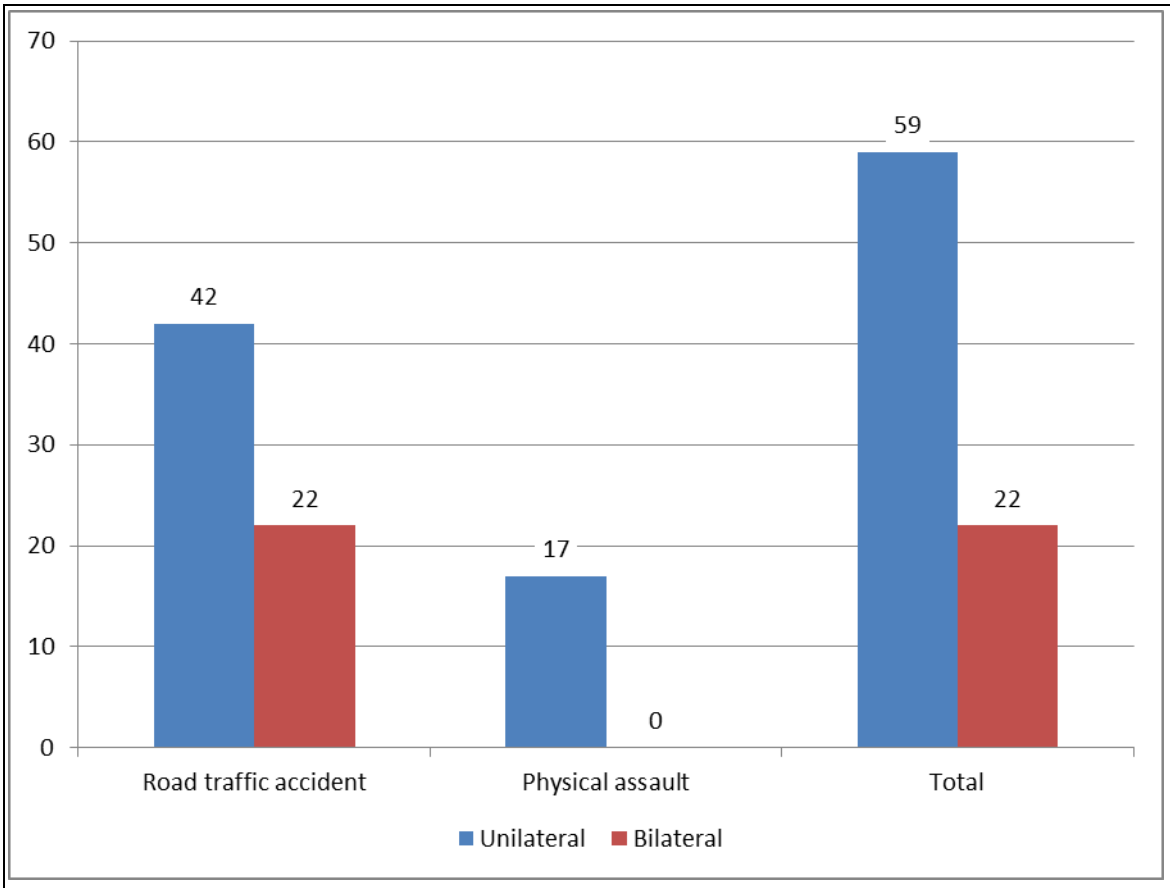


Figure 3 – Manner of injury vs laterality of rib fractures cross tabulation

Chi-Square Tests

	p value	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.005		
Fisher's Exact Test		.004	.002

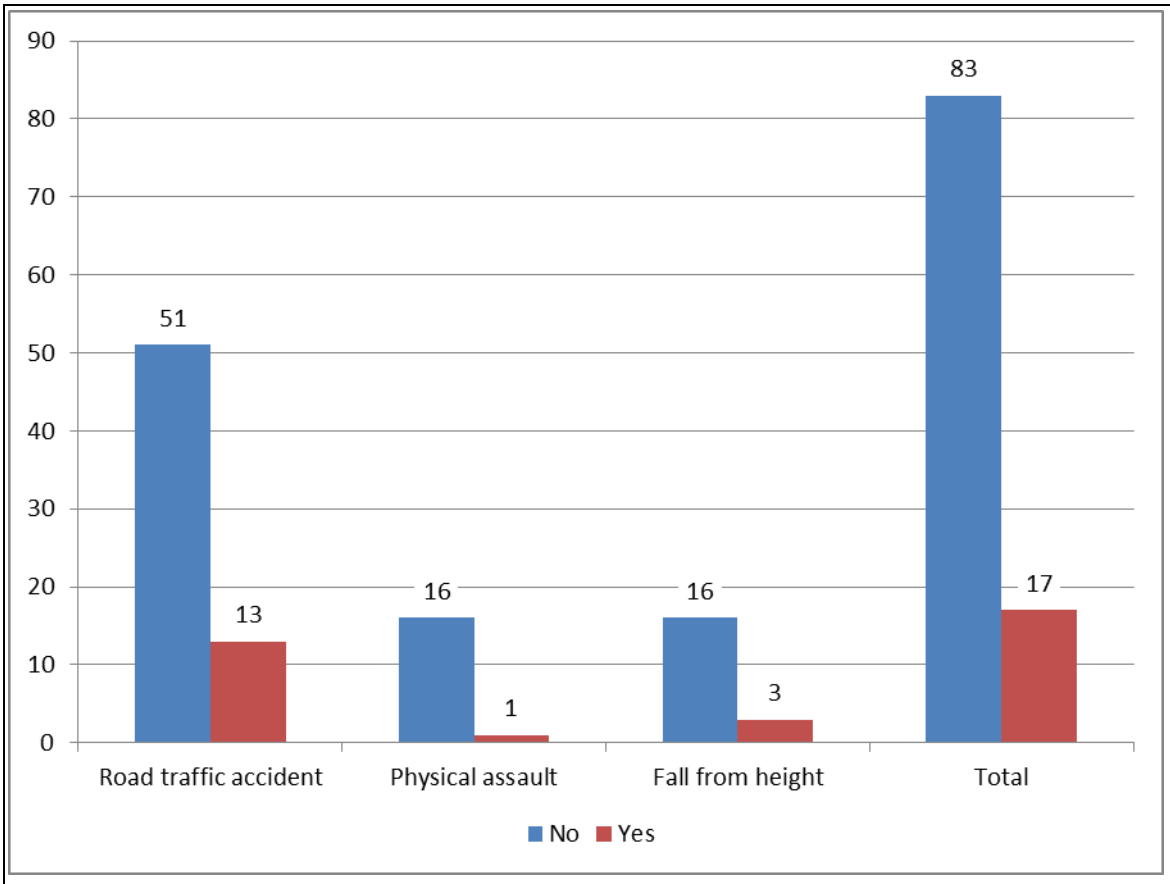


Figure 4 – Manner of injury vs number of cases with multiple fractures of same rib cross tabulation

Chi-Square Tests	
	p value
Pearson Chi-Square	.367