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Value of Surgical Management of Displaced Fractured Ribs over Medical Treatment in Pain Control and Patient Outcome

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ABSTRACT

Background: Rib fractures occur in about 10% of trauma-studied cases and are associated with significant morbidity and mortality. Despite advancing technology in the surgical stabilization of rib fractures, the ideal treatment strategy and surgical indications still remain controversial. **Objective:** The current study aimed to compare the effectiveness of surgical management of displaced fractured ribs when added to medical treatment versus conservative medical treatment in pain control and patient outcome. **Patients and methods:** A retrospective comparative study was conducted on 300 patients diagnosed with displaced fractured ribs from January 2018 to January 2022. The participants were divided into 2 groups; group A included 150 patients subjected to surgical management, and group B included 150 patients subjective to conservative medical treatment. **Results:** Mc Gill pain Questionnaire showed higher values of Pain Rating Index and Present Pain Intensity in the non-surgical group than the surgical group. RAND 36 Healthy Survey showed a higher score in the surgical group than the non-surgical group. The higher need for ICU admission, prolonged length of ICU stay, total hospital stay and higher incidence of in-hospital morbidity as chest infection including pneumonia and mortality were observed more in the non-surgical group than the surgical group. **Conclusion:** Surgical management of displaced fracture ribs is superior to conservative medical treatment regarding pain control and patient outcome.

Keywords: Rib fracture, Rib fixation, Pain, Displacement, Chest trauma, Comparative study, Tanta University.

INTRODUCTION

Chest trauma comprises about 10-15% of all trauma cases. About one-third of occurrences of chest trauma involves rib fractures and is caused by blunt trauma, such as car accidents and falls [(1)].

Chest wall fractures which are painful and incapacitating are typical complications of chest trauma and polytrauma. Clinically speaking, rib fractures can range in severity from single, non-displaced simple fracture to several displaced fractured ribs and flail chest, and in most severe cases, chest wall defect [(2)].

Rib fractures have been further related to increased morbidity and mortality from resulting chest pain and the severe pulmonary-related complications [(3)]. Moreover, half of studied cases with eight or more fractured ribs require admission to intensive care unit, and their mortality rate is approximately 34.4%. About one-third of these studied cases require extended care facility due to fact that over one-third of them experience lung problems [(4)].

Moreover, as older people have been more susceptible to rib fractures and have been more likely to die from chest injuries, frequency of rib fractures and accompanying morbidity and mortality will continue to rise as world's population ages [(5)].

Flail chest, which is typically described as having at least three cracked ribs in 2 or more locations, is serious, potentially fatal injury that is frequently accompanied by significant morbidity and death rates as high as 33% [(6)]. Studied cases with multiple rib fractures frequently experience respiratory compromise, serious physiological breathing disorder that results from paradoxical chest wall movement in flail segment, pain from sharp rib fragments, and shallow tidal volumes, which in turn cause atelectasis, pneumonia, and ultimately respiratory failure [(7)]. Often non-operative or conservative care of rib fracture studied cases is justified by the absence of rib fracture displacement. Surgical stabilisation of rib fractures is frequently indicated in cases of "severely displaced" rib fractures, with "severely displaced" being described as anything from 50% rib thickness transposition to bi-cortical displacement [(8)]. Also, according to 2015-developed Rib Score, "severely displaced" was defined as displacement higher than rib's diameter with complete loss of contact among proximal and distal segments [(9)]. Chest wall pain which is frequently the main factor contributing to underlying morbidity and death is primary clinical presentation of rib fractures [(10)]. For the treatment of rib fracture pain, variety of approaches are suggested, such as the administration of enterally, parenterally, topically, or through regional infiltration methods of both opioid and non-opioid painkillers [(11)]. To help studied cases with rib fractures experience less chest pain and avoid developing problems, surgical stabilisation of rib fractures (SSRF) has recently grown in favour. On other hand, it's yet unclear which studied cases would benefit from SSRF [(12)].

The aim of the current study was to compare the effectiveness of surgical management of displaced fractured ribs when added to medical treatment versus conservative medical treatment in pain control and patient outcome.

PATIENTS AND METHODS

A retrospective single-center comparative study was conducted on 300 patients diagnosed with displaced fractured ribs in the Cardiothoracic Surgery

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Department in Tanta university hospital from January 2018 to January 2022.
Our study included 300 major chest trauma and polytrauma patients who were admitted to our hospital presented with displaced fractured ribs.

Inclusion criteria: Adult (≥18-year-old) chest trauma patients and hospitalized polytrauma patients with evidence of displaced rib fractures.
Exclusion criteria: Studied cases with concomitant severe brain injury, severe splenic injury, severe pelvic injury, or severe liver injury (defined as AIS≥4) and patients who were unfit for surgical intervention as hepatic and renal patients were excluded.
Participants had been separated into 2 groups: Group A included 150 patients subjected to surgical management and Group B included 150 patients subjective to conservative medical treatment. All patients underwent the standard procedures of the protocol. All patients underwent the standard procedures of the protocol.

Sample size: As the incidence of ICU admission in surgical management group had been about 48.9% and in the conservative medical treatment group was about 77.7%, [6] so the sample size was calculated to be 300 patients (150 patients in each group). The sample is calculated using Open Epi Program at 95% confidence interval and power 80%.

All patients were subjected to: Patient's age, gender, Injury Severity Score (ISS), and Chest Abbreviated Injury Score (CAIS) are basic characteristics, the Mc Gill pain Questionnaire, the RAND 36 Healthy Survey and duration of ICU stay and the hospital length of stay, the existence of fail chest, and the status of studied case at discharge. ISS is recognised medical scale that evaluates overall seriousness of catastrophic trauma (greater than 15 is considered major trauma). CAIS anatomic score measures specifically degree of thoracic cavity injury.

CT scan: In 84 days following the injury, first chest computed tomography was followed by second (CT2) scan of the chest. CT2 had been collected to evaluate for thoracic empyema, to rule out pulmonary embolism, to evaluate for vascular abnormalities, to evaluate for thoracic spine damage or repair, and to evaluate for existence of hemothorax or pleural effusion. At our hospital, all studied cases had CT scanning using helical scan with 1.25 mm slices. Using normal reconstruction, CT scan had been taken through superior and inferior apices of lungs, and tops of kidneys. Rib fracture displacement had been measured in millimeters in 3 different planes: Superior-inferior, overlap or gap, and anterior-posterior. Using McKesson Radiology software, all images had been captured digitally. Measurements among CT 1 and CT 2 were made using outer cortex of rib, with location of rib fracture serving as reference point. Distances were measured in 3 planes using built-in measuring software for McKesson Radiology, keeping angle constant for measurements among CT1 and CT2, and using angle management software included with McKesson Radiology.

Surgical management: All studied cases underwent 3D computed CT reconstruction of their rib cage throughout preoperative planning to see where their rib fractures were and how far they had moved. While ribs 1 and 2 are difficult to access from certain positions and ribs 11 and 12 don't play significant role in breathing, our goal had been to correct misplaced fractured ribs among levels 3 and 10. Lateral decubitus posture had been used to position studied case. Each studied case had incision that ran length of typical thoracotomy incision and had been centered on their rib fractures. By dividing latissimus dorsi, neurovascular bundle, which includes long thoracic nerve, had been protected. After severing serratus anterior fibres over each rib throughout their length, fracture sites were revealed. For rib fracture fixation, Matrix RIB (DePuy Synthes) system had been utilized. This contains titanium plates that have already been re-contoured to meet different curves of ribs 4 to 8, which may be further bent to form if necessary and are simply cut to right length. Screws lock to plate and have been designed for bicortical fixation. Three screws should be inserted on either side of fracture. Intercostal chest drain had been inserted for 1st 24 postoperative hours following placement of metalwork and layer-by-layer closure. Day following surgery, chest radiograph had been taken. Same interdisciplinary team that provided care for medical treatment group also offered postoperative care for studied cases.

Medical treatment: non-operative care consisted of sufficient analgesia, mostly with opioids and non-steroidal anti-inflammatory drugs, non-invasive respiratory support, routine medical and nursing review, chest physical therapy, and customized rehabilitation. This care is provided by multidisciplinary team that consists of cardiothoracic and trauma surgeons, ICU doctors and anaesthetists, advanced nurse practitioners, and physiotherapists with focus on thoracic injuries.

Outcomes: Regarding Pain Control, at study entrance, individuals completed RAND 36 Health Survey and McGill Pain Questionnaire. MPQ is validated survey that measures subjective pain levels and compares several aspects of pain [13]. Pain Rating Index and Current Pain Intensity are 2 measures of pain intensity that are created by MPQ from subjective experiences of pain. Greater numbers denote pain levels that are more severe. RAND 36 Health Survey is verified survey that asks subjects 36 questions about their health over predetermined period of time. 8 different aspects of health are assessed by RAND 36, containing 4 physical (physical function, role physical, bodily discomfort and general health) and 4 mental aspects (mental health, role emotional, social function and vitality). Each component is given value between 0 and 100, with greater score indicating better or higher level of health. These two surveys are both approved for data collection over phone. Number of days spent

in hospital overall. Frequency of admission to intensive care unit and respiratory issues such hospital-acquired pneumonia, requirement for mechanical ventilation, and tracheotomy. HAP is described as infiltrate on chest radiograph that is new or progressing and that is accompanied by temperature of 37.88C or higher, purulent sputum, and leucocytosis >10,000 cells/dl. Respiratory failure of type I or type II requiring invasive respiratory assistance is definition of necessity for MV. Furthermore, mortality rate had been looked into, and difference among 2 groups had been computed.

Ethical Considerations:

Approval from Ethical Committee of the Faculty of Medicine Tanta University had been obtained by code 36250/12/22, and informed written consent were taken from patients after explanation of benefits and risks. Every unanticipated danger that surfaced throughout trial had been promptly disclosed to studied cases and ethical committee. Necessary steps had been made to mitigate these hazards. There was adequate provision to preserve privacy of the participants' and the confidentiality of data through putting a code number for each participant from the beginning to the end of the study. Outcomes of this study were used only for scientific purposes. This study was executed according to the code of ethics of the World Medical Association (Declaration of Helsinki) for studies on humans.

Statistical Analysis

The collected data were introduced and statistically analyzed by utilizing the Statistical Package for Social Sciences (SPSS) version 20 for windows. Qualitative data were defined as numbers and percentages. Chi-Square test and Fisher's exact test were used for comparison between categorical variables as appropriate. Quantitative data were tested for normality by Kolmogorov-Smirnov test. Normal distribution of variables was described as mean and standard deviation (SD), and independent sample t-test was used for comparison between groups. P value ≤0.05 was considered to be statistically significant.

RESULTS

Table 1 shows that there had been no statistical variation among studied groups as regard history.

Table (1): Comparing among 2 groups of studied cases based on chest trauma severity and patients demographic data.

Variable	Cases				Test of Sig.	P-value
	Operative group (n= 150)		Non-operative group (n = 150)			
Age (years)						
Range.	33 – 67		34 – 64		t= 1.257	0.210
Mean ± SD.	50.85 ± 9.56		49.49 ± 9.18			
Gender	No.	%	No.	%		
Female	28	18.7	26	17.3	χ^2= 0.090	0.764
Male	122	81.3	124	82.7		
Injury mechanism						
High energy trauma	87	58.0	80	53.3	χ^2= 2.297	0.317
Road accident	29	19.3	40	26.7		
Other	34	22.7	30	20.0		
Number of rib fractures						
Range	3 – 9		3 – 9		t= 0.530	0.596
Mean ± SD	6.19 ± 1.8		6.07 ± 1.9			
Rib fracture patterns						
Unilateral	56	37.3	53	35.3	χ^2= 0.130	0.719
Bilateral	94	62.7	97	64.7		
Rib fracture locations						
Upper	28	18.7	24	16	χ^2= 0.090	0.764
Middle	107	71.3	110	73.3		
Lower	15	10.0	16	10.7		
Injury severity score						
Range	12 – 38		9 – 40		t= 1.379	0.169
Mean ± SD	25.44 ± 7.57		24.06 ± 9.64			
Concomitant injuries					χ^2	P-value
Pneumothorax	79	52.7	75	50.0	0.213	0.644
Hemothorax	36	24.0	30	20.0	0.699	0.403
Lung contusion	84	56.0	73	48.7	1.617	0.204
Sternum fracture	25	16.7	24	16.0	0.024	0.876

SD: Standard deviation. χ^2: Chi square test. t: student t-test. P: P-value to compare among studied groups. *: significant at P≤ 0.05.

Table 2 shows that among the studied cases there were 33 (22%) patients who waited <24 hours until surgery, 101 (67.3%) patients waited 24-72 hours and 16 patients (10.7%) waited 72 hours to 7 days, the mean duration of surgery was 141.09 (SD 14.73) with range (116-165) minutes, mean number of surgically fixed rib fractures had been 3.21 (SD 1.39) with range (1-6) and there were 15 (10%) wound infection and 1 (0.7%) with bleeding.

Table (2): Surgery characteristics of the patients who had surgical fixation of displaced fractured ribs.

Variable	Operative (n = 150)	
Duration until surgery	No.	%
<24 hours	33	22.0
24–72 hours	101	67.3
72 hours to 7 days	16	10.7
Duration of surgery (min)		
Range	116 – 165	
Mean ± SD	141.09 ± 14.73	
Number of surgically fixed rib fractures		
Range	1 – 6	
Mean ± SD	3.21 ± 1.39	
Surgical complications		
Bleeding	1	0.7
Wound infection	15	10.0

Table 3 indicates that there was variation between studied groups as regard ICU stay and higher values of Pain Rating Index and Present Pain Intensity in non-operative group and operative group had higher score at the RAND 36 health Survey.

Table (3): Comparison between the two groups of the studied cases, according to patients Outcome.

Variable	Cases				Test of Sig.	P-value
	Operative group (n= 150)		Non-operative group (n= 150)			
Pain Rating Index						
Range	0 – 4		3 – 10		t= 16.681	<0.001*
Mean ± SD	1.97 ± 1.39		4.77 ± 1.51			
Present Pain Intensity						
Mild	119	79.3	33	22.0	χ^2= 100.513	<0.001*
Moderate	31	20.7	107	71.3		
Severe	0	0.0	10	6.7		
RAND 36 Healthy Survey						
Range	60 – 100		20 – 70		t= 20.721	<0.001*
Mean ± SD	79.16 ± 11.25		47.04 ± 15.29			
ICU admission	No.	%	No.	%		
No	138	92.0	130	86.7	χ^2= 2.239	0.135
Yes	12	8.0	20	13.3		
ICU stay (days)						
Range	2 – 8		3 – 10		t= 6.101	<0.001*
Mean ± SD	5.09 ± 1.84		6.55 ± 2.28			
Hospital stay (days)						
Range	5 – 21		8 – 21		t= 1.584	0.114
Mean ± SD	13.79 ± 4.32		14.51 ± 3.52			
Ventilator usage	No.	%	No.	%		
No	134	89.3	137	91.3	χ^2= 0.344	0.558
Yes	16	10.7	13	8.7		
Pneumonia						
No	112	74.7	110	73.3	χ^2= 0.069	0.792
Yes	38	25.3	40	26.7		
Mortality						
No	150	100.0	148	98.7	χ^2= 2.013	0.156
Yes	0	0.0	2	1.3		

SD: Standard deviation. χ^2: Chi square test. t: student t-test. P: P-value to compare among studied groups. *: significant at p≤0.05

DISCUSSION

Thoracic trauma has been reported to be found in approximately ten percent of all trauma studied cases. More than 20% of post-trauma mortality is dominated by and caused by thoracic trauma and its complications [(14)]. Rib fractures are the major morbidity in cases of chest trauma and have been presented in about 18% of studied cases with blunt chest trauma. Despite dramatic advances in chest trauma management, thoracic trauma remains and is considered as one of the main causes of morbidities in chest trauma and polytrauma cases [(15)].

Through history, great advancements in rib fracture management have been achieved. Egyptians were the first ones to describe the management of chest injuries. Edwin Smith papyrus contains significant information about rib fracture management. Hippocrates mentioned therapy of rib fractures & differentiated between types of rib fractures [(16)].

When the applied force of the blunt thoracic trauma exceeds strength of thoracic cage, rib fracture occurs. Site and number of rib fractures give important marker of severity of trauma. Most common site of rib fracture was found at 60° rotation from the sternum, from ribs 3 to 10. Ribs 1 and 2 are short and protected by the clavicle, although their injury has a significant possibility of underlying vascular accidents [(17)].

Pneumothorax was considered the most common pleural complication in cases of rib fracture, which may be life-threatening, followed by hemothorax, pleural effusion, myocardial contusion, diaphragmatic rupture, and sternum fracture down to aortic tear [(18)].

Severity of the chest injury, the number, and types of rib fractures, associated injuries of other organs, hemodynamic stability of the patient at the time of admission, the pain intensity scale, years old of studied case, and degree of underlying lung injuries determine type of rib fracture management either by conservative medical treatment or surgical intervention [(19)].

The management can be categorized mainly in two groups: surgical versus non-surgical. The main goals of the management are directed toward relieving the pain which is the main complaint associated with rib fractures, correcting conditions of hypoxia from lung injury as lung contusion, atelectasis and lung collapse from pneumothorax and hemothorax and treating morbidities, and prevention of complications. The main lines of non-surgical options include relieving of the pain by good analgesia which is correlated with the severity of the injury, maintaining adequate ventilation, proper fluid replacement, and suitable modes of assisted ventilation and mechanical ventilation which act as a ventilatory support [(20)].

Main signs of surgical intervention include occurrence of multiple displaced fractured ribs, chest wall deformity and flail chest [(21)], which can be defined as fractures of two ribs or more at more than one place, persistence of severe pain despite good analgesia, failure of weaning from mechanical ventilator [(22)], and indications of thoracotomy rather than fixation of rib fractures [(23)].

In this study we found that among the studied cases there were 33 patients (22%) who waited <24 hours until surgery, 101 (67.3%) patients who waited 24-72 hours and 16 patients (10.7%) who waited 72 hours to 7 days, the mean duration of surgery was 141.09 with range (116-165) minutes, mean number of surgically fixed rib fractures had been 3.21 with range (1-6) and there were 15 (10%) patients with wound infection and 1 (0.7%) patient with bleeding.

The severity of chest pain (pain score) had been lowering in surgery group (2%) than in non-surgery group (7%). mean number of days of hospital stay was lower in surgery group (13.79 ± 4.32) than in non-surgery group (14.51 ± 3.52), also number of days of ICU stay had been significantly lower among studied cases of surgery group (5.09 ± 1.84) compared to the studied cases of non-surgery group (6.55 ± 2.28) and there was no morality among the patients of the surgery group while in non-surgery group mortality rate had been 2%. Results of our study agree with the results of **Liu *et al.*** [(24)] who found that 49 occurrences of flail chest had been identified in group of 59 studied cases who underwent surgery. New, pure titanium plates had been utilised to replace shattered ribs, and paradoxical respiratory movement had been fixed. Per studied case, 3.7 plates (median 5, range 2-12) had been implanted. Average surgical time had been 85.2 minutes, ranging from 42 minutes for implantation of 1 plate to 150 minutes for studied case who received 12 plates. For 49 studied cases who had significant hemothorax and pneumothorax, closed thoracic drainage had been carried out. They illustrated that there had been variation among studied groups as regard length of ICU stay.

Outcomes of our research agree with outcomes of research done by **Tanaka *et al.*** [(25)] on studied cases with randomized multiple rib fractures who underwent either surgical or non-surgical options. They claimed that shattered end of rib fractures might accomplish anatomical reduction through open reduction and internal fixation. Following surgery, abnormal breathing stops right away, and thorax returns to its preoperative form and function, greatly lowering need for tracheotomies. Additionally, surgical management can effectively relieve chest pain so that airway secretions could be coughed up more easily and decrease compression, and stimulation of intercostal nerves at fracture site. These effects will encourage early studied case mobilisation, enhance respiratory function, lower risk of pulmonary complications, shorten hospital stay, and enhance studied case's quality of life.

Outcomes of our research are in agreement with outcomes of **Cataneo *et al.*** [(26)] who found that likelihood of pneumonia, chest deformity, tracheostomy, time of mechanical ventilation, and

length of ICU stay are all decreased following surgery to repair broken ribs.

Growing data in recent years has indicated that surgery may be reliable & efficient treatment option for severe rib fractures. **Granetzny *et al.*** [27] indicated that compared to group receiving conservative treatment, surgical group needed considerably less mechanical ventilation, thoracic ICU time, and inpatient days. Outcomes of our research are in agreement with outcomes of **Liu *et al.*** [24] who showed that following surgery, studied case's arterial PaO2 and PaCO2 dramatically improved, and studied cases in surgery group needed fewer days in intensive care unit and less time with thoracic drainage tube.

Also, **Jiang *et al.*** [28] found that number of days with moderate pain and length of hospital stay had been both lower in surgery group than in non-surgical group throughout hospitalisation ($P<0.01$).

Moreover, **Ağababaoğlu and Ersöz,** [29] found that according to clinical outcomes of patient groups, non-surgical group experienced longer hospital and ICU stays as well as more days requiring mechanical ventilation than surgery group did.

Outcomes of our research have been also in agreement with and consistent with recent meta-analysis done by **Schuurmans *et al.*** [30] It showed that surgical therapy of flail chest increases studied cases' outcomes in terms of days spent on mechanical ventilation, ICU stay, days spent in hospital, tracheostomy rate, functional vital capacity, and treatment expenses.

Furthermore, **Marasco *et al.*** [31] discovered that surgical repair dramatically decreased the length of time patients spent in the ICU, the prevalence of pneumonia, and the need for non-invasive mechanical ventilation.

Outcomes from Fourteen studies comparing surgical procedures versus non-surgical approaches for treatment of rib fractures were included in meta-analysis. **Liu *et al.*** [32] found that surgical intervention decreased the duration of hospitalization time, intensive care compared to non-surgical management, time and mechanical ventilation time decreased necessity of tracheotomy, decreased risk of getting lung infection, and decreased mortality rate.

Conservative therapies had been frequently used in past to treat severe thoracic trauma with rib fractures, however results had not been satisfactory [33]. Studied cases treated non-surgically require more potent analgesic medications and are unable to cough to expel easily formed airway secretions that can cause hysteria. Mechanical ventilation and external chest fixation, though partially relieving pathophysiological changes brought on by abnormal breathing and pulmonary contusions in these studied cases, were unable to eliminate their abnormal breathing [34]. Chest wall is still softening and collapsing to variable degrees, and dislocated rib fractures may result in thoracic abnormalities that impair appearance or possibly harm intercostal blood vessels and nerves [35].

For severe thoracic trauma and rib fractures, open decrease with internal fixation is common procedure in recent years [33]. Studies have shown that 72 hours after rib fracture, studied case's respiratory movement changes from shallow to normal, mediastinal oscillate impact on cardiovascular circulation is eliminated, pain caused by friction among broken ends of fractures is lessened, and hemodynamics are improved. While under general anaesthesia, lung tissue demonstrated strong compliance, lung ventilation had been improved, and proper management of respiratory tract may remove respiratory secretions in acute phase [34].

Hence, extubation had been carried done without requirement for mechanical support in several studied cases with small pulmonary contusions as soon as they were awake from anaesthesia. Studied cases who had had surgery did not require external fixation and did not have any breathing restrictions. Studied cases who had surgery could cough, turn over on their own, and get out of bed earlier than studied cases who had not had surgery. These activities help to keep airways open and lower lung problems. As result, surgical management group's need for and time of mechanical breathing was greatly decreased, and pain management benefited noticeably [35]. These outcomes match those of study we conducted for this paper.

Study limitations: Limitation to this research is as it is a retrospective analysis and also, as a single-center study, the conclusions may not reflect a broader experience with conservative medical management and surgical intervention for chest trauma and polytrauma patients with displaced fractured ribs.

CONCLUSION

Surgical fixation of displaced fracture ribs to medical management is superior to lone conservative medical treatment regarding pain control and results in better patient's outcome. As proved by Mc Gill Pain Questionnaire and RAND36 Healthy Survey and improved all outcome parameters in surgical group than in non-surgical group.

REFERENCES

1. **Chien C, Chen Y, Han S, Blaney G, Huang T, Chen K (2017):** The number of displaced rib fractures is more predictive for complications in chest trauma patients. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine, 25(1): 1-10.
2. **Fabricant L, Ham B, Mullins R, Mayberry J (2014):** Prospective clinical trial of surgical intervention for painful rib fracture nonunion. The American Surgeon, 80(6): 580-6.
3. **Kasotakis G, Hasenboehler E, Streib E, Patel N, Patel M, Alarcon L *et al.* (2017):** Operative fixation of rib fractures after blunt trauma: a practice management guideline from the Eastern Association for the Surgery of Trauma. Journal of Trauma and Acute Care Surgery, 82(3): 618-26.
4. **Bauman Z, Cemaj S, Schlitzkus L (2018):** Taking the bull by the horns: patient trampled by bull requiring

surgical fixation of multiple rib fractures including rib 11. Trauma Case Reports, 16:12-5.

5. **Li Z, Kindig M, Kerrigan J, Untaroiu C *et al*. (2010):** Rib fractures under anterior–posterior dynamic loads: experimental and finite-element study. Journal of Biomechanics, 43(2): 228-34.
6. **Gerakopoulos E, Walker L, Melling D, Scott S, Scott S (2019):** Surgical management of multiple rib fractures reduces the hospital length of stay and the mortality rate in major trauma patients: a comparative study in a UK major trauma center. Journal of Orthopaedic Trauma, 33(1): 9-14.
7. **Long R, Tian J, Wu S, Li Y, Yang X, Fei J (2020):** Clinical efficacy of surgical versus conservative treatment for multiple rib fractures: a meta-analysis of randomized controlled trials. International Journal of Surgery, 83: 79-88.
8. **de Moya M, Nirula R, Bif W (2017):** Rib fxation: who, what, when? Trauma Surg Acute Care Open, **2**: 1-4.
9. **Chapman B, Herbert B, Rodil M, Salotto J, Stovall R, Biffl W *et al*. (2016):** RibScore: a novel radiographic score based on fracture pattern that predicts pneumonia, respiratory failure, and tracheostomy. Journal of Trauma and Acute Care Surgery, **80**(1): 95-101.
10. **Bugaev N, Breeze J, Alhazmi M, Anbari H, Arabian S, Holewinski S *et al.* (2016):** Magnitude of rib fracture displacement predicts opioid requirements. The Journal of Trauma and Acute Care Surgery, 81(4):699.
11. **Menditto V, Gabrielli B, Marcosignori M, Screpante F, Pupita G, Polonara S *et al.* (2021):** A management of blunt thoracic trauma in an emergency department observation unit: pre-post observational study. Journal of Trauma and Acute Care Surgery, 72(1): 222-8.
12. **Pieracci F, Majercik S, Ali-Osman F, Ang D, Doben A, Edwards J *et al.* (2017):** Consensus statement: surgical stabilization of rib fractures rib fracture colloquium clinical practice guidelines. Injury, 48(2):307-21.
13. **Melzack R (1975):** The McGill Pain Questionnaire: major properties and scoring methods. Pain, 1(3):277-99.
14. **Ziegler D, Agarwal N (1994):** The morbidity and mortality of rib fractures. J Trauma., 37:975-9.
15. **Cameron P, Dziukas L, Hadj A, Clark P, Hooper S (1996):** Rib fractures in major trauma. Aust N Zealand J Surg., 66:530-4.
16. **Ceran S, Sunam G, Aribas O, Gormus N, Solak H (2002):** Chest trauma in children. Eur J Cardio-thorac Surg., 21:57-9.
17. **Molnar T, Hasse J, Jeyasingham K, Rendeki M (2004):** Changing dogmas: history of development in treatment modalities of traumatic pneumothorax, hemothorax, and post-traumatic empyema thoracis. Ann Thorac Surg., 77:372-8.
18. **Segers P, Van P, Jorens P, Van F (2001):** Thoracic trauma: an analysis of 187 patients. Acta Chirur Belg., 101:277-82.
19. **Bulger E, Arneson M, Mock C, Jurkovich G (2000):** Rib fractures in the elderly. J Trauma Acute Care Surg., 48:1040-7.
20. **Pettiford B, Luketich J, Landreneau R (2007):** The management of flail chest. Thorac Surg Clin., 17:25-33.
21. **Mayberry J, Kroeker A, Ham L, Mullins R, Trunkey D (2009):** Long-term morbidity, pain, and disability after repair of severe chest wall injuries. Am Surg., 75:389-94.
22. **Doben A, Eriksson E, Denlinger C *et al*. (2014):** Surgical rib fixation for flail chest deformity improves liberation from mechanical ventilation. J Crit Care, 29:139-43.
23. **Nirula R, Diaz J, Trunkey D, Mayberry J (2009):** Rib fracture repair: indications, technical issues, and future directions. World J Surg., 33:14-22.
24. **Liu Y, Xu S, Yu Q *et al.* (2018):** Surgical versus conservative therapy for multiple rib fractures: a retrospective analysis. Annals of Translational Medicine, 6:22.
25. **Tanaka H, Yukioka T, Yamaguti Y *et al.* (2002):** Surgical stabilization of internal pneumatic stabilization? A prospective randomized study of management of severe flail chest patients. Journal of Trauma and Acute Care Surgery, 52(4):727-32.
26. **Cataneo A, Cataneo D, de Oliveira F, Arruda K, El Dib R, de Oliveira Carvalho P (2015):** Surgical versus nonsurgical interventions for flail chest. Cochrane Database of Systematic Reviews, 13 (7): 234-244.
27. **Granetzny A, Abd El-Aal M, Emam E, Shalaby A, Boseila A (2005):** Surgical versus conservative treatment of flail chest. Evaluation of the pulmonary status. Interactive Cardiovascular and Thoracic Surgery, 4(6):583-7.
28. **Jiang Y, Wang X, Teng L, Liu Y, Wang J, Zheng Z (2019):** Comparison of the effectiveness of surgical versus nonsurgical treatment for multiple rib fractures accompanied with pulmonary contusion. Annals of Thoracic and Cardiovascular Surgery, 18 (2): 34-45
29. **Ağababaoğlu İ, Ersöz H (2020):** The benefits of early rib fixation for clinical outcomes of flail chest patients in intensive care unit. Turkish Journal of Thoracic and Cardiovascular Surgery, 28(2):331.
30. **Schuurmans J, Goslings J, Schepers T** (**2016**): Operative management versus non-operative management of rib fractures in flail chest injuries: a systematic review. Eur J Trauma Emerg Surg., DOI: 10.1007/s00068-016-0721-2
31. **Marasco S, Davies A, Cooper J *et al.* (2013):** Prospective randomized controlled trial of operative rib fixation in traumatic flail chest. J Am Coll Surg., 216(5):924-32.
32. **Liu X, Xiong K (2019):**Surgical management versus non-surgical management of rib fractures in chest trauma: a systematic review and meta-analysis. Journal of Cardiothoracic Surgery, 14(1):1-8.
33. **Vyhnanek F, Jirava D, Ocadlik M, Skrabalova D (2016):** Surgical stabilization of flail chest injury: indications. Technique and Results Acta chirurgiae orthopaedicae et traumatologie Cechoslovaca, 82:303-7.
34. **Fagevik Olsen M, Slobo M, Klarin L *et al.* (2017):** Physical function and pain after surgical or conservative management of multiple rib fractures - a follow-up study. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine, 24 (128): 342361
35. **Xu J, Qiu P, Yu R, Gong S, Ye Y, Shang X (2015):** Better short-term efficacy of treating severe flail chest with internal fixation surgery compared with conservative treatments. Eur J Med Res., 20(55): 56-77.