Application of fracture body surface localization film combined with CT volume rendering in the minimally invasive rib fractures internal fixation

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Abstract. – OBJECTIVE: To investigate the application value of the technique of fracture body surface localization film combined with CT volume rendering in the selection of minimally invasive incision for internal fixation of rib fractures.

PATIENTS AND METHODS: Clinical data of 55 cases of patients who underwent internal fixation for rib fracture in our hospital from June 2019 to April 2020 were selected. The differences in the accuracy of preset incision, incision length, operation time, intraoperative blood loss, postoperative wound drainage, and postoperative pain score between the group with fracture body surface localization film combined with CT volume rendering (n=32) and the group with traditional localization method (n=23).

RESULTS: Compared with traditional localization method, fracture body surface localization film combined with CT volume rendering could improve the accuracy of surgical incision, reduce the operation time, incision length, intraoperative blood loss, postoperative wound drainage, and postoperative pain score ($p<0.05$).

CONCLUSIONS: The application of fracture body surface localization film combined with CT volume rendering has obvious effects on the accurate selection of incision of rib fracture internal fixation, and it is an effective method that is worthy of promotion.

Key Words:

Minimally invasive internal fixation of the thoracic wall, Body surface localization film, CT volume rendering, Accurate localization.

Introduction

Death from chest trauma accounts for 20-25% of all trauma deaths and is the second leading cause of trauma death[1]. Patients with multiple fractured ribs, especially flail chest, often have severe pain, thoracic wall softening, paradoxical breathing and severe pulmonary contusion, which can easily lead to respiratory failure, requiring thoracic surgery. At the same time, some surgical indications have reached consensus in the industry[2-5]. Since the flat bone and long arc of ribs, large body surface area of the thoracic wall, and multiple ribs involved in the operation, a large incision is usually required to obtain satisfactory exposure of the surgical field of view. During the operation, some muscles, blood vessels and nerves of the thoracic wall are often damaged, which gives rise to increased postoperative incision infection rate, dysfunction and skin numbness of the affected side of the thoracic wall. The improvement of surgical incision accuracy can reduce the injury to thoracic wall thoracic wall muscles, peripheral blood vessels and nerves, save the operation time, reduce postoperative pain and accelerate the recovery of patients. Hence, preoperative determination of incision is of great importance. In this study, a total of 55 cases of patients undergoing internal fixation for rib fractures in our hospital from June 2019 to April 2020 were enrolled in this study and divided into two groups. Patients in the two groups received different methods of rib localization. The clinical value of application of fracture body surface localization film combined with CT volume rendering to determine the incision was discussed in this paper.

Patients and Methods

Clinical Data

A total of 55 patients who underwent internal fixation for rib fractures in our hospital from June

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Table I. Comparison of general data of patients in the two groups.

Groups	Male/Female	Number of localization for fracture	Number of blade plate used
Observation group (n = 32)	19/13	4.96 ± 1.18	5.02 ± 1.02
Control group (n = 23)	14/9	4.76 ± 1.04	5.08 ± 1.16
t-value/χ^2	0.042	0.568	0.412
p-value	0.812	0.572	0.658

2019 to April 2020 were selected as subjects of this study, including 30 males and 25 females, aged 25-73 years, with an average age of 46.5 years. As for cause of injury, there were 18 cases of traffic accident injury, 15 cases of high fall injury, 14 cases of fall injury, and 8 cases of severe crush injury. All of the patients had multiple fractured ribs (4 or more, with dislocation at the broken ends), and were complicated with pulmonary contusion after injury, including 40 cases with multiple fractured ribs. They were divided into an observation group and a control group. A total of 32 cases of patients were included in the observation group, receiving treatment of fracture body surface localization film combined with CT volume rendering technology. A total of 23 cases of patients were included in the control group, receiving treatment of traditional localization method. There was no significant difference in the clinical data between the two groups, as shown in Table I. This study was approved by the Ethics Committee of Tianjin Hospital affiliated to Tianjin University. Signed written informed consents were obtained from the patients.

Surgical Indications and Timing

Multiple fractured ribs with 4 or more dislocated broken ends should be operated on 2-5 days after the injury. Patients with multiple injuries should be treated after the general condition was stable, but the latest time should not exceed 7 days. Patients with severe paradoxical breathing and flail chest should be timely operated on.

Introduction of Localization Film

The localization film is our patented product, which has been filed as National Class I Medical Device (Figure 1). The film consists of protective film, release film and base film. The protective film is adsorbed on one side of the base film by electrostatic adsorption. Easy-to-tear strips are bonded to one end of the protective film, and adhesive is bonded to the other side of the base film. Marking points are set on the base film, and a release film is attached to the adhesive. There are two release films, and the contact ends of the two release films are folded. The contact ends of the two release films are fixed with a fixed strip. The base film is provided with localization mark holes, and the base film is a 3 M film material. The base film consists of a film and an image-forming layer. The image-forming layer is fixed on the film by adhesive glue. The image-forming layer is composed of localization line and marking points. The localization line is a grid structure. Marking points are installed on the localization lines and are represented by letters. A groove is provided on the adhesive, and an image-forming layer is provided in the groove. The image-forming layer is in the same plane as the adhesive. The base film is the image-forming layer, it is the grid formed by stickers. There are letter markers between the grids. The horizontal and vertical directions on the left side of the base film are provided with scaleplate, separately. The localization line and marking point are composed of metal wire, which is stuck in the groove, and the outside of the wire is covered with a protective layer, which is the protein fiber layer. The lo-

Figure 1. Medical device filing and localization film samples.

calization line and marking point are metal powder, which sticks to the groove. The localization line and marking point are bonded by pigments with metal powder.

Surgical Incision Localization

The surgical incision should first meet the needs of surgery, and then be minimally invasive to minimize the length of the incision and shorten the operation time. In order to achieve this goal, we explored the fracture body surface localization film combined with CT volume rendering technology on the basis of traditional localization to determine the surgical incision. Traditional positioning group: after the spiral CT scanning of the ribs, the approximate injury site could be generally determined based on the three-dimensional volume reconstruction images and the chest wall contusion marks. With this site as the center, transverse or longitudinal surgical incisions along the ribs were positioned. Fracture body surface localization film combined with CT volume reconstruction: (1) localization film: based on plain film and preliminary results of emergency chest CT examination, the general site of the fracture was basically determined. Then the body surface localization film was flat and firmly attached to the fracture area. (2) Preparation before scanning: the patient stayed in the supine position. Metals around the body within the scanning range were removed. The patients were trained to hold the breath as much as possible during the scanning process. If the breath cannot be held, the patients were instructed to avoid deep breathing in case of serious respiratory movement artifacts. Adjust the position of both upper limbs depending on the patient's condition. If possible, lift the limbs over the head or put the limbs wherever suitable to fit the surgical position and reduce or avoid intraoperative differences. (3) Scanning technology: GE64 layer OptimaCT scanner was used for spiral CT scanning (other types of spiral CT models with 16 rows of detectors and above could also be used). (1) Scanning range: the scanning range can be adjusted according to the CT scan positioning image. In principle, the scanning range must include the complete bony rib cage, generally from the upper edge of the rib cage entrance to waist 3 level. (2) Scanning layer thickness and mode: the parameter setting varies slightly with the scanning machine model. No matter what kind of scanning machine, the scanning method must be Helical scanning. The scanning layer thickness and mode selection can be slightly different; but the basic principle should be followed: the scanning should be as fast as possible to acquire sufficient information, to reduce or avoid breathing artifacts caused by poor breath holding. Because of the large thoracic scanning range and poor breath holding of the patient, it is critical to reduce or avoid breathing movement artifacts as much as possible for accurate positioning. Therefore, large number of detectors, large scanning field of view (SFOV), and a moderate pitch (generally 1.575:1) should be used when considering the layer thickness and selecting the modes. For the purpose of general positioning rather than understanding the shape of fine fractures, the demand on scanning layer thickness could be compromised. If the machine's performance was not good, layer thickness could be set as 5 mm. If the machine had good performance with fast scanning speed, the layer thickness can be set as 1.25 mm or 0.625 mm. (3) Scanning conditions: generally, the tube voltage was 120 kV and the tube current was 200-250 mA, which can be increased or decreased according to the patient's body shape. (4) The scan matrix was generally 512×512. (4) Reconstruction technology: after the scanning, the original data bone algorithm and standard algorithm were immediately used for reconstruction. After reconstruction by different algorithms, the image displayed different effects, mainly represented by the sharpness of the image edge. Bone algorithm reconstruction was generally used for multi-level reconstruction to show fine fractures, while the volume reconstruction image under the standard algorithm was more three-dimensional, authentic, and the image signal-to-noise ratio was better. Reconstruction minimum layer thickness also depends on the model of scanners. Generally, for high-performance scanners, the minimum reconstruction layer thickness should be 0.625 mm. For lower performance models such as GE 16 row Bright Speed SysCT16, 1.25 mm was also acceptable. (5) Reconstruction and positioning method of rib fracture and filming: the CT scanner host workstation automatically reconstructed the original data and transmitted the data to the ADW4.6 post-processing workstation. The physician can perform image post-processing at the workstation immediately. For pre-operative positioning, the thin-layer image under the standard algorithm could be directly used. By the rib volume reconstruction (VR) technology, the interference from bones and surrounding structures around the upper limbs and rib cage can be excluded. Then, the three-dimensional simulation image of the posi-

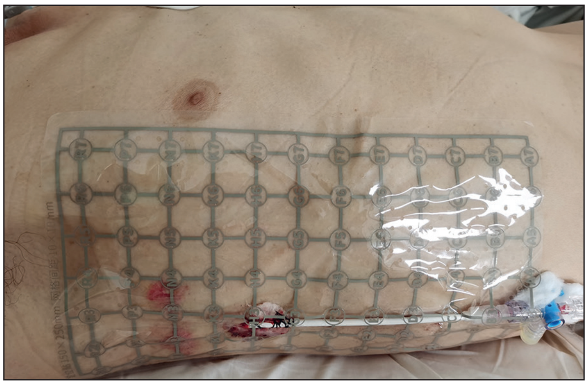

Figure 2. Filming before CT scan.

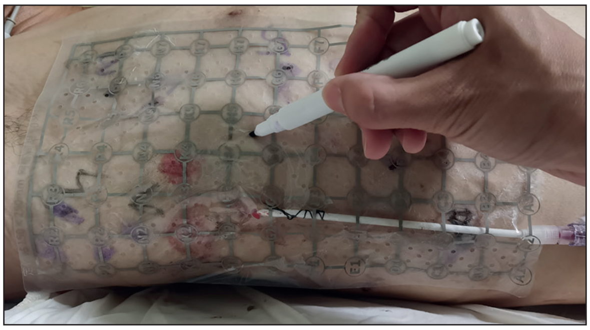

Figure 4. Fracture body surface location mark.

tioning membrane and bony rib cage were shown. Observe the rib fracture site and the inner pane of the localization membrane, clarify the position of the fracture in the pane, then measure and record the values at the corresponding horizontal and vertical coordinates of the basic pane division point of the localization film. Immediately mark the corresponding measurement position of the localization film on the patient's thoracic frame to obtain the accurate fracture body surface location. On this basis, the preoperative planning can be made, and minimally invasive surgical incision could be designed. The specific operation diagram is shown in Figures 2-5.

Surgical Methods

All the surgeries were performed by transosseous thorax tunnel endoscopic rib fixation[6], the type of rib plate was determined by the specific fracture morphology. The details of surgical methods were as follows: Paravertebral nerve block anesthesia or general anesthesia single cavity intubation was adopted in the operation, patient's surgical position (supine position, prone position, left and right lateral position, etc.) was determined according to the location and number of fractures of the ribs, and the intraoperative position might be changed when necessary. Fracture body surface localization film combined with CT volume rendering was applied to mark the fracture end of the body surface localization. The incision was located by the anatomical distribution of the muscle in the thoracic wall at the fracture site, generally, the central location of multiple fractured ribs and the muscular space of the thoracic wall were considered (common approaches included pectoralis major adjacency approach, mammary gland lower margin approach, triangle of auscultation approach, erector spinae adjacency approach, oxter approach, etc.). Transverse, longitudinal or oblique incisions could be made, with a length of about 3-5 cm. It was freed subcutaneous and muscular layers, dissected along the intermuscular space and muscle texture to the

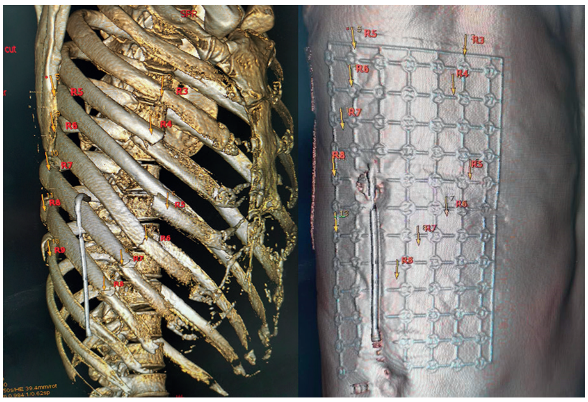

Figure 3. CT scan of fractures corresponds to mesh markers.

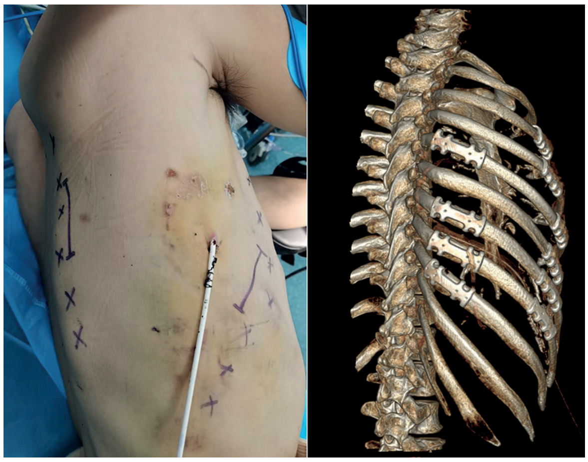

Figure 5. Preoperative surgical incision plan and postoperative internal fixation.

Table II. Accuracy of the preset incision of the two groups (n).

Groups	Number of cases	Accurate prediction	Inaccurate prediction
Observation group	32	32	0
Control group	23	18	5
χ^2 =4.820, p = 0.027			

surface of the bony thorax to avoid breaking muscle. Part of the muscle attachment points were cut along the surface of the skeletal thorax, and the special surgical instrument was used to prop up the muscular thorax in the direction perpendicular to the osseous keletal thorax (this thoracic wall expanders of our hospital has been granted the national utility model patent, with an application number of 201721524911.X) to separate skeletal thorax and muscular thorax, so as to leave a room for thoracoscope place. Under the guidance of the endoscope, the necessary muscular thorax was freed to form a temporary tunnel inside the thoracic wall to provide operating space for the surgery (as shown in the operation figure). This operation avoided overstretching in all directions along the incision and maximized muscle integrity. The rib fractures under direct vision were fixed routinely. Distal rib fractures were operated under the guidance of an endoscope. If the fracture dislocation was obvious, the periosteum should be opened along the fracture line to expose the broken end of the fracture, without too much free.

Compared with conventional surgery, video-assisted thoracic surgery could provide good lighting, make the exploration of tissue structure around the broken end of the fracture more visually, clearly and comprehensively, determine the specific location, number and severity of the rib fracture, effectively avoid the damage of intercostal vessels and nerves, and reduce postoperative intrathoracic hemorrhage and effusion. At the same time, the operation did not cut the muscles and nerves of the thoracic wall, which could significantly reduce postoperative complications. Internal fixation for multiple fractured ribs would be another important area for thoracoscopic surgery, which is worthy of clinical application.

Outcome Measures

The differences in the accuracy of the preset incision, incision length, operation time, intraoperative blood loss, postoperative wound drainage and postoperative pain score between the two groups were evaluated.

Statistical Analysis

SPSS 19.0 (IBM, Armonk, NY, USA) statistical software was used for analysis. Results were expressed as $\bar{x} \pm s$. The *t*-test was used for counting data such as VAS score, operation time and incision length. Chi-square test was used for the accuracy of preset incision. $p<0.05$ was considered statistically significant.

Results

The patients (observation group) who underwent minimally invasive internal fixation of ribs under endoscopic surgery by using the technique of fracture body surface localization film combined with CT volume rendering were compared with those who underwent minimally invasive ribs internal fixation under endoscopic surgery with traditional localization method (control group). In the former case, the accuracy of the preset incision was significantly increased, which notably reduced the operation time, incision length, intraoperative blood loss, postoperative wound drainage and postoperative pain score. The difference was statistically significant (Tables II-V).

Table III. Comparison of operation time and incision length between the two groups.

Groups	Operation time (min)	Incision length (cm)
Observation group	53.26 ± 9.32	6.25 ± 1.02
Control group	70.50 ± 11.01	10.23 ± 1.35
p-value	0.003	0.017

Table IV. Comparison of intraoperative blood loss and postoperative wound drainage between the two groups.

Groups	Blood loss (ml)	Wound drainage (ml)
Observation group	20.17 ± 10.43	45.72 ± 7.21
Control group	40.58 ± 12.15	65.35 ± 14.13
p-value	0.001	0.002

Table V. Comparison of VAS score before and after operation.

Groups	Observation group	Control group	*t*-value	*p*-value
Before operation	7.32 ± 1.05	7.35 ± 1.04	-0.020	0.984
1 day after operation	3.75 ± 1.12	4.75 ± 1.05	-4.172	0.000
3 day after operation	3.53 ± 1.07	3.97 ± 1.13	-2.692	0.009

Discussion

Chest injuries often result in multiple fractured ribs, with local pain and limited breathing. When flail chest is present, the patient will experience abnormal respiratory movements, which in turn will cause circulatory disturbances and induce acute respiratory distress syndrome (ARDS) or multiple organ failure. Therefore, it is necessary to fix the rib fracture in the chest injury[7-11]. In the past, pectoral girdle compression external fixation and ventilator-assisted breathing were usually used for multiple fractured ribs, which can improve the thoracic wall collapse and paradoxical breathing to a certain extent. Nowadays, with the development of medical technology and internal fixation materials[12,13], the use of internal fixation of ribs for multiple fractured ribs has become an industry consensus. This surgery can alleviate the pain of patients, reduce the occurrence of related complications, accelerate the recovery of patients, and improve the prognosis of patients. With the progress of surgical technology, the clinical application of 3D printing technology, and the update of surgical materials, especially the research and development of absorbable fracture fixation materials, the surgery tends to be minimally invasive, thus reducing surgical complications[14-16], and increasing requirements for accurate localization of surgical incision.

At present, patients with rib fractures usually receive three-dimensional CT scan of the ribs to make a clear diagnosis and understand the alignment of fracture ends. The traditional method of rib localization refers to that the surgeon can determine the surgical incision of the patient by three-dimensional CT imaging of the rib before operation, usually with certain errors. Because of the anatomical characteristics of the ribs and the large surface area of the thoracic wall, it is very important to determine the incision of internal fixation for rib fractures. If the incision is selected accurately, the surgical incision can be made minimally invasive, which can reduce the injury to the thoracic wall muscles, reduce the damage to the peripheral blood vessels and nerves, significantly shorten the operation time, reduce the postoperative pain of patients, and accelerate the recovery of patients. The error value of the fracture body surface localization can be limited within 1 cm. With simple operation and strong feasibility of clinical promotion, the technique of fracture body surface localization film combined with CT volume rendering can more accurately determine the location of the rib fracture body surface and determine the location of the surgical incision. Although the change of body position may bring about a small error, compared with the traditional rib localization method, however, there are still obvious advantages, which can make the operation smoother and cause fewer postoperative complications.

Conclusions

To sum up, in the minimally invasive surgical treatment of multiple fractured ribs, the preoperative application of fracture body surface localization film combined with CT volume rendering technique to predetermine the surgical incision can reduce the length of the surgical incision, shorten the operation time, reduce the postoperative pain of patients, and reduce the occurrence of related complications, which is worthy of widespread promotion in clinical practice.

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Conflict of Interest

The Authors declare that they have no conflict of interests.

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