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Original Article

Comparison of the Effectiveness of Surgical Versus Nonsurgical Treatment for Multiple Rib Fractures Accompanied with Pulmonary Contusion

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Objective: To compare the effectiveness of surgical versus nonsurgical treatment for multiple rib fractures accompanied with pulmonary contusion.

Methods: The clinical records of consecutive 167 patients with multiple rib fractures accompanied with pulmonary contusion, who were treated from June 2014 to June 2017, were retrospectively analyzed. Of them, 75 and 92 underwent surgery (surgery group) and non-surgical treatment (non-surgery group), respectively. Patient pain score, complications, length of hospital stay, cost of hospitalization, and post-treatment 3-month follow-up results were compared.

Results: The mean number of days and moderate pain in the surgery group was significantly lower than that of the non-surgery group ($p < 0.01$). The incidence of post-treatment complications was significantly lower in the surgery group than in the non-surgery group. The length of hospital stay of the surgery group was also significantly shorter than that of the non-surgery group ($p < 0.01$). The cost of hospitalization was significantly higher in the surgery group than in the non-surgery group ($p < 0.01$). The chest computed tomography (CT) scan which was performed 3 months after the treatment revealed that the surgery group had a better recovery than the non-surgery group. Physical recovery of the surgery group was also significantly better than that of the non-surgery group.

Conclusion: Surgery to treat multiple rib fractures (≥ 4 fractures) accompanied with pulmonary contusion is safe and effective.

Keywords: multiple rib fractures, pulmonary contusion, effectiveness, surgery

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Introduction

As economy develops quickly in China, trauma injuries caused by car accidences and construction accidences such as fall from height are increasing. In addition to brain and abdominal trauma, multiple rib fractures accompanied with pulmonary contusion are very common in patients with trauma injuries. Multiple rip fractures usually indicate a major energy transfer, which can destabilize the rib cage, soften chest wall, and consequently cause flail chest and adversely affect breathing. Pulmonary contusion is the most common injury found in blunt chest trauma which accounting for 25–35% of

the patients, severe pulmonary contusion can lead to pulmonary edema, resulting in pulmonary infection, breathing difficulties or acute respiratory failure.[1,2] Conservative therapies mainly include pain relievers and ventilator-assisted respiratory support, the patients would require long-term hospitalization. However, the conservative therapies are often associated with pulmonary infection, chronic pain, and long-term pulmonary dysfunction.[3,4] Recently, rib stabilizer, especially memory alloy embracing fixator, has been increasingly used in the surgical treatment of multiple rip fractures. Thus, thoracic cavity examination, repair of lacerated lung tissue, effective hemostasis of the chest wall or lung, and removal of blood clot inside the chest cavity can be performed during the thoracic surgery.

Surgical examination and treatment for patients with multiple rib fractures accompanied with pulmonary contusion but without progressive hemothorax are currently not very common. Only 2% of those patients undergo surgical examination and treatment.[5] One possible reason for the low rate of surgery may be associated with patients' low acceptance of open thoracic surgery, which is invasive and involves a complex procedure. Since 1990, video-assisted thoracic surgery (VATS) has become a popular surgical method to treat thoracic diseases and chest trauma. VATS is minimally invasive and allows surgeons to see rib fractures and bleeding points clearly. VATS can be performed to repair rib fracture and restore rib cage integrity. VATS can locate the incision wounds accurately and decrease the incidence of pulmonary infection, time on ventilator, and length of hospital stay.[6–8] Reports on multiple rib fractures accompanied with pulmonary contusion are sparse, and guidelines for treatments for this condition are unavailable. In addition, patients with multiple rib fractures with or without pulmonary contusion account for a substantial proportion of in-hospital patients.[9,10]

Most previous studies focus on surgical treatments for multiple rib fractures. However, investigations on surgical treatments for multiple rib fractures accompanied with pulmonary contusion are lacking.[5,6,11,12] This study aimed to compare the effectiveness of surgery versus non-surgical treatments for multiple rib fractures accompanied with pulmonary contusion.

Materials and Methods

Patient inclusion and exclusion criteria

Medical records of consecutive patients visiting the emergency clinic at Yiyuan People's hospital from June 2014 to June 2017 were retrospectively reviewed. And 167 consecutive patients who were diagnosed as multiple rib fractures accompanied with pulmonary contusion were enrolled in our study. The diagnosis of multiple rib fractures accompanied with pulmonary contusion was confirmed by the chest computed tomography (CT) which appeared as areas of lung consolidation in the chest trauma patients with multiple rib fractures. The inclusion criteria included the following: (1) multiple rip fractures (≥4 rip fractures) accompanied with pulmonary contusion which was diagnosed by chest CT; (2) with more than two rib fractures showing dislocation (>1 cm) at the fracture sites; and (3) with post-treatment 3-month follow-up examination. Patients with the following characteristics were excluded: (1) with concomitant injuries in the trachea, esophagus, great vessels of the heart, and other life-threatening complications; (2) with residual foreign bodies in the thoracic cavity; (3) with severe cerebral contusions; (4) with unstable vital signs for ≥5 days. Data of the patient's pain scores, length of hospital stay, complications, cost of hospitalization, and results of follow-up examination were collected.

Treatments

After being admitted to the emergency room, patients were examined by chest CT and diagnosed with multiple rib fractures accompanied with pulmonary contusion (**Fig. 1**). If patients had accompanied pneumothorax (unilateral lung compression >30%), routine thoracic closed drainage should be performed in the second intercostal space along the midclavicular line. If patients had accompanied hemothorax (intrapleural blood volume >400 mL), pneumohemothorax or chest tightness, thoracic closed drainage should be performed at the sixth intercostal space along the midaxillary line. Conservative therapies include oxygen inhalation, oral analgesics, antibiotics, thoracic cavity stabilization, and mechanical ventilation if patients had abnormal breathing. If patients had breathing difficulty, persistent bleeding, and/or pulmonary leak, they underwent surgery 2–4 days after admission in addition to those conservative therapies.

Surgical procedure

Patients received general anesthesia and tracheal intubation and were at supine position on the healthy side. A thoracoscope was placed at the sixth or seventh intercostal space along the axillary midline through a 2 cm incision.

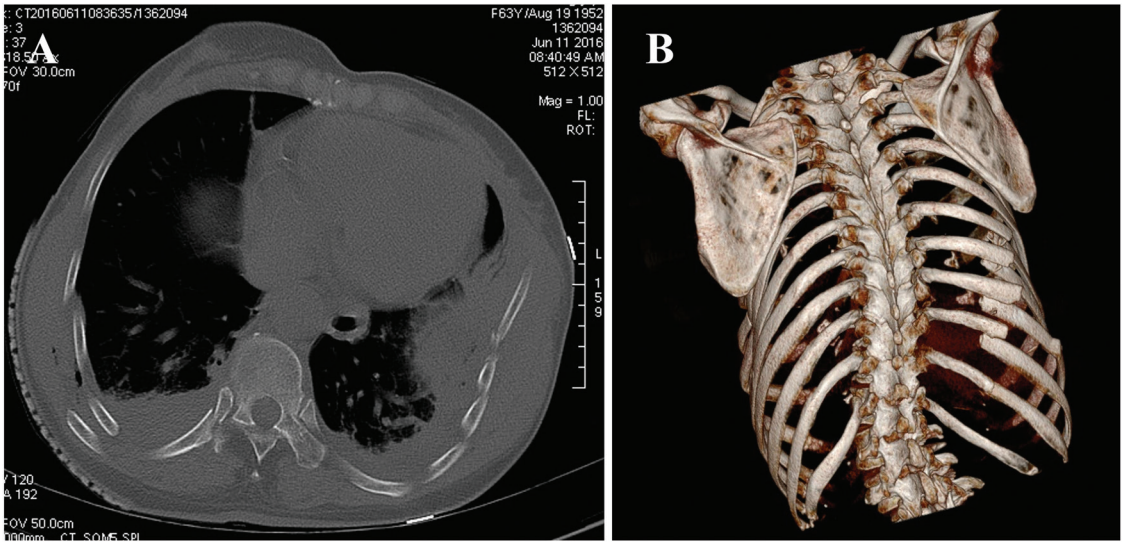

Fig. 1 Multiple rib fractures accompanied with pulmonary contusion on chest CT. (**A**) transverse plane, (**B**) three-dimensional reconstruction. CT: computed tomography

The thoracoscopy revealed dislocated rib fractures. A 5- to 7-cm incision was made at the site of rib repair. Intrathoracic blood was first removed by repeating flushing. Lacerated lung tissue was sutured and repair. Severely damages lung tissue was removed (Partial or complete lobectomy was performed). Diaphragm rupture was also repaired. Electrocoagulation or suture was performed to stop the bleeding at the lung and chest wall.

The muscle layer was cut in the direction of the muscle fibers and transverse muscles were maximally preserved. The fractured rib ends were isolated. Rib fractures were repaired and secured with a memory alloy embracing fixator. One incision was usually sufficient for rib fracture repair. Additional incision might be needed if rib fractures were not close. Memory alloy embracing fixators were expanded in ice water and then placed at the repair site. On postoperative day 1, patients were on a conventional analgesic pump. Patients underwent postoperative aerosol and anti-inflammatory treatments. When closed thoracic drainage was <100 mL and became clear yellow color, chest CT or X-ray was performed. The drainage was removed when patients had no abdominal bloating and pleural effusion.

Pain, complication, and follow-up assessment

Pain was assessed using the Visual Analogue Scale (VAS) with "0" representing no pain and "10" representing the worst pain. Score 1–3 represents mild pain; 4–6 represents moderate pain; and 7–10 represents severe pain. Pain was assessed at hospital admission and 9:00 every morning during hospitalization. The number of days of pain score >4 was counted. The complications included pneumonia, atelectasis, heart failure, and respiratory failure during hospitalization.

Three months after being discharged from hospital, patients received the follow-up chest CT examination (**Fig. 2**). Absence of pleural effusion and pulmonary infection and presence of osteophyte formation at the fracture site indicated satisfactory recovery. The presence of atelectasis, pleural effusion, and/or clear fracture line at the fracture site suggested unsatisfactory recovery. Patient physical fitness was also estimated at the follow-up examination. Patients were considered in satisfactory fitness if they did not have pain, post-physical activity chesty tight, and thoracic deformity, and were able to do gentle physical activity, and they were considered in unsatisfactory fitness if they had those discomforts and were unable to do daily physical activity.

Statistical analyses

Data were analyzed using the statistical analysis software SPSS 20.0 (2011; IBM, Armonk, NY, USA). Continuous variables were compared using t-test or rank sum test. Categorical variables were compared using the chi-square test; $p < 0.05$ was considered significantly different.

Results

Patient clinical data

A total of 167, including 75 in the surgery group and 92 in the non-surgery group, were analyzed. Of the

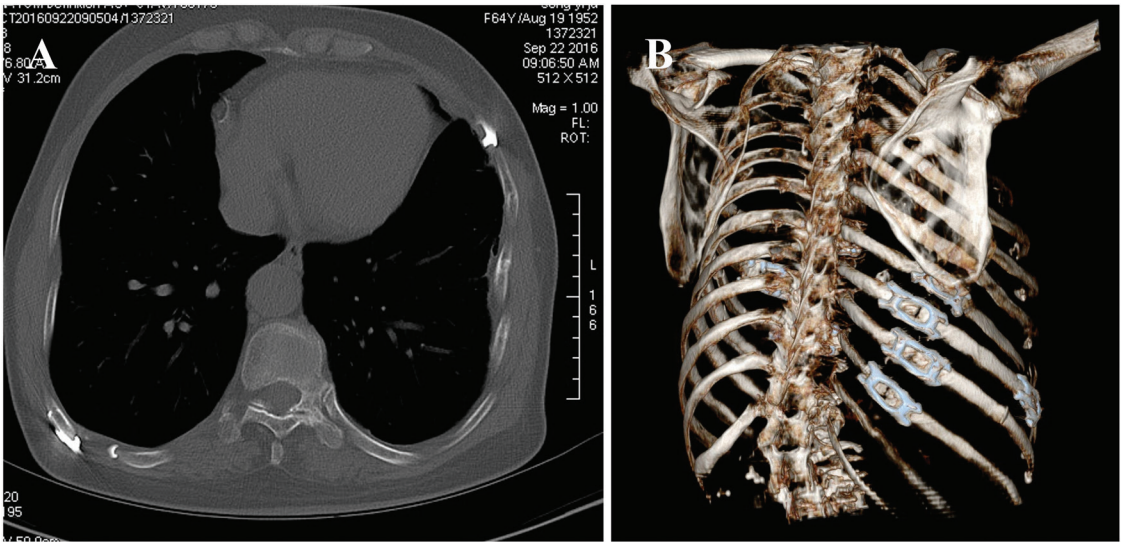

Fig. 2 The follow-up chest CT of a multiple rib fractures accompanied with pulmonary contusion patient who receive surgical treatment. (**A**) transverse plane, (**B**) three-dimensional reconstruction. CT: computed tomography

Table 1 The demographic characteristics and cause of injuries of two groups

Clinical data	Surgery group N = 75	Non-surgery group N = 92	p Value
Sex (male/female)	38/37	51/41	0.270
Age (years)[a]	52.6 ± 12.7 (24–77)	56.2 ± 13.3 (25–82)	0.079
Number of rib fractures	7 (4–9)	5 (3–6)	0.128
Lung disease history (%)	25 (33.3)	28 (30.4)	0.407
Previous chronic heart disease (%)	28 (37.3)	32 (34.8)	0.428
Cause of injuries			0.973
Car accidence (%)	36 (48.0)	43 (46.7)	
Fall from height (%)	24 (32.0)	31 (33.7)	
Other causes (%)	15 (20.0)	18 (19.6)	

[a]Mean ± SD.

75 patients in the surgery group, 51 underwent surgery for breathing difficulty and 24 for persistent pulmonary bleeding and pulmonary leakage. Patients in the surgery and non-surgery groups showed similar proportion of male, mean age, and mean number of rib fractures. The proportion of patients with lung disease history and chronic heart disease was also similar in the two groups (**Table 1**). The causes for injuries included car incidence, fall from height, physical fights, or accidents at work. The causes for injuries were similar in the surgery and non-surgery groups (**Table 1**).

Pain, length of hospital stay, and cost of hospitalization

During the hospitalization, the number of days of moderate pain and length of hospital stay were significantly lower in the surgery group than in the non-surgery group (p <0.01), whereas cost of hospitalization was significantly higher for the surgery group (**Table 2**). The incidences of pneumonia, atelectasis, and respiratory failure were significantly lower in the surgery group than in the non-surgery group (All p <0.01), whereas the incidence of heart failure was similar in the two groups (**Table 2**).

Follow-up results

Chest CT at 3-month follow-up showed that the proportions of patients with clear rib fracture line and pulmonary inflammation were significantly lower in the surgery group (All p <0.05, **Table 3**). Although fewer patients in the surgery group showed pleural effusion than in the non-surgery group, the difference was not statistically significantly. Significantly fewer patients

Table 2 Comparison of days of moderate pain, length of hospital stay, complications, and cost of hospitalization

Clinical data	Surgery group N = 75	Non-surgery group N = 92	p Value
Number of days of moderate pain	3.9 ± 1.1	4.4 ± 1.2	0.006
Length of stay	8.9 ± 2.2	9.9 ± 2.5	0.009
Ventilator support	23	12	0.005
Complications during hospitalization			
Pneumonia	11 (14.7)	35 (38.0)	0.001
Atelectasis	12 (16.0)	33 (35.9)	0.003
Respiratory failure	7 (9.3)	22 (23.9)	0.010
Heart failure	3 (4)	4 (4.3)	0.612
Cost of hospitalization	18586.9 ± 3008.4	10936.9 ± 412808	<0.01

Table 3 Comparisons of chest CT and physical fitness at follow-up

Clinical data	Surgery group N = 75	Non-surgery group N = 92	p Value
Chest CT at follow-up			
With clear rib fracture line (%)	7 (9.3)	20 (21.7)	0.024
With pleural effusion (%)	9 (12.0)	21 (22.8)	0.052
Pulmonary inflammation (%)	6 (8)	19 (20.7)	0.018
Physical fitness			
With pain at the fracture sit (%)	11 (14.7)	36 (39.1)	0.001
Post-physical activity chest tight (%)	11 (14.7)	34 (37.0)	0.001
Thoracic deformity (%)	8 (10.7)	38 (41.3)	<0.01

CT: computed tomography

in the surgery group had pain at rib fracture site, post-physical activity chest tight, and thoracic deformity than in the non-surgery group (All $p < 0.05$, **Table 3**), suggesting better physical fitness of the surgery group.

Discussion

The proportion of rib fractures accompanied with pulmonary contusion is very high in patients with trauma. Common therapies for this condition include oxygen inhalation, oral analgesics, antibiotics to prevent infection, chest fixation, and mechanical ventilation support if abnormal breathing occurs.[13,14] In the past decade, surgical treatment of traumatic rib fractures has been increasing practiced. This may be due to a better understanding of rib cage biomechanics and chest fracture patterns, improved internal fixation method, and advanced surgical techniques. As minimally invasive techniques advance, thoracic surgical incisions is becoming smaller. The emergence of new rib fixation materials reduces operative duration and improves surgical outcomes. Surgery-associated trauma to the patient is also milder. VATS can be used to remove hematomas, repair lung, and stop bleeding in the chest wall. VATS can shorten chest drainage duration. With thoracoscopy, we often use small incisions and cut the muscles along the direction of the chest wall muscles to reduce the trauma caused by the large incisions and transverse muscles. VATS is associated with reduced postoperative pain, faster patient recovery, and decreased incidence of postoperative complications.

The main causes for multiple rib fractures accompanied with lung contusion are car incidence, fall from height, and physical fight. Approximately 9% of the patients with high-energy trauma have multiple rib fractures and flail chest. The mortality rate due to simple rib fractures is very low, and as the number of rib fractures and the severity of pulmonary contusion increase, the mortality rate increases.[15] Of the 167 patients in the current study, only five had isolated chest injuries; others had multiple injuries. No mortality occurred during the hospitalization and in the 3 months after hospital discharge. We excluded patients with severe head trauma and unstable vital signs in the current study, who might have higher mortality.

For patients with multiple rib fractures accompanied with pulmonary contusion, surgery is often performed on patients with respiratory dysfunction. Pain and quality of life of patients are often ignored during the treatment. A previous study has shown that acute pain can lead to respiratory diseases and chronic pain reduces quality of life of patients.[4] In a prospective randomized controlled trial by Tanaka et al., chest tightness, chest pain, and dyspnea were more frequent in patients undergoing non-surgical treatment.[5] In the current study, the number of days of moderate pain, complications, and length of hospital stay were significantly reduced in the surgery group compared with those in the non-surgery group. Although we found that the cost of surgical treatment was relatively high, the clinical benefits from surgery may actually support the cost-effectiveness of surgery.

The quality of life of patients with rib fractures accompanied with pulmonary contusion is often reduced after treatment. Marasco et al. found that 71% of patients undergoing non-surgical treatments experienced pain, had poor quality of life, even became disable 3 months after the treatment,[16] whereas 48% of patients undergoing surgery showed such poor clinical characteristics. These results suggested that surgery might reduce the chance of disability. Granetzny et al. used Kirschner pins to fix the ribs and found that patients undergoing surgery had better lung function 2 months after the surgery than patients receiving conservative treatments.[7] In the current study, we found that physical fitness of the surgery group was significantly better than that of the non-surgery group at 3-month follow-up examination, suggesting that surgery may improve quality of life.

In patients with multiple rib fractures accompanied with pulmonary contusion, surgery can effectively stop bleeding in the chest cavity and reduce blood loss. Early removal of blood in the chest cavity reduces the incidence of lung disorders, such as infection and empyema. Prompt fixation after fracture repair and effective analgesia can relieve post-traumatic pain. The accurate resetting and fixation of the rib fractures can prevent thoracic deformity and improve the quality of life.[17]

Our study has some limitations. Multiple rib fractures with pulmonary contusion are not absolute surgical indications. In addition, the cost of surgery is much greater than conservative treatment. Prospective randomized controlled trials to compare surgery versus non-surgical treatment would be ideal to examine the safety and effectiveness of surgery for multiple rib fractures with pulmonary contusion.

Conclusions

Our study suggests that surgery to treat multiple rib fractures accompanied with pulmonary contusion appear to be safe and effective. Compared with the non-surgical therapies, surgery was associated with reduced pain, shorter hospital stay, and improved physical fitness.

Disclosure Statement

All authors declare that they have no conflict of interest.

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