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Original Article / *Özgün Makale*

The benefits of early rib fixation for clinical outcomes of flail chest patients in intensive care unit

Erken dönem kosta fiksasyonunun yoğun bakım ünitesindeki yelken göğüs hastalarının klinik sonuçları üzerine faydaları

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ABSTRACT

Background: In the present study, we aimed to compare clinical results of conservative and surgical stabilization approaches and to investigate the effect of early reduction in patients with a flail chest.

Methods: Between March 2013 and December 2017, 34 patients (23 males, 11 females; mean age 43.7±12.1 years; range, 20 to 74 years) with a flail chest who underwent early rib fixation were included in the surgical group and 29 patients with a flail chest (19 males, 10 females; mean age: 45.7±15.8 years; range, 24 to 74 years) who were followed with the conservative approach were included in the conservative treatment group between February 2012 and December 2017. We applied early rib reduction on the first or the next day (within 24 to 36 h) of trauma. The length of hospitalization, the presence of pneumonia and septic complications in the postoperative period, mortality, mechanical ventilation duration, tracheostomy rate, respiratory function test results, and pain scores were recorded and compared between the groups.

Results: The length of stay in the hospital and intensive care unit, and duration of mechanical ventilation were statistically significantly higher in the conservative treatment group than the surgery group ($p<0.001$, $p<0.001$, and $p<0.001$, respectively). None of the patients required tracheostomy in the surgical group, while five patients required tracheostomy in the conservative treatment group ($p=0.004$). Mortality rates were 2.94% and 20.69% in the surgery and conservative treatment groups, respectively ($p=0.027$). Pain scores were statistically significantly different in favor of the surgical group compared to the conservative treatment group ($p=0.0038$ and $p=0.044$, respectively).

Conclusion: The results of our study show that early fixation and weaning reduce the need for mechanical ventilation, length of hospitalization, the need for tracheostomy, and mortality rates. This approach also provides a significant improvement in the long-term pain complaints and pulmonary function tests of patients with a flail chest.

Keywords: Flail chest, locked rib plates, rib fracture, thoracic trauma.

ÖZ

Amaç: Bu çalışmada yelken göğüs hastalarında konservatif ve cerrahi stabilizasyon yaklaşımlarının klinik sonuçları karşılaştırıldı ve erken redüksiyonun etkisi araştırıldı.

Çalışma planı: Mart 2013 - Aralık 2017 tarihleri arasında erken kaburga fiksasyonu yapılan yelken göğüslü 34 hasta (23 erkek, 11 kadın; ort. yaş 43.7±12.1 yıl; dağılım 20-74 yıl) cerrahi grubuna ve Şubat 2012 - Aralık 2017 tarihleri arasında konservatif yaklaşım ile takip edilen yelken göğüslü 29 hasta (19 erkek, 10 kadın; ort. yaş 45.7±15.8 yıl; dağılım 24-74 yıl) konservatif tedavi grubuna alındı. Travmanın olduğu gün veya bir sonraki gün (24 ila 36 saat içerisinde) erken kaburga redüksiyonu uygulandı. Hastanede kalış süresi, ameliyat sonrası dönemde pnömoni ve septik komplikasyon varlığı, mortalite, mekanik ventilasyon süresi, trakeostomi oranı, solunum fonksiyon test sonuçları ve ağrı skorları kaydedildi ve gruplar arasında karşılaştırıldı.

Bulgular: Hastanede ve yoğun bakım ünitesinde yatış süresi ve mekanik ventilasyon süresi cerrahi grubuna kıyasla, konservatif tedavi grubunda istatistiksel olarak anlamlı düzeyde daha uzun idi (sırasıyla $p<0.001$, $p<0.001$ ve $p<0.001$). Cerrahi grupta hiçbir hastada trakeostomi gerekmez iken, konservatif tedavi grubunda beş hastada trakeostomi gereksinimi oldu ($p=0.004$). Mortalite oranları cerrahi ve konservatif tedavi gruplarında sırasıyla %2.94 ve %20.69 idi ($p=0.027$). Ağrı skorları, konservatif tedavi grubuna kıyasla, cerrahi grup lehine istatistiksel olarak anlamlı düzeyde farklı idi (sırasıyla $p=0.0038$ ve $p=0.044$).

Sonuç: Çalışmamızın sonuçları erken fiksasyon ve erken ekstübasyonun mekanik ventilasyon gereksinimini, hastanede yatış süresini, trakeostomi ihtiyacını ve ölüm oranlarını azalttığını göstermektedir. Bu yaklaşım, yelken göğüs hastalarında uzun dönem ağrı şikayetinde ve solunum fonksiyon testlerinde önemli bir iyileşme sağlar.

Anahtar sözcükler: Yelken göğüs, kilitli kaburga plağı, kaburga kırığı, toraks travması.

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In most traumas, blunt thoracic injuries are seen. In such injuries, costal fractures are often encountered. Observation of multiple rib fractures shows signs of high-energy trauma which can be seen with hemothorax, pneumothorax, and pulmonary contusion.[1] The more the number of rib fractures in the thoracic wall, the higher the mortality rate is in this sense.[2] If there is flail chest due to trauma, the situation is more complicated and, even in the presence of an isolated flail, chest mortality rate increases up to 17%.[3] In the presence of a flail chest, the thoracic wall cannot carry out its function in the respiratory cycle fully as a rigid structure. As the cases cannot perform the respiratory function, hypoxia and carbon dioxide retention develop.[4] The general approach in the treatment of flail chest cases is to take the cases into intensive care observation and switch to mechanical ventilation and sedation support. Early surgical stabilization of the ribs that cause the fail chest may be another option against the traditional approach. However, there is no generally accepted treatment algorithm.

In the present study, we aimed to compare clinical results of conservative and surgical stabilization approaches and to investigate the contribution of early surgical approach in the treatment process in patients with a radiologically and clinically flail chest and requiring intensive care and mechanical ventilation support.

PATIENTS AND METHODS

In our clinics, there are two groups with a different approach to fail chest cases in the intensive care unit (ICU). Some of our surgeons have abandoned the conservative approach to fail chest cases since March 2013 and started to apply rib stabilization. Some of our surgeons have, however, continued to apply the non-surgical treatment. In this study, we documented all that were treated for fail chest and whose records were accessible in our clinic. Records were kept by a surgeon from an external clinic, and data entry was performed as group A' or group B', not surgery, non-surgical. We applied exclusion criteria strictly to standardize and specify the results of both groups of the patients. No additional randomization was performed.

The data of 69 patients who underwent open rib reduction fixation were evaluated and 34 patients (23 males, 11 females; mean age 43.7±12.1 years; range, 20 to 74 years) who met the inclusion criteria between March 2013 and December 2017 were included in the surgical group. The non-surgical group consisted of patients who met the flail chest criteria and were followed in the ICU with mechanical ventilator support. The records of 56 patients followed with the conservative approach were examined between February 2012 and December 2017, and 29 patients (19 males, 10 females; mean age 45.7±15.8 years; range, 24 to 74 years) who met the study criteria were included in the study. Patients with additional organ injuries which may cause mortality, additional diseases which may cause susceptibility to infection, and those with chronic obstructive pulmonary disease (COPD) and asthma were excluded from the study. Also, those with sternum fractures, bilateral rib fractures, clavicular and vertebral fractures were not included in the study. In the surgical group, 10 patients were excluded from the study, as they were operated at or after 24 to 36 h and did not meet the criteria to operate on the day of trauma or the following day (24 to 36 h). All of these patients who were operated in the early period were evaluated according to the time after trauma. Eleven patients had sternal clavicular and vertebral fractures, one patient had immunosuppressive disease, three patients had COPD and asthma, and 10 patients had additional organ injuries, and all were excluded from the study. In the non-surgical group, nine patients with sternal clavicular and vertebral fractures, four patients with COPD and asthma, and 14 patients with additional organ injuries were also excluded (Figure 1). A written informed consent was obtained from each patient. The study protocol was approved by the Yildirim Beyazit University, Faculty of Medicine, Ethics Committee (2018/73). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The patients were intubated during the early period and followed under sedation with mechanical ventilator support in the ICU in both groups. Patients were intubated under elective conditions due to paradoxical chest movement, dyspnea, and the tendency to increase partial carbon dioxide in arterial blood gas. Patients with hemothorax or pneumothorax were applied tube thoracostomy in the emergency setting or during the operation, if necessary (Figure 2). Patients who underwent early rib reduction and fixation on the first or the next day of trauma were evaluated in the surgery group. All patients were extubated postoperatively or on the first postoperative day to shorten the ICU stay and reduce the risk for nosocomial infections. In the non-surgical group, the weaning process was initiated when the paradoxical movement of the chest wall disappeared, and the stability of the chest was achieved. Tracheostomy follow-up was initiated in cases that mechanical ventilator duration was longer than 14 days.

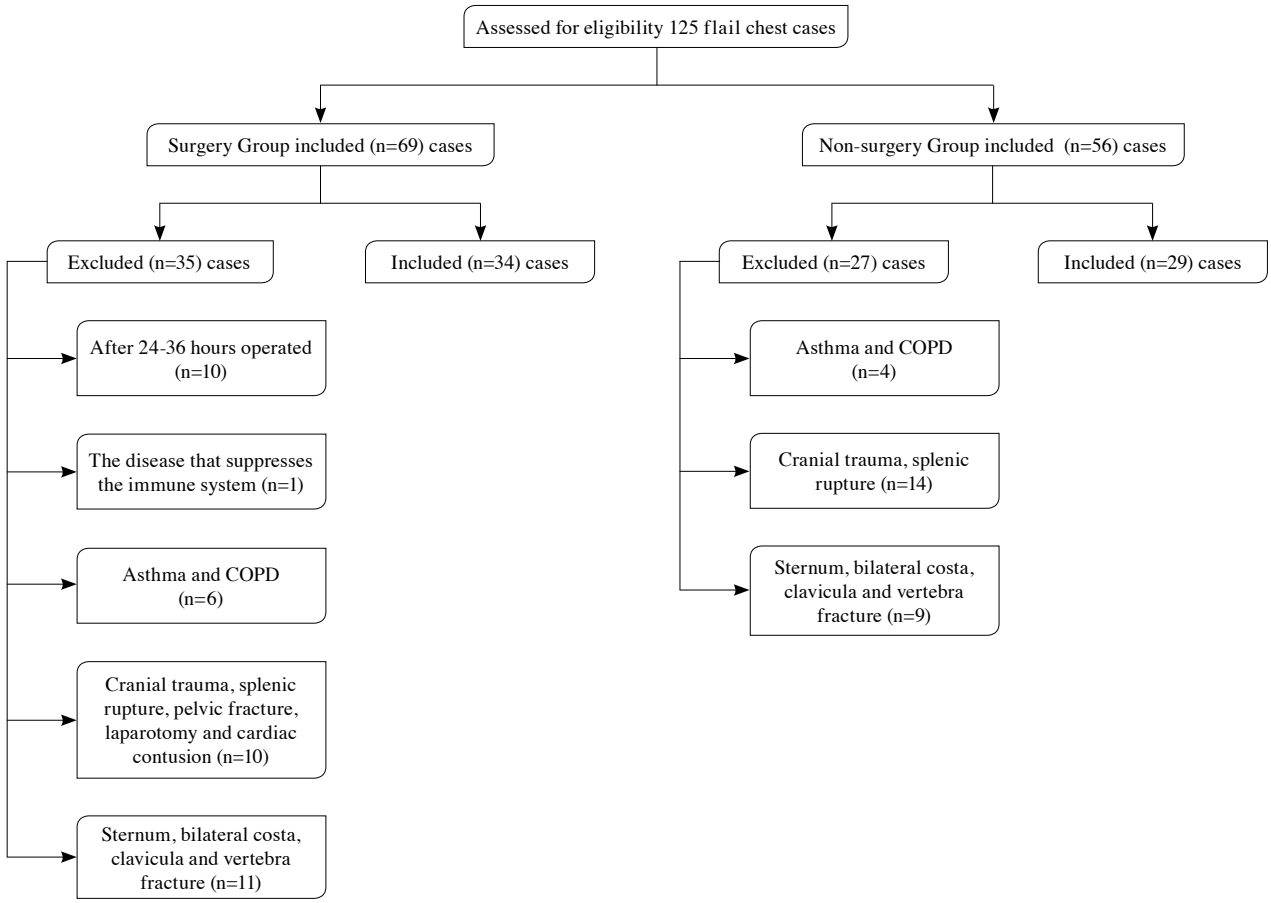

Figure 1. Study flowchart.
COPD: Chronic obstructive pulmonary disease.

Locked plates which were unsuitable for the thin structures of the ribs (titanium 3D rib clip, 6 segments, MedXpert GmbH, Eschbach, Germany) were used during surgery instead of screwed plates. Although there are many studies on open reduction of fractures with rib plate and screw, our surgical experience

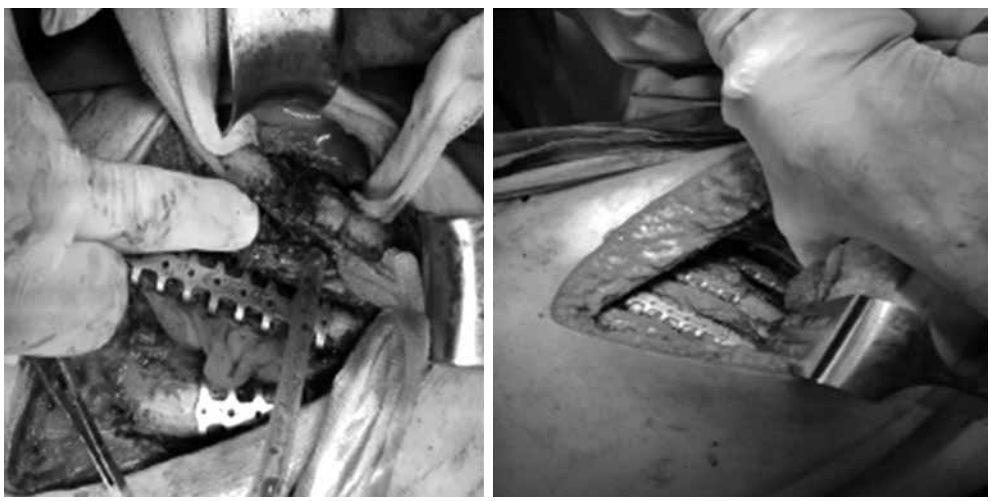

Figure 2. Fourth, fifth, sixth, and seventh rib fractures. An intraoperative view of reconstruction with Titanium 3D rib clip 6 segment clips.

Figure 3. Pre- and postoperative chest X-ray of a 48-year-old female patient.

contradicts with these results.[5,6] Therefore, we used the titanium 3D rib clip, 6 segments rib plate for the fixation according to the location of the fracture and size of the rib (Figure 3). Fixation was not performed for posterior and subscapular fractures. Of note, a fail chest is not very common in this region, as the major muscle structures and fascias prevent such a condition. Furthermore, there is a high need for dissection in this area which causes more harm than good.

Table 1. Demographic and clinical characteristics of study groups

	Surgery group			Non-surgery group				
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	t	*p*
Age (year)	45.8±15.6			43.7±12.1			0.597	0.553
Hospitalization (day)*		7.00	5-16		11.00	6-25	4.305	<0.001
ICU (day)		1.00	1-12		4.00	2-17	5.606	<0.001
Mechanical ventilation (day)		1.00	1-12		3.00	1-17	4.537	<0.001
Rib number		4	3-6		4	3-7	2.004	0.085
Pain 1		2	1-4		3	0-6	2.076	0.038
Pain 2		2	1-5		3	0-6	0.158	0.044
FEV_1 (%)	83.2±14.9			68.3±16.3			3.553	0.001
FVC (%)	84.3±14.2			70.0±16.6			3.454	0.001

	Gender							
	Male			Female				
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	t	*p*
Age (year)*		41.00	24-74		42.00	20-74	0.680	0.497
Hospitalization (day)		9	6-17		8	5-25	0.561	0.575
ICU (day)		2	1-17		2	1-16	0.147	0.883
Mechanical ventilation (day)		2	1-17		2	1-15	0.061	0.952
FEV1 (%)	77.6±12.9			76.8±19.0			0.181	0.857
FVC (%)	77.7±19.0			78.8±18.5			0.226	0.822

SD: Standard deviation; Min: Minimum; Max: Maximum; ICU: Intensive care unit; FEV_1: Forced expiratory volume in one second; FVC: Forced vital capacity; Mann-Whitney U test was used.

Medical records of both groups of patients were examined and length of stay in the ICU and hospital, the presence of pneumonia and septic complications in the postoperative period, mortality, mechanical ventilator time, and tracheostomy rates were documented. Pulmonary contusion, hemothorax, pneumothorax, and rib fractures were evaluated using X-ray and thoracic computed tomography. Pulmonary contusions of the cases were documented as positive or negative. Although there are several scoring systems for pulmonary contusion and trauma, there is no scoring system used in clinical routine.[7,8] Therefore, we did not make a detailed evaluation of pulmonary contusion. Pulmonary function tests and quality of life questionnaire (Short Form-36 [SD-36]) were performed in the sixth postoperative month and the results were evaluated. Two questions were asked to evaluate the pain in the questionnaire: *(i)* "How much bodily pain have you had during the past four weeks?" (none: 1, very mild: 2, mild: 3, moderate: 4, severe: 5, very severe: 6) and *(ii)* "How much did pain interfere with your normal work?" (Not at all: 1, A little bit: 2, Moderately: 3, Quite a bit: 4, Extremely: 5). To evaluate the capacity of the surgical intervention to protect the respiratory reserves, forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) values were used.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). The normality tests of the parameters were investigated with the Shapiro-Wilk test. Descriptive data were expressed in mean ± standard deviation (SD), median (min-max), or number and frequency. Relations among the categorical variables were investigated using the chi-square test. Independent samples t-test or Mann-Whitney U test were used to detect the differences in respect of surgery/non-surgery or gender groups. A p value <0.05 was considered statistically significant.

RESULTS

There was no significant difference between the groups in terms of gender (p=0.858) or age (p=0.576). Fifteen of the patients in the surgery group had pneumothorax and 18 of them had hemothorax. A total of 22 patients underwent tube thoracostomy. In the non-surgical group, 10 patients had and 16 patients had hemothorax. Fifteen patients required tube thoracostomy. The median number of ribs required a reduction was four in both groups, indicating no statistically significant difference (p=0.085). Table 1 shows the demographic and clinical characteristics of the study groups.

Table 2. Distributions of nominal parameters and comparison results

	Surgery group		Non-surgery group			
	n	%	n	%	C^2	p
Gender					0.032	0.858
Male	11	32.35	10	47.62		
Female	23	67.65	19	55.81		
Pulmonary contusion					0.387	0.534
Negative	15	44.12	16	55.17		
Positive	19	55.88	13	44.83		
Pneumonia					1.008	0.315
Negative	24	70.59	16	55.17		
Positive	10	29.41	13	44.83		
Septic complications					2.899	0.068
Negative	32	94.12	22	75.86		
Positive	2	5.88	7	24.14		
Mortality					5.361	0.021
Negative	33	97.06	23	79.31		
Positive	1	2.94	6	20.69		
Tracheostomy					8.267	0.004
Negative	34	100.00	24	82.76		
Positive	0	0.00	5	17.24		

According to the clinical results of patient groups, length of stay in the hospital and ICU and days of mechanical ventilation were all higher in the non-surgical group than the surgery group ($p<0.001$, $p<0.001$, and $p<0.001$, respectively). However, pulmonary contusion, pneumonia, and septic complication were identical between the groups ($p=0.534$, $p=0.315$, and $p=0.189$). Some of the patients had prolonged ICU and mechanical ventilation period, and none of the patients needed tracheostomy in the surgical group, while five needed in the non-surgical group, indicating a statistical significance ($p=0.004$). Also, the mortality rates were 2.94 % and 20.69% in the surgery and non-surgical groups, respectively and the mortality rates were significantly different between the surgery and the non-surgical groups ($p=0.027$).

According to the quality of life evaluation at six months postoperatively, the median scores were 2 and 3 in the surgery group and non-surgical groups, respectively for the first question ($p=0.0038$). For the second question, the median score was 2 in the surgery group and 3 in the non-surgical group, indicating a statistically significant difference in favor of the surgical group ($p=0.044$).

Based on the pulmonary function test, the mean FVC value was 84.3±14.2 in the surgery group and 70.0±16.6 in non-surgical group, and these values were statistically significant for both groups ($p=0.001$). The mean FEV_1 was 83.18±14.85 for the surgery group and 68.3±16.3 in the non-surgical group, also indicating a statistical significance for both groups ($p=0.001$) (Table 2).

Among 10 patients with a flail chest, two (2.9%) died after seven days. Compared to the patients we operated in the early period (20.0%), it was found to be statistically significant ($p=0.012$). Similarly, pneumonia developed in five (50.0%) of these 10 patients, indicating a statistically significant difference compared to the early period (29.4%) ($p=0.027$).

DISCUSSION

Flail chest is a condition which clinicians frequently encounter in high-energy traumas. It is difficult and complex to manage from the emergency department to the ICU. The surgeon who will carry out the treatment process has not sufficient data for the decision-making process. The characteristics of the cases in the studies are not homogeneous. Besides, we do not have any scientific data regarding the period in which the cases were operated or should be operated.[9-11] Therefore, we did not perform our study in all cases of rib fractures to obtain more specific results. In this study, we only evaluated fail chest cases requiring mechanical ventilator support in the ICU and applied open reduction and stabilization for rib fractures within 24 to 36 h after admission to the ICU. In the literature, there is only one study that describes the timing of reduction and stabilization applied to these cases and the authors compared the patients who underwent external stabilization with a bandage and those who underwent open reduction and fixation.[12] This is not consistent with routine chest trauma and fail chest management, indicating a different approach.[13] The main goal of our surgical approach is to maintain adequate ventilation, to reduce progressive damage, and to prevent complications and sequelae. In addition, in some studies for rib fracture cases, it is recommended that the cases should be operated within 24 to 72 h. However, these results are not based on any statistical analysis, but are based on the personal opinions of the authors.[14]

In the present study, we found no statistically significant difference in the rate of pneumonia and septic complications between the patient groups. We consider that stabilization of the thoracic wall and the paradoxical chest movement correction in the surgical group may have positively affected the thoracic compliance. Even in such a case, the likelihood of atelectasis is greatly reduced.[10,11,15] Therefore, the patients had less pneumonia in the surgical group, although we found no significant difference between the study groups. The incidence of pneumonia was reported in the literature as 38% in fail chest cases who were not treated with surgery.[15] This is similar to the results of our study. However, the rate of pneumonia and septic complications were significantly lower in the patients who underwent a surgical reduction in the literature.[12,16,17] We believe that the most important reason for this is the infection rates in our ICU. The high infection rates in the ICU in our country eliminate the statistically significant difference between our groups. Hence, it is more valuable to compare the incidence of pneumonia in our early and late operated cases. In this respect, in our early cases, we encountered much less pneumonia and septic complications compared to late cases. Nonetheless, it would be more reasonable to compare the results of early and late cases in larger series with the prospective, randomized groups. However, our data provide valuable information on surgical timing.

When mechanical ventilator and treatment costs were evaluated as another important clinical data, we

found a significant difference in favor of the surgical group. This was due to the elimination of paradoxical chest movement by the early reduction in surgical group patients. Naturally, carbon dioxide retention and hypoxia, the physiological results of a flail chest, are not seen in the surgical group cases and there is much less impairment in the blood gas results of this group. Therefore, the weaning process takes much longer in these cases and the need for the mechanical ventilator is inherently longer. Due to the shorter mechanical ventilation requirement, the ICU stay of our surgical group cases was shorter and, in only one case in the surgical group, there was a need for tracheostomy as an invasive approach. This decrease in the duration of hospitalization has also a lowering effect on the treatment costs. In this respect, these results are consistent with previous studies.[18-20] Garenza et al.[12] reported the mean number of days needed for a mechanical ventilation in flail chest cases as 12 days. This result is much more than the mean mechanical ventilator requirement of our patients in the surgical group, suggesting that the early surgical approach is useful.

Mortality in flail chest cases is usually due to septic complications.[20] Patients followed with mechanical ventilator support in the ICU have a risk for hospital-acquired pneumonia. These patients may have a mortal process leading to sepsis and multiple organ failure. In the literature, the mortality rates in flail chest cases is as high as 22 to 40%[21,22] In the surgical group, the need for mechanical ventilator and ICU hospitalization was shorter, and the risk for complications was lower in our study. Therefore, the mortality rate in the surgical group is much lower than in the non-surgery group. A review of three prospective, randomized studies of fail chest cases revealed that the incidence of pneumonia was significantly reduced for the rib reduction group.[10] However, there was no significant difference in the mortality rates in the same study. While there was no difference in the mortality rate between the surgical group and the non-surgical group, we found a significant difference in the rate of serious complications such as pneumonia in favor of the surgical group. The main difference between the approach to our surgical group cases with the approach in review cases is that we operated our patients within the first 24 to 36 h and started the weaning process for the first postoperative day; however, mechanical ventilator duration of the patients discussed in the review is much longer than in our surgical group. In this respect, we believe that the most important point in the treatment of fail chest cases is the reduction of the ribs as soon as possible and the initiation of the weaning process. Also, compared to the results of late surgical cases in our clinic, we observed much less mortality in early cases. This result emphasizes the importance of shortening the follow-up period in the ICU with a mechanical ventilator.

The two most important parameters defining the quality of life are pain scores and pulmonary function tests. In the light of the data, our patients in the surgical group reported less pain at six months postoperatively and that the pain had less effect on their daily activities. These findings show us that the surgical group patients are more comfortable in their daily activities with reduced loss of labor force. Most surgeons tend not to care much about pain in a surgical procedure and most of studies do not even evaluate pain in rib fracture cases. However, the long-term follow-up of patients is mainly about pain management. In a previous study, pain was found in 59% and physical activity limitation was found in 79% after six weeks.[23,24] Besides, rib fixation is beneficial in pain management in cases of simple rib fractures in addition to very painful traumas such as a fail chest.[25] Therefore, it is useful to apply the surgical approach in the early period to correct pain management for fail chest cases in the ICU.

One of the most important data to evaluate the long-term effects of trauma on cases is to evaluate pulmonary function tests. When the two groups were compared for the pulmonary function test, the results were obtained in favor of the surgical group. Early reduction of the paradoxical thoracic segment had significant improvement in pulmonary function test and chronic pain, compared to conservative treatment in the long-term period.[18,26] Thoracic deformity and pleural thickening are seen in a significant proportion of patient groups who were not operated due to multiple rib fractures and followed with the non-surgical approach. This physiological response usually manifests as a decrease in lung compliance and vital capacity of the patients.[27,28] Therefore, we evaluated the pulmonary function parameters of both groups and achieved much better results in the surgical group. However, to evaluate ideally the results of the pulmonary function tests, it should be compared with preoperative values of cases in both groups. This is very challenging in terms of methodology. In this respect, one of the major studies evaluating the effect of rib fixation on pulmonary function test was performed by Caragouinis et al.[29,30] They evaluated lung volume from preoperative and postoperative computed tomography images and compared the results with postoperative pulmonary function tests. In the early period in which the cases were intubated, there

was no significant difference in the FVC and total lung capacity. However, they found that the evaluation to be made by thoracic computed tomography was effective in detecting the losses in pulmonary function test values at six months. According to the results, we believe that early rib fixation has very positive results in the long-term quality of life.

Nonetheless, there are some limitations to this study. We performed our study in patient groups that matched the exclusion criteria required mechanical ventilation support in the ICU. We could design a retrospective study in a limited number of cases. Therefore, more accurate results can be achieved in randomized, prospective studies in patients undergoing early rib reduction and fixation. In particular, a prospective study can be performed to evaluate the results of patients operated within 24 to 36 h and those operated later.

In conclusion, the rib cage should be intact to maintain respiratory physiology. Surgical chest stability reduces the need for a mechanical ventilator in the intensive care unit, hospitalization time, the need for tracheostomy, and mortality rate. Besides, this treatment approach provides a significant improvement in the long-term pain complaints and pulmonary function test results. Thus, early fixation (within 24 to 36 h) and early weaning should be the most important treatment strategy for flail chest cases with mechanical ventilator support in the intensive care unit.

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