Original Article
Operative ease and efficiency of nitinol memory rib plaque on the multiple costa and sternum fractures: three-year clinical experience

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Abstract: Background: We wished to put forward the easy and rapid applicability of Nitinol memory rib plaques as well as their postoperative benefits in the cases with multiple costa fractures which lead to the occurrence of a flail chest and give rise to serious pain. Material and Methods: During the study period, at least three costa fractures and/or sternum fractures were detected in the Department of Thoracic Surgery, Bozok University between the period January 2013 and December 2015, and the medical files of 44 patients treated in the clinic were retrospectively reviewed. 15 of these patients (34.1%) received a costa fixation through the use of Nitinol memory plaques, whereas 2 of them (4.5%) had a sternum fixation and 27 of them (61.4%) had a conservative treatment. Results: 38 of the patients (86.4%) were male, whereas 6 of them (13.6%) were female, and the mean age was 57.38. While 13 of the cases (29.55%) had costa fractures on their right side and 20 of them (45.45%) had the same problem on their left side, 9 of them (20.45%) had bilateral costa fractures, 2 cases (4.55%) had isolated sternum fractures and 2 cases (4.55%) had the coexistence of sternum + costafractures. 14 of all the cases (31.81%) had the presence of a flail chest. The mean duration of operations was 29 minutes. The postoperative pain in the cases operated on was seen to be lower. While the mean hospitalization periods of the patients operated on was 6.47±2.98 days, the mean hospitalization periods of those not operated on was calculated as 5.19±2.02 days. In none of the patients operated on was any postoperative intensive care or mechanical ventilation required. Conclusions: We wished to emphasize the fact that the requirement for and the complications of a mechanical ventilator for the fractures in the cases with a heavier trauma score, those in need of a mechanical ventilation due to a flail chest, and also in the selected multiple fractured costa patients having problems in breathing since the pain level is rather high could be prevented thanks to the stabilization through a Nitinol memory plaque, which is reliable, easy and quick to apply.

Keywords: Thoracic trauma, rib fracture, nitinol-plaque, rib stabilization

Introduction

Thoracic traumas, among all the others, falls in the 3rd place after head and extremity traumas [1]. While 10% of mortalities due to trauma were directly associated with chest (thoracic) trauma, 18% of them were found to be indirectly related with thoracic trauma [2]. The majority of thoracic traumas comprise blunt thoracic traumas. In the conducted studies, it was reported that blunt thoracic trauma proved to be between 34-85%, whereas penetrating trauma was between 15-63%. On the other hand, in most of the reports, the most frequently-seen type of thoracic trauma was stated to be the costa fractures [3]. In the study conducted

by Şentürk et al., costafractures were seen to be at the rate of 35.8% in all thoracic traumas, while they were observed to be 80% in the study by Başoğlu et al., 71.7% in the study by Tekinbaş et al., and 56% in the study by Çakan et al. [3-6]. The factors increasing mortality and morbidity in the patients with costa fractures are age, the number of costa fractures, the presence of a flail chest, the presence of a bilateral costa fracture, the presence of lung contusion, the development of pneumonia and the pre-existing co-morbidities [7].

The most frequently-used method for eliminating the hemodynamic instability that develops in the case of a flail chest is the mechanical

ventilation. The process referred to as the internal pneumatic stabilization should be performed for at least 3 weeks until the paradoxical motion ends [8]. In this process, common and mortal complications may develop, such as deterioration of gas transfer due to the inconveniences in ventilator performance, ventilator-related pulmonary damage due to the maladjustment of ventilator settings, ventilator-related pneumonia, or hypotension and renal failure as the result of a positive pressure ventilation [9, 10]. In order to avoid all of these complications, the requirement for the use of a mechanical ventilator is tried to be minimized along with the use of rib and sternum stabilizers, the usage of which has become quite common in recent years.

Here, we have aimed to present 44 cases, along with all their clinical features, who applied to the emergency service of our Faculty with the complaint of multiple rib and/or sternum fractures.

Material and method

In this study, the medical files of the patients who applied to the Emergency Service of Bozok University, Medical Faculty between the period January 2013 and December 2015 and who were evaluated by the Clinic of Thoracic Surgery and were treated with the diagnosis of at least three costa fractures and/or sternum fractures were retrospectively reviewed. A total of 44 patients were incorporated into the study. After the necessary interventions for hemodynamic stabilization and the physical examinations had been performed on all the patients by the emergency specialists at the time the patients arrived at the emergency service, their radiography (X-Ray) examinations for trauma were performed, as well. The Thoracic CT Scans for a detailed evaluation were performed on all the patients who were detected to have had multiple costa fractures in the wake of Radiography. The patients' ages and genders, the way they got injured, the number of the fractured ribs, the number of the displaced costa fractures, intrathoracic pathology accompanying the costa fractures, whether or not any operation was performed, how many fixators were used, whether or not any chest tube was placed in, concomitant extrathoracic bone fractures and the duration of hospitalizations were all recorded.

Our criteria for surgical indication

In accordance with the Thoracic CT images, the cases who had displaced rib fractures and whose displaced costa ends harmed the pulmonary parenchyma and caused deformity on the thoracic wall underwent the fixation process. Separately, fixation was also performed on the cases who had flail chest leading to hemodynamic instability, and on those with hypoxemia finding as the result of their pulse-oximetric examinations and blood gas analyses (pO_2 < 90) as well as those likely to be in need of mechanical ventilation. The cases we operated on were thosewho applied to the description of high-risk-patients in terms of mortality and morbidity in accordance with the scorings that indicated to the severity of thoracic trauma in general [11]. A conservative approach was shown to all of the patients who remained out of these criteria.

Our fixation practice methods

After the preoperative preparations for all the patients were completed, the skin projections of the costae to be subjected to fixation in accordance with the tomographic evaluation and the palpation examination were found and marked with a pen. Afterwards, the patient was intubated with an orotracheal single-lumen intubation tube by those to apply anesthesia. After the patient was provided with a proper position in accordance with the localization of the rib fracture to be stabilized, his/her skin region was washed up with the betadine solution. Under the guidance of a marking pen, a 5-7 cm long-skin incision was performed on all the fractures from a localization of approximately the same distance. The costa level was reached by protecting the muscle tissues as much as possible. No entry was done into the thoracic space in the cases with no hemothorax or pneumothorax. A drainage tube was placed in the thorax from the lowermost level and the posterior part in the cases who had hemothorax or pneumothorax but had previously no drainage tube placed in them in the emergency service, and then the blood and air within the thorax were drained away. Later on, the fractured costae were identified, and the periost layer on the surface was stripped from the lower and upper parts and lateral surface of the costa within a length that the stripper and the fixator would be placed in, without
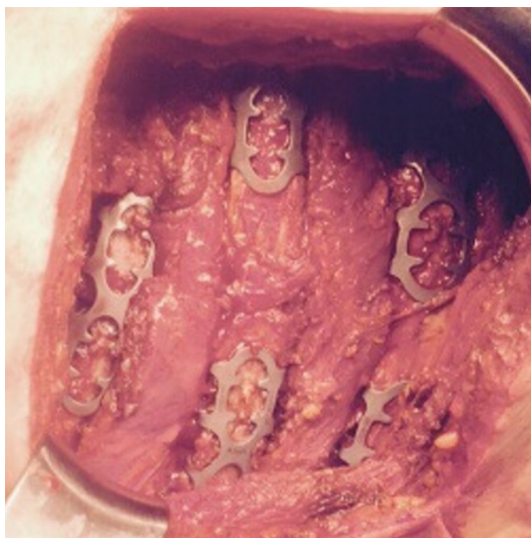
Figure 1. The images during the operation pertaining to the case who received a multiple costal fracture stabilization through a Nitinol costal plaque.

causing any damage to the pleura and the intercostal neurovascular pocket. Then, in a physiological saline solution at +4°C, the legs of the costa Nitinol memory plaque, which would hold the costa, were opened with the help of a special clamp after the fractured costae were brought tip-to-tip. After both tips/ends of the Nitinol memory costa plaque were placed on the costa in the way that it would bring the fractured line in the center, a sponge soaked with +45-50°C- hot physiological saline solution was put over it, and the plaque legs were made to close up and grasp the costa in a hot atmosphere, thus, fixing the fractures (**Figure 1**). Also on the sternum fractures, Nitinol memory plaques with similar characteristics that were specially designed for the sternum in terms of shape were used.

All the cases who developed no complication during the postoperative early period were taken to the service beds and were followed up later on; and in none of our cases was any postoperative intensive care or mechanical ventilation required. All the patients routinely received a 4×500 mg dose of intravenous paracetamol infusion for postoperative pain control, and in those whose pain level was serious, 50 mg of Dexalgine was administered intravenously.

Findings

38 (86.4%) of the patients were male, whereas 6 of them (13.6%) were female. Their ages var-

ied between 18 and 79, and the mean age was 57.38. In 31 of these cases (70.46%), the etiologic cause was the traffic accident, while the etiologic cause in 11 of them (25.0%) was falling down from height, another cause was the assault in 1 of them (2.27%), and the other cause was the occupational accident in one of them (2.27%). While 13 of the cases (29.55%) had rib fractures on their right side and 20 of them (45.45%) had the same problem on their left side and 9 of them (20.45%) had bilateral rib fractures, 2 cases (4.55%) had isolated sternum fractures and 2 cases (4.55%) had the coexistence of sternum + multiple rib fractures (**Table 1**). The average number of rib fractures in the isolated right hemithorax was 4.61, whereas the average number of rib fractures in the isolated left hemithorax was 5.5, and the average number of rib fractures in the right hemithorax of the cases with bilateral rib fracture was 4.44, whereas this average was 5.33 in the left hemithorax. While there was an average of 3.9 displaced rib fractures in 10 (50%) out of all the cases (n:20) who had rib fracture in their left hemithorax, there was an average of 3.6 displaced rib fractures in 6 (46.15%) out of all the cases (n:13) who had rib fracture in their right hemithorax. In 3 (33.3%) of the cases (n:9) who had bilateral rib fractures were an average of 3.3. displaced rib fractures on the right and 3.6 displaced rib fractures on the left side. When the number of rib fractures were calculated according to the etiology; the average (mean) number of rib fractures in the patients who had traffic accidents was 6.16±3.21 and the number of displaced rib fractures was calculated as 1.77±2.62, whereas the average number of rib fractures for falling down from height was 5.45±0.69, and the number of displaced rib fractures was calculated as 2.45±2.87. No statistically significant difference was found between traffic accident and falling down in terms of the number of rib fractures and displaced rib fractures (P:0292) (p:0.323).

In 14 (31.81%) of all the cases was the presence of a flail chest. There was the presence of a flail chest in 4 (30.76%) of the cases (n:13) with rib fracture in the right hemithorax, in 5 (25.0%) of the cases (n:20) with rib fracture in the left hemithorax, and in 5 (55.5%) of the cases (n:9) with bilateral rib fracture. While there was pneumothorax in 16 (36.36%) out of all the cases (n:44), 8 (50%) out of all pneumo-

Table 1. The demographic features of the patients with multiple costal fractures

Gender	
Female	6 (13.6%)
Male	38 (86.4%)
Etiology	
Traffic accident	31 (70.46%)
Falling down	11 (25.0%)
Assault	1 (2.27%)
Occupational accident	1 (2.27%)
Fracture side	
Right	13 (29.55%)
Left	20 (45.45%)
Bilateral	9 (20.45%)
Sternum	2 (4.55%)
Sternum + rib fracture	2 (4.55%)
The presence of flail chest	14 (31.81%)
Those operated on	
Rib fracture	15 (34.1%)
Sternum fracture	2 (4.5%)
Those medically followed-up	27 (61.4)
Duration of their hospitalizations	
For those operated on	6.47±2.98 days
For those medically followed-up	5.19±2.02 days

thoraxes were found in the cases with displaced fracture, and 8 (50%) of them were present in the cases with non-displaced rib fracture. There was hemothorax in 20 (45.45%) out of all the cases (n:44). 12 (60%) out of all hemothoraxes were found in the cases with displaced rib fractures, whereas 8 (40%) of them were present in the cases with non-displaced rib fractures. 14 (31.81%) out of all of these hemothoraxes and pneumothoraxes were in the form of hemopneumothorax.

While 15 (34.1%) of the patients received costal and 2 (4.5%) of them received sternum fixations, 27 (61.4%) of them underwent a conservative treatment. In the conservative treatment, the patients' pain controls were ensured, an antibiotic prophylaxis was performed, and mucolytic and bronchodilator therapies as well as gastroprotective treatment were routinely applied. There was an average of 7.42±1.32 fractured costae in 15 patients whose costal fixations were performed, and in these patients were an average of 4.46±1.32 fixators used. Since there was a simultaneous multiple costal fracture in 2 out of a total of 4 cases with ster-

num fractures, there was the presence of a flail chest, and the occurrence of a flail chest was prevented by performing only a sternum fixation on these two cases. Due to hemothorax, pneumothorax or hemopneumothorax, a unilateral chest tube was placed in 17 (38.63%) patients, while a bilateral chest tube was placed in 2 (4.54%) patients. The duration of the operation that lasted from the time of skin incision until the final skin suture was removed in 5 patients on whom 5 costal fracture fixations were performed was 25 minutes at minimum and 35 minutes at maximum, and the mean operation period was calculated as 29 minutes.

During the period when Paracetamol was only intravenously administered to all the patients for analgesic purposes, pain scoring process was performed in accordance with the Verbal Category Scale. According to this scale, the painful conditions of the patients were questioned, and the types of pain were calculated as follows: Slight Pain: 1 point, Disturbing: 2 pts, Severe: 3 pts, Very Severe: 4 pts, and Unbearable Pain: 5 points [12]. While the pain score was calculated as 3.18 according to this scoring process in the patients who were not operated on, the mean pain score in those operated on was calculated as 1.58. Considering these rates, it is seen that the postoperative pain in the cases operated on proved to be at a lower level. On the other hand, 50 mg of Dexalgine was intravenously administered to the cases with high pain level.

In 18 (40.90%) out of all our cases with thoracic trauma was an extrathoracic bone fracture detected. The most commonly seen bone fractures were found in extremity (n:9), vertebra (n:6), pelvis (n:2) and skull base (n:2) localizations, respectively. No correlation was found between the number of costal fractures and the incidence of fractures in the extrathoracic bones (P:0.08). The incidence of extrathoracic bone fracture was found to be higher in the patients who had larger number of displaced costal fractures (P:0.015) (r:0.363).

While the mean hospitalization period of the patients operated on was 6.47±2.98 days, the mean hospitalization period of those not operated on was calculated as 5.19±2.02 days, and no statistically significant difference was found between the patients operated on and those
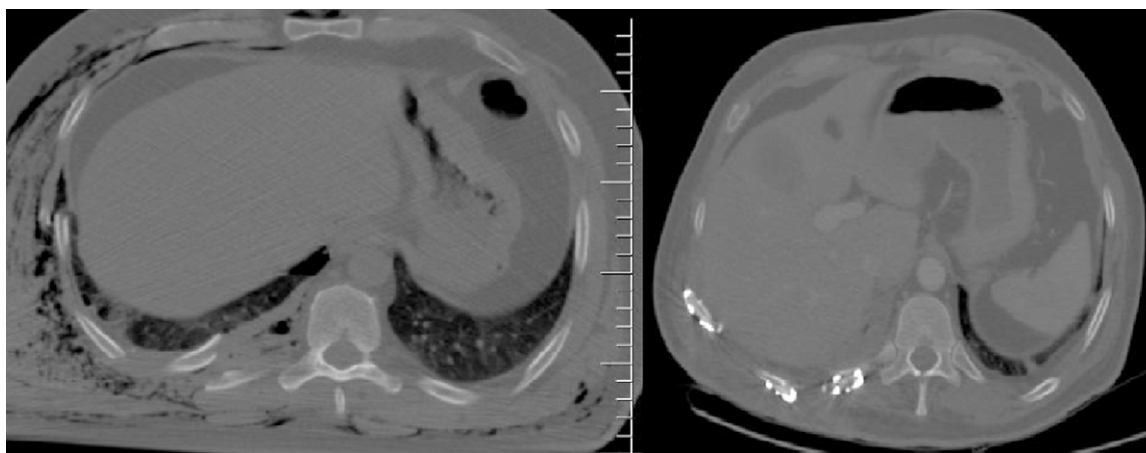
Figure 2. The pre- and post-operative Thorax CT images of the patient operated on due to the displaced costal fractures in the right hemithorax.

that were not in terms of the durations of hospitalizations (P:0.509).

Our postoperative follow-up period took a minimum of 3 and a maximum of 36 months, and the average was calculated as 13.72 months. In none of the patients, either both operated on or not operated on, was any problem seen, which required a re-hospitalization due to a thoracic trauma (**Figure 2**).

Statistical method

The data were evaluated on SPSS statistical program. Since the distribution of the numeric data was not normal and the number of groups was few, Mann-Whitney U test was performed as the non-parametric test. As for the statistically significant results, those with P < 0.05 were accepted.

Discussion

In recent years, a prominent increase is observed in thoracic traumas due to the increase in traffic accidents, natural disasters, occupational accidents and the activities involving violence. The primary cause of death in men younger than the age of thirty-four is traumas, and the majority of these traumas are caused by motor vehicle accidents [13]. In the USA, almost 20-25% of mortalities due to trauma involve the thoracic traumas. It is assumed that about 16000 patients per year are lost in the wake of a thoracic trauma [14]. In our study, 38 (86.4%) of our patients were male, whereas 6 (13.6%) of them were female, and the male

patients comprised the majority. The patient age varied between 18 and 79, and the mean age was 57.38. When classified in terms of etiology, in 31 (70.46%) of the cases did the traffic accidents, in 11 (25.0%) of them did falling down from height, in 1 (2.27%) of them did the assault, and again, in 1 (2.27%) of them did the occupational accidents comprise the etiologic causes. In our study, when the number of costal fractures was calculated in accordance with the etiology, the average number of costal fractures in the patients (n:31) with trauma due to a traffic accident was 6.16±3.21, whereas the number of their displaced costal fractures was calculated as 1.77±2.62. In the cases (n:11) with trauma due to falling down, however, the average number of costal fractures proved to be 5.45±0.69, whereas the number of displaced fractures were calculated as 2.45±2.87. No statistically significant difference was found between the traffic accident and falling down in terms of the number of costal fractures and displaced costal fractures.

In thoracic traumas are flail chests at the rate of 4-15% seen [2, 4, 15]. A flail chest appears on the frontal or lateral side of the thorax when at least three successive costae are broken from at least two parts; or we can encounter flail chests also in sternum fractures or in the separation of costocondral junctions [16]. A flail chest poses a major life-threatening danger since it causes hemodynamic changes in the process. The most important event that affects hemodynamics in flail chest is the mediastinal flatter. The paradoxical motion in the thoracic

wall in the cases in whom mediastinal flatter develops causes torsions in the superior and inferior vena cavae, whether there may be pneumothorax or not. As a result, with the reduction of the blood that reaches the heart, the cardiac output drops down, and hypotension, syncope, or even a sudden cardiac death may develop in the cases [17]. In this case, it is necessary to follow up flail chest cases during the intensive care. In the cases in which the number of respirations exceed 30/min, the oxygen saturation proves to be < 90, the PaO_2 value drops down to 60 mmHg and the PCO_2 value rises up to 45 mmHg, a mechanical ventilation support must be taken into consideration. In the study conducted by Başoğlu et al., it was stated that a mechanical ventilation was required in 55% of the cases in whom a chest flail developed [4]. In 14 (31.81%) of our cases, on the other hand, there was the presence of a flail chest, the rate of which was much higher than those in the literature. While there was a flail chest in 4 (30.76%) of the cases (n:13) with a costal fracture in the right hemithorax, whereas 5 (25.0%) of the cases (n:20) with a costal fracture in the left hemithorax had a flail chest. In 5 (55.5%) of our cases (n:9) with a bilateral costal fracture was a flail chest observed, and this high percentage seemed to support the literature [2, 4, 15, 18]. While 15 (34.1%) of our patients received a costal fixation and 2 (4.5%) of them received a sternum fixation, a conservative treatment was performed on 27 (61.4%) of them without applying any fixation. In 15 patients on whom costal fixation was performed, there was an average of 7.42±1.32 fractured costae, and an average of 4.46±1.32 fixators were used on these patients. Since there was also a simultaneous multiple costal fracture in 2 out of a total of 4 cases with sternum fractures, there was the presence of a flail chest; thus, the flail chest was prevented by applying only sternum fixation to both of these cases. The cases we operated on were the most severely-injured ones among all 44 traumatic cases, and they were the ones most likely to be in need of a mechanical ventilation during the preoperative period. Considering such features, the fact that no postoperative intensive care or mechanical ventilation was required in any of the patients operated on revealed the fact that the operations were beneficial.

The mean duration of the operation that lasted from the time of skin incision until the final skin suture was removed in 5 patients on whom 5 costal fracture fixations were performed was calculated as 29 minutes. The most effective factor in performing such a short operation period is the easy applicability of the Nitinol memory costal plaques. After the necessary incisions and costal preparation have been performed, the placement of each plaque takes shorter time than an average of one minute. The fact that it was so easy to apply allowed us to keep the incision line smaller, as well.

As the result of the fact that the thoracic wall fails to take part in the respiratory process due to pain, some clinical pictures such as atelectasis, pneumonia and respiratory failure may develop in patients. While pain control with oral analgesics could be sufficient in a young patient with a single costal fracture, in the elderly patients with more than one costal fracture, however, additional parenteral narcotic analgesia is generally required for pain control. The intercostal nerve blockage and intrapleural catheter analgesia are alternative treatments to narcotic analgesia. However, each time the intercostal blockage is performed, it carries with it the risk of pneumothorax. Since the prognosis and drainage of lungs in multiple or bilateral costal fractures depend on how many costal fractures there are, the age of the patient and his/her pulmonary condition, the importance of early analgesic preventions in these patients gains importance once more [19]. We performed a pain scoring process in our cases according to the Verbal Category Scale [12]. While the pain score in our patients who were not operated on was calculated to be at the average of 3.18, it was calculated as 1.58 in those operated on. According to these rates, the fact that the postoperative pain proved to be lower in the cases operated on shows concordance with the literature [20]. Consequently, the mean duration of hospitalizations of our patients we operated on, whose clinical conditions were much more serious, was 6.47±2.98 days, whereas the mean duration of hospitalizations of those not operated on was calculated to be 5.19±2.02 days. In this way, we had the opportunity to discharge the cases whose trauma scores were higher and who were expected to stay in hospital for a longer period by operating on them and by discharging them from the hospital during the same period as those with a trauma score at a slighter level.

In 18 (40.90%) of our cases was an extrathoracic bone fracture found. The most frequently seen bone fractures were in the extremities (n:9), in vertebra (n:6), pelvis (n:2) and skull base (n:2) localizations, respectively. No correlation was found between the number of costal fractures and the incidence of a fracture in the extrathoracic bones (P:0.08). Yet, the incidence of extrathoracic bone fracture in the patients in whom there were larger number of displaced costal fractures was found to be higher (P:0.015) (r:0.363), which suggests this is the evidence of the fact that the number of displaced costal fractures [12], which are the indicators of scoring the severity of thoracic trauma, indicate to a traumatic severity.

As the result of our study, we wished to emphasize the fact that the requirement for and the complications of a mechanical ventilator for the fractures in the cases with a heavier trauma score, for those in need of a mechanical ventilation due to a flail chest, and also for those having problems in breathing since the pain level is rather high could be prevented thanks to the stabilization through a Nitinol memory plaque, which is reliable, easy and quick to apply.

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Disclosure of conflict of interest

None.

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