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Original Article

Internal fixation of claw-type rib bone plates on multiple fractured ribs

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Abstract: Objective: Our study aimed at exploring the efficacy as well as feasibility of internal fixation of claw-type rib bone plates on multiple fractured ribs. Methods: The clinical materials of 25 cases with multiple fractured ribs caused by blunt chest trauma, including 18 males and 7 females, averagely aging (60.1±13.3) years old, were retrospectively analyzed in our hospital from October 2012 to January 2016. They received open reduction and treatment of claw-type rib bone plates fixation under general anesthesia. Additionally, visual analogue score (VAS) was utilized to evaluate the pain. Results: Satisfactory effects were obtained in all patients with fractured ribs using rib bone plates. Postoperative recheck of chest X-rays or chest CT demonstrated favorable reduction without migration or dislocation, meanwhile, bilateral thoraces were roughly symmetrical and thoracic deformity disappeared on affected side compared with that before the surgery. The chest wall was stabilized and patients were satisfied with rectification of chest wall deformity after undergoing rib bone plates fixation; patients' postoperative pain was significantly relieved. All the surgeries were successful and the rib bone plates were taken out from patients, consequently, patients recovered postoperatively without those preoperative symptoms. Conclusions: The efficacy of internal fixation of claw-type rib bone plates on multiple fractured ribs was satisfactory no matter whether patients suffered from flail chest or not, possessing a higher clinical application value.

Keywords: Claw-type rib bone plates, multiple fractured ribs, flail chest

Introduction

Fractured ribs are the most common in chest trauma, accounting for 55% [1]. Multiple fractured ribs, particularly multiple fractures of multiple ribs could result in chest wall malacia along with flail chest and subsequently paradoxical respiratory movement, which seriously affecting respiratory function to gradually menace patients' lives [2]. Conventional therapy for multiple fractured ribs includes local pressure dressing, rib traction and ventilator internal fixation. With the development of surgical instruments as well as fixed materials, internal fixation treatment has been gradually adopted in fractured ribs and tended to be minimally invasive.

From October 2012 to January 2016, 25 cases with multiple fractured ribs were treated by internal fixation of claw-type rib bone plates in our hospital with satisfaction of the efficacy.

Materials and methods

General materials

25 patients in our group consisted of 18 males as well as 7 females with the average age being 60.1±13.3 years old. The symptoms involved chest pain, dyspnea and they were more heavier when the posture was alternated. In the meanwhile, among the 25 cases there were 15 cases suffering from car accidents, 8 cases from falling down and 2 cases from the falling injure from the high place. Then 7 cases were with bilateral fracture of rib, 8 cases with fracture of left rib and 10 cases with fracture of right rib. The amount of fractured ribs varied from 3 to 18 pieces, averagely 7.5±4.4 pieces. Fracture of multiple ribs occurred in 16 patients and the rest 9 cases suffered from multiple fractures of multiple ribs, what is more, 7 cases among them were subjected to flail chest with the combination of paradoxical breathing. 4

Table 1. The general materials and results

Cases	Gender		Age	Fracture amount	Fixation amount	Rib bone plates	VAS		Follow-up
	Male	Female					Preoperative	Postoperative	
25	18	17	60.1±13.3	7.5±4.4	4.9±3.5	5.2±3.5	7.7±1.0	2.8±1.0	19.3±10.2
							t=14.8		
							P=0.000		

Table 2. Preoperative and postoperative VAS

	VAS	T value	*P* value
Preoperative	7.7±1.0	14.8	0.000
Postoperative	2.8±1.0		

Figure 1. Claw-type rib plated manufactured by Changzhou Waston Medical Corporation in China.

cases were exposed to the combination of hemopneumothorax and pulmonary contusion together with craniocerebral trauma, 3 cases to abdominal visceral injury (1 case with splenectomy), 6 cases to fracture of the extremities and 2 cases to clavicular fracture. The surgery was arranged in 3.4±1.5 days averagely after patients get injured in 1~7 day. VAS was utilized to assess the pain, the preoperative VAS reaching 5~10 grades and averagely being 7.7±1.0 grades (**Tables 1**, **2**).

The criteria of included patients

The criteria of included patients were as follows: patients were subjected fracture of multiple ribs and obvious displacement of fracture segments; multiple fractures of multiple ribs lead to apparent thoracic deformity and instability of chest wall malacia resulted in flail chest and generating paradoxical respiration; multiple fractures of multiple ribs were in combining hemopneumothorax and chest wall underwent intractable pain accompanied by dyspnea; patients with fractured ribs and thoracic visceral organ injury required thoracotomy to probe hemostasis; violent pain influenced patients' daily life so they strongly demanded surgical treatment.

Internal fixed materials

In terms of internal fixed materials, claw-type rib plates manufactured by Changzhou Waston Medical Corporation in China were adopted in the surgery. Such sort of rib bone plates were chiefly composed of pure titanium, being characterized by specific plasticity, exerting no influence on CT as well as magnetic resonance imaging (MRI) check and possessing a good ability to be compatible with tissues, so there was no need to take them out from patients by reoperation (**Figure 1**).

Preoperative check and management

All the patients received chest CT scanning and the three-dimensional reconstruction preoperatively, determining the rib fracture as well as hemopneumothorax caused by thoracic trauma. Closed drainage of thoracic cavity was exposed on 22 patients with serious hemopneumothorax preoperatively and 4 cases suffering from flail chest attributed to severe trauma had failure of respiration, so breathing machine was utilized to assist patients with respiration preoperatively, subsequently, the surgical treatment was carried out after patients calmed down. As regards those 10 cases with high aging being subjected to chronic obstructive pulmonary disease (COPD), they received anti inflammatory and analgesic therapy preoperatively; respiratory secretions were cleaned to relieve dyspnea.

Surgical methods

Double lumen endotracheal intubation, venous complex as well as general anesthesia were implemented during the surgery. Body posture was mastered flexibly on the basis of injured parts, 13 cases being with lateral position and 12 cases with half lateral position. The surgical vision was required to be exposed to the utmost. The seventh rib of Ipsilateral axillary midline was treated with 1 cm incision, placed into thoracoscope to detect the thoracic cavity. The hematocele as well as blood clot was cleared up to figure out bleeding site. The injured pulmonary tissues were checked, if necessary, repair of lung was applied or linear Stapling Device was utilized to wedge-resect injured pulmonary tissues. When it comes to hemorrhage of chest wall, it was handled by coagulation and suture.

CT was used to further observe and determine the site as well as the number of fractured ribs, moreover, the appropriate surgical incision was selected to expose fractured ribs to the utmost for the convenience of surgery. Oblique or longitudinal incision with proper length should be taken, incising skin, hypoderm gradually and cutting off partial muscles on the chest and back (sometimes, the muscles were stretched after blunt dissection, avoiding unnecessary muscle cutting as much as possible) so that ribs with fracture could be exposed. Key fixed method was conducted to fasten ribs, that is to say, we just fixed principle supporting ribs rather than fastened those neighbored ribs with not severe fracture and not obvious displacement. According to fracture site we cut each layer of chest wall, exposed ribs segments that needed fixation, respectively stripped periosteum at both ends of ribs to 2 cm and carried through anatomical reduction, avoiding destructing pleura as much as possible.

Firstly, we should bend rib bone plates in conformity with walking direction of ribs, withhold them and make them cling to segments of rib fractures in anatomical reduction; rib bone plates forceps were applied in clamping 4 pairs of claw feet of rib bone plates, making claw feet adduct and closely stick to ribs, all of which were inevitable to accomplish fracture fixation. It should be observed that whether the fixation was satisfactory and loose or not. The selection of corresponding types of rib bone plates intraoperatively conformed to oblique length of fracture as well as thickness of rib. 55 mm × 19 mm rib bone plates were adopted when the oblique length of rib fracture was long and the rib was thick while 45 mm × 19 mm rib bone plates were utilized when the oblique length of rib fracture was short and the rib was a bit thinner. And then the originally separated periosteum was sutured to accelerate fracture healing. The negative pressure drainage tube was placed into the region between the fixed rib surface and muscular layer in case that fluid was accumulated in chest wall to bring about infection, which would not beneficial to fracture healing. Closed drainage tube was put into the original thoracic entrance, connecting with drainage bottle.

Results

The results of surgeries

All the surgeries obtained a good result ultimately with surgical time being 25~60 min, averagely 34±13 min. There were 2 cases subjected to hemorrhage owing to laceration of lung, also 6 cases suffering from hemorrhage of ribs broken segment and intercostal artery. 2 cases were treated with wedge resection of lung by linear stapling device under the assistance of thoracoscope due to laceration of lung. In terms of rib fixation, 1~18 pieces of ribs were fixed, averagely reaching 4.9±3.5 pieces; 2~17 rib bone plates were used, averagely reaching 5.2±3.5. 4 cases required breathing machine to support their respiration postoperatively since they were elderly with serious pulmonary contusion as well as a large number of respiratory secretions. 1 case suffered from pulmonary infection along with atelectasis, after that they received bronchofibroscope suction and anti-inflammatory therapy, fortunately they recovered finally. As for drainage tube exelcymosis time, it was arranged in 3~6 day postoperatively (3.9±1.1 day averagely). Postoperative VAS reached 1~5 grade (2.8±1.0 grade averagely), in addition, the pain relieved and had significant difference ($t=14.8$, $P=0.000$) compared with that before the surgery. Patients with chest wall collapse, deformity preoperatively were all satisfied with rectification. 4 cases with craniocerebral trauma were undergone with conservative treatment by neurosurgery. Abdominal cavity visceral

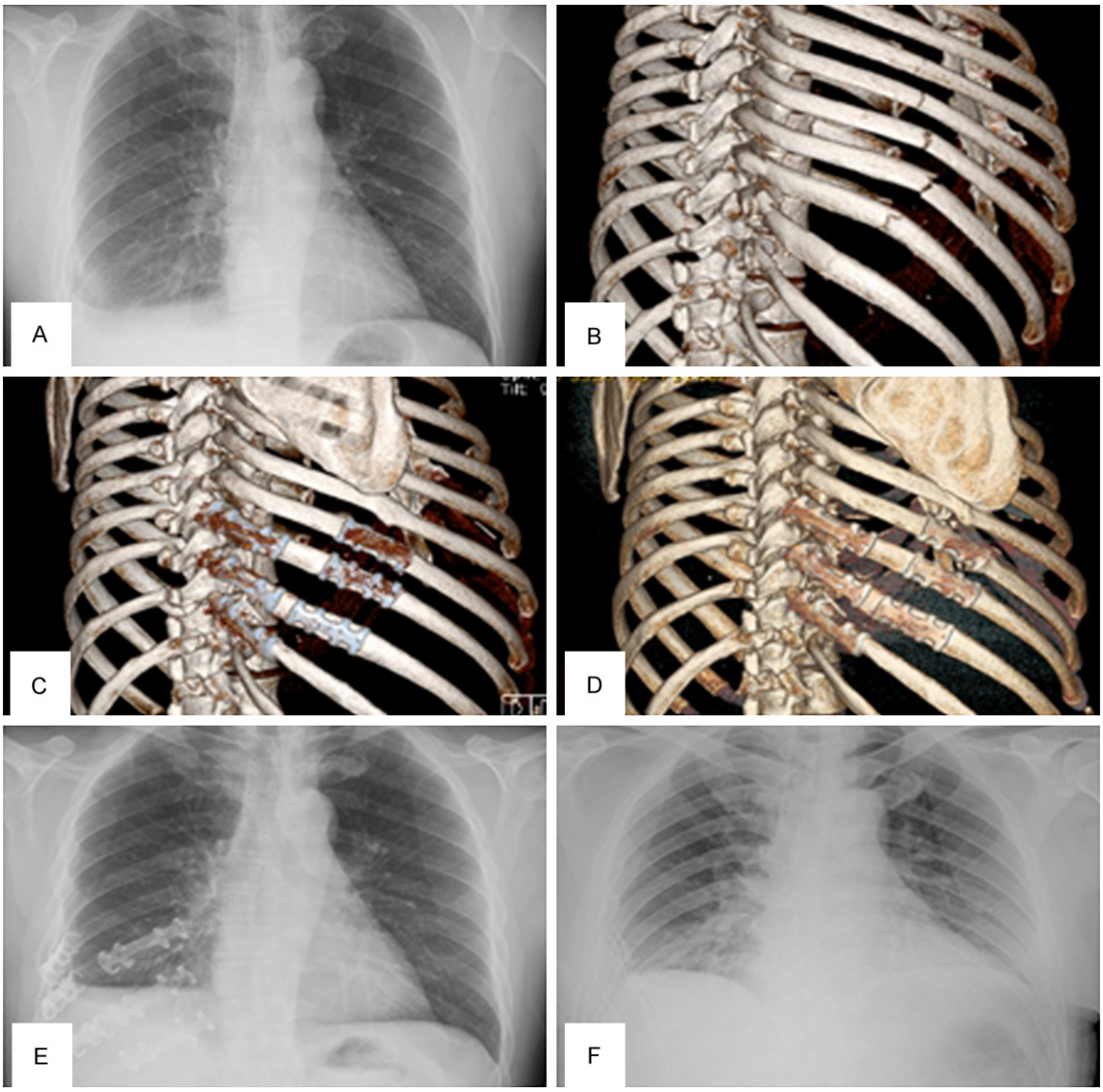

Figure 2. It referred to a 56-years-old man suffered from multiple fractures of multiple ribs (the 7th~11th piece) on the right as well as less hematopneumothorax. A. Was chest CT in the first day after he was injured, implying a small amount of effusion in pleural and not obvious fractured ribs; B. Was reconstruction of CT in the first day, indicating multiple fractures of multiple ribs on the right; C. Referred to reconstruction of CT in the 7th day after he got injured, demonstrating there was not displacement of fractured ribs after internal fixation of multiple fractures of multiple ribs on the right; D. Was reconstruction of CT in 15 month postoperatively, illustrating no displacement of fractured ribs; E. Referred to chest CT manifestation in 15 month postoperatively; F. Was chest CT manifestation in 15 month postoperatively after rib bone plates were taken out.

organ injury occurred in 4 cases, including 2 cases with contusion of kidney, 1 case with liver contusion and 1 case with rupture of spleen treated with lienectomy, the other 3 cases healed totally through conservative treatment. There were 6 cases going through fracture of the extremities, 2 cases suffering from clavicular fracture and they received fixed surgery in the Department of Orthopedics.

Results of follow-up

Generally speaking, the fractured ribs would clinically heal in the original period of callus formation, in other words, within 12~24 week after fracture. With reference to fracture clinical healing standard, chest X-ray demonstrated that rib bone plates were without loosening, displacement, fracture, which illustrated that it

satisfied the clinical healing criteria 3 months later by rib fracture surgery. 25 cases received 1~39 month's follow-up (19.3±10.2 month averagely) and chest X-ray indicated that rib bone plates were without loosening, displacement, fracture and obvious complications did not occur, all of them reaching clinical healing. What's more, 2 cases demanded surgeons to take rib bone plates out from their bodies due to postoperative sense of numbness as well as radiated pain in the surgical region, consequently, rib bone plates were respectively taken out in the 15th and 21st month postoperatively. All the surgeries were implemented under general anesthesia without any problem; rib bone plates were taken out completely and patients' symptoms vanished postoperatively (**Figure 2**).

Discussion

With the development of iconography, materials methodology as well as surgical means, the diagnosis and therapy for fractured ribs has been promoted subsequently, besides, it has become a tendency that internal fixation of rib bone plates should be carried out as soon as possible if injured. Time of mechanical ventilation together with ICU monitoring, incidence of pneumonia and chest wall deformity rate in surgical group with multiple fractured ribs are significantly lessened than that in non-surgical group, at the same time, the largest forced vital capacity (FVC) of surgical group significantly enhanced and patients can do normal daily work postoperatively [3, 4].

The diagnosis of fractured ribs primarily relies on iconography examination, including X-ray, CT test and so on. Meanwhile, chest X-ray enjoys the most popularity among surgeons as it is more intuitive to diagnose fractured ribs by X-ray than by CT, nevertheless, many factors such as a pocket like rib, multi organ overlap and projection means were able to contribute to missed diagnosis, the rate of which is up to over 15% [5-8]. Chest X-ray possesses a lower diagnostic sensitivity of complications like slight fracture, hemopneumothorax and pulmonary contusion, therefore, immediate diagnosis is postponed. With the purpose of improving the diagnostic rate of fractured ribs, patients in surgical group in our study were checked by multi-slice spiral CT (MSCT) as common practice and their ribs' three-dimensional CT imaging were reconstructed to make up for disadvantages of two-dimensional CT, for instance, lacking sense of three-dimension and failing to evaluate fracture along with bone fragments from all the round; as to patients with slight and not complete fractured ribs, they were observed critically and received good treatments. Moreover, three-dimensional reconstruction of MSCT possesses a much more precise, intuitive characteristic to locate fractured ribs compared with common CT, more importantly, it is of great guiding significance for surgeons to properly select surgical sites, as a result, regular preoperative MSCT is recommended to be applied in patients with fractured ribs.

Fractured ribs are the most ordinary in thoracic injury, the common reason of which includes direct violence injury, high falling injury and traffic accidents. Flail chest resulting from multiple fractures of multiple ribs is the most severe, the paradoxical respiratory movement would lead to pendular movement of mediastinum, subsequently affecting respiratory as well as cycling function, if serious, it could result in acute respiratory distress syndrome (ARDS) and if with which cannot be dealt immediately, the patients would likely to die from it.

In recent years, with the development of surgical fixed instruments, materials and endoscopy technology, it has become a tendency that internal fixed apparatuses are applied in internal fixation to cure multiple fractured ribs and correct flail chest, what is more, they become more and more convenient as well as minimally invasive. Patients with flail chest or severe pulmonary contusion even traumatic shock and respiratory failure ought to be rescued positively combined with breathing machine; surgical treatments are implemented after patients calm down. The 3 cases in our study got injured badly due to car accidents even though they were younger, which accounted for flail chest together with failure of respiration; breathing machine was used to support respiration preoperatively and patients received surgical treatments after calming down. Although some elderly patients with COPD was not injured badly or subjected to flail chest, the suffered from dyspnea to result in failure of respiration, which was caused by trauma, pain, pulmonary contusion or increasing excreta of air tube. As for such sort of patients, they should receive positive surgical therapy to relieve pains, in the meanwhile, breathing machine ought to be uti-

lized to clear up respiratory secretions and improve pulmonary function. Judging from the age of patients with fractured ribs, most patients are elderly, what is worse, with the increase of age the menace of that to patients' is more serious [9]. The mortality of patients aged over 65 years old can increase by 5% only if patients with fractured ribs are elder and elder annually [10].

In our group, 3 elderly cases (73, 81, 93 years old respectively) suffered from falling down, accounting for multiple fractures of multiple ribs as well as hemopneumothorax, agrius pains accompanied by COPD, pulmonary contusion and large quantities of respiratory secretions; even though flail chest did not come into being, such type of trauma was capable of leading to patients' failure of respiration, which should be highly focused on. After thoracoscope was performed to detect the traumatic condition, rib bone plates fixation was adopted to handle fractured ribs, supported by breathing machine postoperatively so as to effectively clear up large quantities of respiratory secretions and avoid serious pulmonary infection; extubation was conducted after patients calmed down; patients' pains were significantly relieved postoperatively and managed to expectorate strongly. We perceive that the indications of breathing machine to support respiration are as follows: firstly, severe trauma, extensive pulmonary contusion, a large quantity of hemopneumothorax, flail chest, traumatic shock or failure of respiration; secondly, as to elderly patients with COPD, dyspnea becomes more severe because of trauma, pains, pulmonary contusion or the increasing number of excreta of air tube, gradually bringing about failure of respiration.

At present, there are many methods as well as materials applied in internal fixation of fractured ribs with their advantages and disadvantages [10-18], for instance, plate and screw (titanium plate, "U" shaped plate), titanium nickel memory alloy embracing fixator and intramedullary fixation devices (Kirschner wire, bone nail); internal fixed materials comprise absorbable material, degradable material along with tissue engineering technological materials. Claw-type rib plated manufactured by Changzhou Waston Medical Corporation in China were adopted in the study. Such sort of rib bone plates are mainly made of pure titanium, exerting no effects on CT, MRI check and possessing a good ability to be compatible with tissues, so there is no need to take them out from patients by reoperation. What's more, it possesses certain plasticity because of moderate hardness, which could be moulded appropriately on the basis of shape of ribs, in terms of operations, it is very easy and convenient without screw reinforcing, moreover, fixed effects ate exact and broken segments won't be loose easily.

Voggenreiter et al. [19] considered that it is unnecessary to fasten over 3 or 4 pieces of fractured ribs for patients with 3~7 pieces of fractured ribs. We believe that there is no need to fasten each fractured rib. Key fixation of fractured ribs was performed in our study, that is to say, just principle supporting ribs were fixed instead of fastening those neighbored ribs with not severe fracture and not obvious displacement, which could lessen trauma and save costs. On the other hand, when it comes to the first, second fractured rib, the fixation was not recommended, the reason of which is that the scapula deep rib fracture does not have an impact on chest wall stability overall and its' operation is quite intricate, so internal fixation is unnecessary. The amount of fractured ribs varied from 3 to 18 pieces, averagely 7.5±4.4 pieces; the number of fractured ribs fixation was 1~18 pieces (4.9±3.5 pieces averagely); the amount of rib bone plates varied from 2 to 17 (5.2±3.5 averagely).

Selection of right time for surgery is beneficial to patients' recovery and can lessen surgical difficulty. In the early stage of trauma, most paradoxical respiratory movement is not so obvious that muscular relaxation occurs due to fatigue several hours later, plus retention of excreta of air tube, both of which contribute to the enhancement of respiratory muscle work as well as the enlargement of respiratory motion and gradually obvious pendular movement of mediastinum in patients with paradoxical breathing. The optimal time for surgery should be within 3 days after patients get injured, if it has been delayed for 2 weeks the bad surgical results will emerge and incidence of some complications like pulmonary infection, atelectasis, ARDS would be generally a bit higher if the best surgical time is missed. All patients in our study received the surgeries within 1 week after being injured or when their

vital sign calmed down, combined with therapic experience of our hospital in recent years we suggest that the time of patients' surgeries should be no more than 2 weeks. The enhancement of surgical difficulty is attributed to formation of fibrous scar in fractured ribs, in addition, the incidence of some complications such as pulmonary infection, atelectasis would be significantly heightened.

As a most common tool in thoracic surgery, video-assisted thoracoscope (VATS) has been widely applied in some fields like lung cancer [20-22], esophageal cancer and mediastinal mass [23] to assist surgeons to treat patients, moreover, it also plays a vital role in the diagnosis as well as management of chest trauma [24-26], compared with traditional thoracotomy, VATS will bring about fewer trauma, less pain and is more beneficial to patients' quick recovery [27]. Under the direction of VATS, surgeons are able to observe hemorrhage of pleural directly and then put hemostasis into effect as well as clear up hematocele and blood clots; under inward vision, surgeons also can confirm the sites along with number of fractured ribs, diagnose severity of fracture and assess the effects of internal fixation of rib bone plates; additionally, placement of guiding chest tube will be observed directly.

All in all, we speculate that the application of VATS in combination with pure titanium rib bone plates in treating patients with multiple fractured ribs as well as hematopneumothorax or flail chest is characterized by the following advantages: fewer trauma, convenient operation, reliable fixation and a good compatibility with tissues, which is beneficial to accelerate the healing of fractures, correct deformities and ameliorate respiratory function, consequently, as an effective method to cure multiple fractured ribs as well as hematopneumothorax, it deserves to be spread up and popularized.

Disclosure of conflict of interest

None.

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