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Application of Grooved Negative Pressure Drainage Tube in Surgical Stabilization of Rib Fractures

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Abstract: *Objective:* To explore the application value of disposable grooved negative pressure drainage tubes in rib fracture incision and internal fixation. *Methods:* Seventy-five patients admitted to our Department of Trauma Surgery from June 2022 to April 2024 who underwent rib fracture osteotomy and internal fixation were selected. According to the types of drainage tubes left in the patients after the operation, they were divided into the observation group (35 cases who were left with disposable grooved negative pressure drainage tubes) and the control group (40 cases who were left with closed silicone thoracic drainage tubes). Comparison of chest drainage, pain, postoperative complications, secondary chest penetration rate, drain placement time, hospitalization time, and treatment costs were compared between the two groups. *Results:* The total postoperative chest drainage volume of the observation group was less than that of the control group ($P < 0.05$); the degree of pain, the incidence of postoperative complications, and the rate of secondary chest puncture in the observation group were lower than that of the control group three days after the operation ($P < 0.05$); and the time of drain placement in the observation group was shorter than that of the control group ($P < 0.05$). *Conclusion:* The application of disposable grooved negative pressure drainage tubes in rib fracture incision and internal fixation can significantly improve patients' postoperative pain and discomfort, reduce complications, lower the rate of secondary chest penetration, promote patients' postoperative recovery, decrease the amount of postoperative chest drainage, and shorten the time of drain placement, which is worthy of clinical promotion and application.

Keywords: Grooved drainage tube; Postoperative drainage; Rib fracture; Internal fixation

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1. Introduction

Rib fractures are the most common type of chest injury [1]. Research indicates that each year, the number of patients suffering from rib fractures in China reaches 1.5 to 2 million, surpassing those afflicted with chest tumors [2,3]. The occurrence of rib fractures not only causes significant pain but can also lead to various complications, some of which may threaten the patient's life [4]. Currently, the clinical treatment for rib fractures primarily includes conservative management and surgical intervention. In recent years, with the advancement of microsurgical techniques, surgical stabilization of rib fractures (SSRF) has been widely adopted, benefiting a large number of patients. Postoperatively, thoracic drainage tubes are often required to remove air and fluid accumulations, thereby facilitating lung re-expansion [5]. Traditionally, our department has used closed silicone thoracic drainage tubes connected to a water-seal bottle for postoperative drainage. Due to their rigid material, these tubes frequently cause discomfort and pain, adversely affecting the patient's mobility and pulmonary function recovery. Over the past two years, our department has introduced disposable grooved negative pressure drainage tubes for postoperative drainage, which have shown improved efficacy. This study compares these two types of drainage tubes to explore the application value of disposable grooved negative pressure drainage tubes in post-SSRF drainage.

2. Subjects and methods

2.1. Inclusion and exclusion criteria

Inclusion criteria: (1) Patients diagnosed with rib fractures according to the criteria outlined in the 9th edition of *Surgery* [6]; (2) Patients indicated for and undergoing SSRF; (3) Patients aged 18 years or older.

Exclusion criteria: (1) Patients with pathological rib fractures; (2) Patients with malignant tumors; (3) Patients with multiple severe injuries throughout the body; (4) Patients with chronic pulmonary diseases or severe pulmonary infections; (5) Patients with psychiatric or cognitive disorders. This study adheres to the ethical standards of our hospital and has received approval (Approval number: YS2024-496).

2.2. Clinical data and grouping

From June 2022 to April 2024, 75 patients who underwent SSRF for rib fractures and had thoracic drainage tubes placed postoperatively were selected. Based on the type of drainage tube used postoperatively, patients were divided into two groups: the observation group, which was left with disposable grooved negative pressure drainage tubes, and the control group, which was left with closed silicone thoracic drainage tubes connected to water-seal bottles. There was no statistically significant difference in the general data between the two groups ($P > 0.05$), as shown in **Table 1**.

Table 1. Comparison of basic data between groups

Item	Observation group (n = 35)	Control group (n = 40)	t	χ^2	P
Gender [n (%)]				0.321	0.427
Male	28 (80)	28 (70)			
Female	7 (20)	12 (30)			
Age (years, mean ± SD)	59.94 ± 11.10	54.78 ± 10.95	-1.870		0.066
BMI (kg/m^2, mean ± SD)	22.55 ± 3.21	23.05 ± 3.10	0.687		0.494
Smoking history [n (%)]				0.249	0.618
Yes	16 (45.71)	16 (40)			
No	19 (54.29)	24 (60)			

Table 1 (Continued)

Item	Observation group (*n* = 35)	Control group (*n* = 40)	*t*	χ^2	*P*
Number of fractured ribs (mean ± SD)	7.43 ± 3.42	6.50 ± 2.64	-1.326		0.189
Type of fracture [*n* (%)]				0.064	0.800
Flail chest	13 (37.14)	16 (40)			
Non-flail chest	22 (62.86)	24 (60)			
Cause of injury [*n* (%)]				0.890	0.828
Traffic accident	13 (37.14)	16 (40)			
Fall from height	9 (25.71)	13 (32.5)			
Fall	12 (34.29)	10 (25)			
Other	1 (2.86)	1 (2.5)			

Abbreviations: BMI: Body mass index; SD: Standard deviation

2.3. Methods

Both groups of patients were administered general anesthesia with endotracheal intubation. After successful anesthesia, the patients were positioned in a healthy lateral decubitus position. The location and direction of the surgical incision were determined based on preoperative imaging and factors such as the location and number of rib fractures. Standard aseptic procedures were followed with draping, and the chest wall tissues were incised layer by layer. The muscle layers were bluntly separated, and chest wall hematomas were cleared. A thoracoscope was inserted to inspect and remove intrathoracic blood clots and hemothorax. Electrocautery was used for hemostasis at sites of pleural damage and intercostal vascular bleeding. The fractured rib ends were exposed, compressive intercostal blood vessels and nerves were released, and each fracture was anatomically realigned. Rib osteosynthesis plates were tailored according to the curvature of the ribs and used to secure the fracture ends. Circumferential osteosynthesis plates were applied to stabilize the fractured costal cartilage ends. The thoracic cavity was irrigated, and a repeat thoracoscopic examination confirmed the absence of active bleeding before removing the scope. Subcutaneous tissues were dissected bilaterally to identify the supplying arteries and create a pedicled composite fascial flap to cover the wound. Complete hemostasis was achieved in the surgical field before irrigating the wound again. In the observation group, a disposable grooved negative pressure drainage tube was placed, connected to a corresponding negative pressure drainage bulb and anti-reflux drainage bag. In the control group, a closed thoracic drainage tube was installed, connected to a water-seal bottle for drainage. After ensuring all gauzes and instruments were accounted for, the incision was closed. Cosmetic suturing was used on the skin, and a skin tension reducer was employed to approximate the skin edges. Sutures were used to secure the drainage tube to the chest wall skin, and the area was dressed and bandaged. All surgeries in this study were performed by the same lead surgeon.

2.4. Observation indicators

2.4.1. Thoracic drainage volume

The postoperative 24-hour thoracic drainage volume and total thoracic drainage volume during the tube placement period were recorded for both groups.

2.4.2. Pain level

The Numeric Rating Scale (NRS) was used to evaluate pain levels over the first three days postoperatively. Patients rated their pain on a scale from 0 to 10, where 0 indicated no pain; 1–3 mild pain; 4–6 moderate pain; and 7–10 severe pain. Higher scores represent more severe pain.

2.4.3. Postoperative complications and secondary thoracentesis rate

The incidence of complications such as atelectasis, pulmonary infection, pneumothorax, and pleural effusion, as well as the occurrence of secondary thoracentesis, were documented for both groups.

2.4.4. Duration of drainage

The timing for tube removal in both groups was determined by similar criteria: radiological evidence of good lung re-expansion, good auscultatory breath sounds on the operated side, absence of air leaks, and a thoracic drainage volume of less than 100 mL in 24 hours, with the drainage fluid being serosanguinous.

2.4.5. Hospitalization duration and treatment costs

The duration of hospital stays and associated costs incurred during the hospitalization were compared between the two groups.

2.5. Statistical analysis

Data were analyzed using SPSS27.0 software. Quantitative data were presented as mean ± standard deviation (SD) and analyzed with the *t*-test. Categorical data were expressed in percentages and analyzed using the chi-square test. Ordinal data were analyzed using the Mann–Whitney U test. $P < 0.05$ was considered statistically significant.

3. Results

3.1. Thoracic drainage volume

There was no statistically significant difference in the postoperative 24-hour thoracic drainage volume between the two groups ($P > 0.05$). However, the total postoperative thoracic drainage volume was significantly lower in the observation group compared to the control group ($P < 0.05$). **Table 2** shows the comparison of thoracic drainage volumes between the groups.

Table 2. Comparison of thoracic drainage volumes between groups (mean ± SD, mL)

Item	Observation group (*n* = 35)	Control group (*n* = 40)	*t*	*P*
24-hour thoracic drainage volume	260.14 ± 149.53	254.95 ± 178.80	-0.135	0.893
Total thoracic drainage volume	815.09 ± 477.04	1170.28 ± 952.02	2.080	0.042

3.2. Postoperative pain scores

Pain levels within the first three days post-surgery were significantly lower in the observation group compared to the control group ($P < 0.05$). **Table 3** presents the comparison of pain levels between the groups.

Table 3. Comparison of pain levels between groups [*n* (%)]

Item	Observation group (*n* = 35)	Control group (*n* = 40)	Z	*P*
1st day post-surgery			-2.305	0.021
No pain	14 (40)	7 (17.5)		
Mild pain	19 (54.29)	27 (7.5)		
Moderate pain	2 (5.71)	6 (15)		
Severe pain	0 (0)	0 (0)		
2nd day post-surgery			-2.369	0.018
No pain	16 (5.71)	7 (17.5)		
Mild pain	16 (45.71)	28 (70)		
Moderate pain	3 (8.58)	5 (12.5)		
Severe pain	0 (0)	0 (0)		
3rd day post-surgery				
No pain	13 (37.14)	10 (25)	-1.981	0.048
Mild pain	22 (62.86)	23 (57.5)		
Moderate pain	0 (0)	7 (17.5)		
Severe pain	0 (0)	0 (0)		

3.3. Postoperative complications and secondary thoracentesis rate

There was no significant difference between the two groups in the rates of postoperative atelectasis and pulmonary infections ($P > 0.05$). However, the rates of pneumothorax, pleural effusion, overall complications, and secondary thoracentesis were significantly lower in the observation group compared to the control group ($P < 0.05$), as shown in **Table 4**.

Table 4. Comparison of postoperative complications and secondary thoracentesis between groups [*n* (%)]

Item	Observation group (*n* = 35)	Control group (*n* = 40)	χ^2	*P*
Total complications	5 (14.3)	16 (40)	6.122	0.013
Atelectasis	1 (2.9)	4 (10.0)	1.531	0.216
Pulmonary infection	2 (5.7)	2 (5.0)	0.019	0.891
Pneumothorax/pleural effusion	2 (5.7)	10 (25.0)	5.166	0.023
Secondary thoracentesis	2 (5.7)	9 (22.5)	4.202	0.040

3.4. Duration of drain placement

Based on **Table 5**, the duration of drain placement was significantly shorter in the observation group than in the control group ($P < 0.05$).

3.5. Hospitalization duration and treatment costs

According to **Table 5**, there was no significant difference in the duration of hospital stay or the costs incurred during hospitalization between the two groups ($P > 0.05$).

Table 5. Comparison of drain placement duration, hospitalization time, and treatment costs between groups

Item	Observation group (n = 35)	Control group (n = 40)	t	P
Drain placement duration	5.83 ± 1.77	7.25 ± 3.82	2.110	0.039
Hospitalization time (days)	16.26 ± 5.47	17.77 ± 5.72	1.170	0.246
Hospitalization costs (ten thousand RMB)	8.72 ± 3.05	7.40 ± 3.45	-1.749	0.085

4. Discussion

4.1. Reduction of postoperative drainage volume with grooved drainage tubes after SSRF

The pleural cavity in humans is a closed potential space formed by the visceral and parietal pleurae transitioning at their reflections. Normally, it contains a small amount of serous fluid to reduce friction during respiration and is under negative pressure. When rib fractures are compounded by hemopneumothorax or severe damage to the chest wall soft tissues disrupting the blood circulation at the incision, or during invasive procedures like thoracic exploration or pleural damage during SSRF, air and fluid often accumulate. This accumulation disrupts the negative pressure within the thoracic cavity. Postoperative reductions in patient activity and weakened coughing further hinder the body's ability to absorb these accumulations [7,8]. Therefore, thoracic drainage tubes are commonly placed post-SSRF to facilitate adequate drainage. Our study findings indicate no significant difference in the 24-hour postoperative thoracic drainage volumes between the grooved and traditional drainage tubes ($P > 0.05$), suggesting that the type of drainage tube does not markedly affect the immediate postoperative drainage volume. However, the total postoperative thoracic drainage volume was significantly lower in the observation group ($P < 0.05$), demonstrating that disposable grooved negative pressure drainage tubes can reduce the overall postoperative thoracic drainage volume, aiding in the prompt removal of air and fluid from the pleural cavity after surgery. The likely explanation for this is that the disposable grooved negative pressure drainage tubes are smoother, more flexible, and elastic, thereby causing less irritation to surrounding tissues during drainage. This reduced local inflammatory response subsequently decreases the drainage volume.

4.2. Reduction of postoperative pain with grooved drainage tubes after SSRF

Due to advancements in surgical materials and equipment, rib fracture osteosynthesis under thoracoscopic assistance has become the most commonly used surgical method for treating rib fractures clinically. This approach offers clear visualization, precise localization, minimal trauma, and effective prevention of iatrogenic secondary injuries [9]. It facilitates the realignment and healing of fractured rib ends, improves patients' pain symptoms [10], enhances the quality of life, and enables patients to resume their daily activities sooner [7,11,12]. However, various factors can still contribute to postoperative pain, with the placement of thoracic drainage tubes being a notable one [13]. The pain can induce a stress response in patients, potentially prolonging their recovery time [14]. Our results show that the pain levels during the first three days post-surgery were significantly lower in the observation group than in the control group ($P < 0.05$), indicating that disposable grooved negative pressure drainage tubes can effectively reduce postoperative pain after SSRF. This reduction in pain is primarily because traditional closed thoracic drainage tubes are typically rigid, with a larger diameter, and are inserted to a shorter length with their end connected to a bulky water-seal bottle. These factors can cause irritation or pull on the intercostal nerves and diaphragm during patient movements, deep breathing, or coughing, resulting in severe pain [15,16]. In contrast, disposable grooved drainage tubes are softer and thinner than traditional tubes, are inserted to a longer length, and are connected to a lightweight negative pressure drainage bulb and anti-reflux drainage bag. This setup not only makes them more portable but also addresses some of the disadvantages associated with traditional closed thoracic drainage tubes, thereby improving patient comfort and reducing pain.

4.3. Reduction of postoperative complications with grooved drainage tubes after SSRF

Despite the clear benefits of using thoracoscopic assistance for SSRF in treating rib fractures, postoperative complications remain unavoidable and their prevention and management continue to be a clinical priority. Research indicates that pulmonary complications are the most common postoperative issues following rib fractures, including pulmonary infections, pneumothorax, pleural effusion, and atelectasis [17]. Pain severity post-SSRF can limit patients' daily activities and respiratory movements, leading to ineffective coughing and reduced ventilatory function, which in turn may cause pulmonary infections and atelectasis [18]. Furthermore, if the postoperative drainage tubes do not maintain effective drainage, the risk of complications can increase. The results of this study show no significant difference in the incidence rates of atelectasis and pulmonary infections between the observation and control groups ($P > 0.05$), suggesting that further research with a larger sample size is needed for verification. However, the rates of pneumothorax, pleural effusion, overall complications, and secondary thoracentesis were significantly lower in the observation group ($P < 0.05$). It has been noted that the volume of pneumothorax and pleural effusion is a primary clinical indicator for deciding whether thoracentesis is necessary [19], and in this study, the rates of these complications and secondary thoracentesis were positively correlated. This supports the conclusion that using disposable grooved negative pressure drainage tubes post-SSRF can reduce the incidence of postoperative complications, particularly pneumothorax and pleural effusion, and decrease the rate of secondary thoracentesis, thereby offering higher safety and effectiveness. Firstly, disposable grooved negative pressure drainage tubes represent a new type of active drainage device that alters the traditional side-hole structure. The design featuring four longitudinal grooves elevates drainage from a point-and-plane method to a three-dimensional one [20], effectively preventing issues such as drainage impairment due to tube twisting or folding. Secondly, the continuous negative pressure created between the drainage tube's end and the drainage bag helps balance the intrapleural pressure, maintaining a negative pressure state in the thoracic cavity, thereby avoiding pulmonary compression and mediastinal shift and promoting lung re-expansion [21]. Additionally, the active valve design at the connection between the drainage tube and the drainage bulb prevents backflow of drainage fluid, reducing the risk of retrograde infection [22], and prevents sudden increases in intrathoracic pressure caused by compressing the drainage tube, which could lead to lung tissue pain or even bleeding [23].

4.4. Impact of grooved drainage tubes on drain placement duration, hospitalization time, and costs after SSRF

With the increasing adoption of enhanced recovery after surgery (ERAS) principles in surgery, clinical staff are focusing more on improving postoperative comfort, reducing complications, shortening hospital stays, and alleviating patients' medical financial burdens. A key aspect of this is the timely removal of thoracic drainage tubes after SSRF, ensuring patient safety while accelerating recovery. Our study found that the duration of drain placement was significantly shorter in the observation group compared to the control group ($P < 0.05$), indicating that disposable grooved negative pressure drainage tubes can reduce the time drains need to be in place after SSRF. This may be due to the enhanced drainage efficiency of these tubes, which reduces the volume of drainage and complications, promotes lung re-expansion, and thus meets the criteria for earlier removal of the drain. Furthermore, the study showed no significant differences in hospitalization duration and costs between the two groups ($P > 0.05$). This outcome may be limited by the sample size or influenced by the fact that the costs incurred during hospital stays were predominantly related to surgical expenses, leading to no substantial differences in overall costs between the groups.

5. Conclusion

The application of disposable grooved negative pressure drainage tubes in SSRF has shown considerable value. These tubes can reduce total postoperative thoracic drainage volume, decrease the incidence of postoperative complications and secondary thoracentesis rates, alleviate patient discomfort and pain, and shorten the duration of postoperative drain placement, thus facilitating faster patient recovery. Their use is highly recommended for clinical adoption. However, this study has its limitations. It is retrospective in nature, lacking the robustness of a prospective randomized controlled trial. The patient sample was drawn from a single hospital, which may introduce bias due to the small sample size. Further research with a larger, more diverse cohort across multiple centers is necessary to validate and generalize these findings.

Disclosure statement

The authors declare no conflict of interest.

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