

Non-intubated Minimally Invasive Chest Wall Stabilization for Multiple Rib Fractures: a Prospective, Single-arm Study

Weigang Zhao

Shanghai Jiao Tong University

Yonglin Chen

Shanghai Jiao Tong University

Weiwei He

Shanghai Jiao Tong University

Yonghong Zhao

Shanghai Jiao Tong University

Yi Yang (✉ dryangyi12312@163.com)

Shanghai Jiao Tong University Affiliated Sixth People's Hospital <https://orcid.org/0000-0003-4561-2513>

Research article

Keywords: non-intubated, minimally invasive, chest wall stabilization, rib fracture

Posted Date: August 3rd, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-49542/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published on September 23rd, 2020. See the published version at <https://doi.org/10.1186/s13017-020-00335-y>.

Abstract

Background

Non-intubated video-assisted thoracoscopic surgery has been widely reported in the past decade while non-intubated chest wall stabilization has not been reported previously. The aim of this study was to evaluate the safety and feasibility of non-intubated minimally invasive chest wall stabilization in patients with multiple rib fractures.

Methods

We conducted a prospective, single-arm, observational study. In this prospective study, 20 consecutive patients with multiple rib fractures were treated using non-intubated minimally invasive chest wall stabilization.

Results

Minimally invasive chest wall stabilization were mostly performed for lateral rib fractures in this study (n = 8). The mean operation time was 92.5 minutes and mean blood loss was 49 ml. No patient required conversion to tracheal intubation. The mean extubation of laryngeal mask time was 8.9 minutes, mean postoperative fasting time was 6.1 hours, mean postoperative hospital stay was 6.2 days, mean postoperative drainage was 97.5 ml, mean postoperative pain score was 2.9 points at 6 hours, 2.8 points at 12 hours, and 3.0 points at 24 hours, mean postoperative nausea and vomiting score was 1.9 points at 6 hours, 1.8 points at 12 hours, and 1.7 points at 24 hours.

Conclusions

Non-intubated minimally invasive chest wall stabilization is safe and feasible in carefully selected patients. Further study with large sample size is warranted.

Introduction

Chest wall stabilization (CWS) has been widely performed in patients with multiple rib fractures all over the world in the past two decades with satisfactory outcomes [1]. It is generally accepted that patients with three or more acutely displaced rib fractures or flail chest should be considered for CWS [2]. However, there are still many patients with multiple rib fractures refuse to accept CWS. One major concern for above situation is that the trauma caused by surgery is too great. Under this circumstance, developing some new methods to reduce surgical trauma in CWS is really important.

Double-lumen endotracheal tube and one-lung ventilation has been considered a safe and conventional routine methodology for thoracic surgery. However, adverse effects such as sore throat, pain, hoarseness, and respiratory complications are not uncommon after conversional intubation and general anesthesia [3–4]. Compared with general anesthesia with intubation, non-intubated anesthesia can obviously reduce above adverse events, which has aroused great interest in thoracic surgery in the past decade [5–9]. Previous study has confirmed that non-intubated video-assisted thoracoscopic surgery (VATS) is safe and feasible for multiple thoracic conditions, without risk of complications caused by conversional intubation and general anesthesia [10].

To further reduce surgical trauma of CWS, some experienced thoracic surgeons adopted muscle sparing incisions in CWS to minimize the soft tissue injury. Since the major morbidity of CWS is the size of the incisions required to perform an open procedure, some surgeons tried to perform minimally invasive video-assisted rib plating (VARP) in CWS [11]. Compared with traditional CWS, minimally invasive CWS using above techniques can obviously minimize the soft tissue injury and reduce the size of incisions.

Basing on results of above studies, we believe that non-intubated minimally invasive CWS are esthetically appealing and can obviously reduce surgical trauma. However, no study about non-intubated minimally invasive CWS has been reported till now. So it remains uncertain whether non-intubated minimally invasive CWS is safe and feasible. In this study, we firstly report our experience of using non-intubated minimally invasive CWS in patients with multiple rib fractures.

Patients And Methods

Study Design and Patients

This study was a prospective, single arm, observational study approved by the Ethics Committee of Shanghai Sixth People's Hospital (approval No: 2019-53). All subjects and/or legal have signed informed consent in this trial. The study is registered at www.chictr.org.cn (ChiCTR1900025698).

Twenty patients who underwent non-intubated CWS for multiple rib fractures in Shanghai Sixth people's Hospital between June 2019 and September 2019 were included in this study. The inclusion criteria were: 1) American Society of Anesthesiologists (ASA) grade I–II; 2) 18–70 years old; 3) body mass index (BMI) < 28 kg/m²; 4) multiple rib fractures patients scheduled for CWS; 5) preoperative arterial oxygen partial pressure > 60mmhg and carbon dioxide partial pressure < 50mmhg. The exclusion criteria were: 1) difficult airway; 2) history of esophageal reflux; 3) myasthenia gravis; 4) coagulation disorders; 5) gastrointestinal ulcer or bleeding; 6) anesthetic drugs allergy history; 7) asthma, or chronic obstructive pulmonary disease; 8) pregnant women. The algorithm for patient selection is shown in Fig. 1.

Anesthetic Procedure

Anesthesia was performed by the same team of anesthesiologist. One-shot paravertebral block was performed using 0.4% ropivacaine (3 ml for each segment) before anesthesia induction (Fig. 2). Make

Loading [MathJax]/jax/output/CommonHTML/jax.js

sure the anesthesia level has covered all the operation area. Patients were placed in the lateral position (lateral fractures), supine position (anterior and antero-lateral fractures), posterior decubitus position (posterior fractures). Electrocardiogram, noninvasive blood pressure, pulse oximetry and index of consciousness (IOC) were strictly monitored during entire process. IOC is a new anesthesia depth-monitoring indicator. It can be divided into index of consciousness 1 (IOC1) and index of consciousness 2 (IOC2). IOC1 is used to evaluate a patient's sedation state while IOC2 is used for reflecting analgesic depth. Penehyclidine hydrochloride (0.5 mg) and Rocuronium (5–10 mg) was given by intravenous injection. Dexmedetomidine hydrochloride ($0.3 \mu\text{g}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$) was given for sedation with target-controlled infusion pump, Propofol and Remifentanil were given using a venous pump. Laryngeal mask airway was used for patients undergoing CWS when the IOC1 achieves a value between 40 and 60 (Fig. 3). Oxygen was delivered by mechanical ventilation (oxygen flow 2 L/min, vital volume 8 ml/kg, breath rate 12 times/min, $\text{FiO}_2 = 0.5$). Another round of Rocuronium (5–10 mg) was given during surgery when necessary. When spontaneous respiration was recovered, mechanical ventilation was stopped and oxygen supply was maintained through anesthesia machine (oxygen flow 2 L/min, $\text{FiO}_2 = 0.5$).

Surgical Procedure

All operations were conducted by the same team of surgeons. Chest computer tomography and three-dimensional reconstruction of the ribs was performed before surgery to clarify the fracture situation and determine the optimal incision position (Fig. 4). A small incision of about 5–7 cm in length was made using muscle sparing technique (Fig. 5). Front rib fractures: an incision was made at the lateral margin of the pectoralis major and the front margin of the latissimus dorsi muscle to dissociate the muscles and expose the fracture ends through the muscle gap. Lateral rib fractures: an anterior lateral incision was made to dissociate tissue subcutaneously along the anterior iliac muscle fibers to the fracture ends. Posterior rib fracture: an incision was made from the lower edge of inferior angle of scapula to the medial edge of scapula through the auscultation triangle. When dislocated ribs were located in more than one location, respectively, and more than one incision were made. VARP was performed in some cases with poor operating field (Video 1). Postoperative negative pressure drainage was routinely performed in each case while pleural drainage was performed only when necessary. All displaced fractures of ribs were fixed.

Data Collection and Analyses

We recorded the following baseline characteristics: gender, age, side, location and number of fractures. SpO_2 , PaO_2 , PaCO_2 , blood pressure (BP), heart rate (HR), vital volume, breathing rate were recorded at the following time points: preoperative, intraoperative and postoperative. Operation time, blood loss, dosage of opioid and vasoactive drugs was recorded during anesthesia. Time during extubation after operation was also recorded. The Visual Analog Scale (VAS) was used to evaluate pain score at 6 hours, 12 hours, 24 hours after operation and postoperative nausea and vomiting (PONV) score at 12 hours, 24 hours, 48 hours after operation. All operative and postoperative complications, including anesthesia related complications were recorded in this study.

Data statistical analyses were performed using SPSS version 23.0 (SPSS Inc., Chicago, IL, USA). Continuous data were described as means and standard deviations or medians and range. Categorical data are described as absolute and relative frequencies.

Results

From June 2019 through September 2019, non-intubated minimally invasive CWS was performed in 20 patients with multiple rib fractures. The characteristics of these patients are reported in Table 1. Among these patients, the mean age was 59.7 years, and 12 patients (60%) were men. CWS were mostly performed for lateral rib fractures in this study (n = 8). SpO₂, PaCO₂, BP, HR, vital volume and breathing rate are all maintained at normal level before operation. The mean pain score was 4.2 points before operation. The intraoperative results were listed in Table 2. The mean operation time was 92.5 minutes and mean blood loss was 49 ml. No patient required conversion to tracheal intubation. SpO₂, PaCO₂, BP, HR, vital volume and breathing rate are also maintained at normal level during operation. The postoperative results were listed in Table 3. The mean extubation of laryngeal mask time was 8.9 minutes, mean postoperative fasting time was 6.1 hours and mean postoperative hospital stay was 6.2 days. Intercostal drainage was needed in only 7 patients and mean postoperative drainage was 97.5 ml. Only one case developed pulmonary infection after operation. Mean postoperative pain score was 2.9 points at 6 hours, 2.8 points at 12 hours, and 3.0 points at 24 hours. Mean postoperative nausea and vomiting score was 1.9 points at 6 hours, 1.8 points at 12 hours, and 1.7 points at 24 hours.

Table 1
Clinical characteristics of 20 patients received non-intubated chest wall stabilization

Characteristic	
Gender	12 (60%)
male	8 (40%)
female	62(27–77) 59.7 ± 12.6
Age	8 (40%)
Side	12 (60%)
right	6 (30%)
left	8 (40%)
Location	6 (30%)
anterior ^a	5 (4–7) 5.3 ± 1.1
lateral ^a	96 (91–97) 95.9 ± 0.9
posterior ^a	92.1 (66.9-105.2) 91.6 ± 10.2
Number of fractured ribs	
SPO ₂ (%)	
PaO ₂ (mmHg)	37.9 (33.4–42.3) 38.1 ± 2.2
PaCO ₂ (mmHg)	123 (105–140) 122.1 ± 9.3
Blood pressure (systolic blood press, mmHg)	81 (70–89) 76.3 ± 7.6
Blood pressure (diastolic blood press, mmHg)	75 (65–95) 79.8 ± 8.6
Heart rate (times/min)	4 (3–6) 4.2±0.8
Pain score (VAS)	450 (400–490) 451.3 ± 25.7
Vital volume (ml)	17 (14–20) 16.8 ± 1.7
Breathing rate (times/min)	

^a: If a patient has two or more sites of rib fractures, define the site where the fractures are most severe as fracture site.

Table 2
Intraoperative results of 20 patients received non-intubated chest wall stabilization

variable	
Operation time (min)	87.5(50–130) 92.5 ± 24.7
Blood loss (ml)	50(20–100) 49 ± 24.5
Conversion to treacheal intubation	0
Opioid dosage (ug)	10 (10–15) 12.0 ± 2.5
Dosage of vasoactive drugs	80 (80–160) 96.0 ± 30.2
norepinephrine (ug)	10 (5–20) 11.2 ± 4.2
Dosage of muscles relaxants	96 (94–97) 97.2 ± 1.2
Rocuronium (mg)	89.2 (74.5-104.5) 88.6 ± 8.0
SPO ₂ (%)	38.2 (32.5–43.5) 38.5 ± 2.8
PaO ₂ (mmHg)	119.5 (90–135) 115.2 ± 10.7
PaCO ₂ (mmHg)	74 (56–84) 71.9 ± 9.6
Blood pressure (systolic blood press, mmHg)	70.5 (60–99) 75.4 ± 12.6
Blood pressure (diastolic blood press, mmHg)	390 (350–440) 402.5 ± 35.6
Heart rate (times/min)	14 (11–15) 13.6 ± 9.0
Vital volume (ml)	
Breathing rate (times/min)	

Table 3
Postoperative results of 20 patients received non-intubated chest wall stabilization

variable	
Time during extubation after operation (min)	8 (5–15) 8.9 ± 2.6
Postoperative fasting time (hour)	6 (4–8) 6.1 ± 1.2
Length of postoperative hospital stay (day)	6 (3–9) 6.2 ± 1.6
Drainage (ml)	90 (30–200) 97.5 ± 46.1
Morbidity	1
pulmonary infection	96 (94–97) 95.7 ± 0.7
SPO ₂ (%)	95.4 (70.5-110.5) 93.5 ± 10.5
PaO ₂ (mmHg)	36.8 (32.9–42.0) 37.0 ± 2.5
PaCO ₂ (mmHg)	125 (93–142) 121.3 ± 15.2
Blood pressure (systolic blood press, mmHg)	74 (56–84) 75.6 ± 9.8
Blood pressure (diastolic blood press, mmHg)	78 (58–94) 76.8 ± 10.9
Heart rate (times/min)	460 (420–490) 453 ± 22.1
Vital volume (ml)	18 (15–21) 17.7 ± 1.6
Breathing rate (times/min)	3 (1–4) 2.9±0.7
Pain score (VAS)	3 (1–4) 2.8±0.8
6 hours after operation	3 (1–4) 3.0±0.8
12 hours after operation	2 (1–3) 1.9 ± 0.6
24 hours after operation	2 (1–3) 1.8 ± 0.5
Postoperative nausea and vomiting (VAS)	2 (1–3) 1.7 ± 0.5
12 hours after operation	
24 hours after operation	
48 hours after operation	
VAS: visual analog scale.	

Discussion

Our study is the first study showing that non-intubated minimally invasive CWS is safe and feasible in carefully selected patients with multiple rib fractures. Our study showed the intraoperative and postoperative results were satisfactory. SpO₂, PaO₂, PaCO₂, BP, HR, vital volume and breathing rate are all maintained at normal level during and after operation.

No patient required conversion to tracheal intubation in this study. There are several reasons may account for above results. First of all, previous study showed patients with a body mass index of more than 30.0 kg/m² was not suitable for non-intubated anesthesia due to vigorous diaphragmatic and mediastinal movement [12]. Since the body mass index of patients was strictly limited to lower than 28 kg/m² in our study, the risk of conversion to general anesthesia was reduce to the minimum. Secondly, most procedures in CWS did not involve in intrathoracic dissection, which were not easily affected by vigorous diaphragmatic and mediastinal movement.

Only one patient developed pulmonary infection after surgery. It is generally accepted that patients with multiple rib fractures who are afraid of coughing is likely to develop pulmonary infection. Since the postoperative analgesia was satisfactory in all patients, it seems unlikely that patients were afraid to cough because of pain in this study. The cause of pulmonary infection may be connected with the trauma itself other than anesthesia procedure.

Unlike previous studies [5–9], paravertebral block was performed before anesthesia induction in our study. Previous study showed preemptive pharmacological blockade had been effectively used in surgical patients with satisfactory results [13]. It is generally accepted that preemptive analgesia can alleviate pain and stress reaction, maintain hemodynamic stability, reduce intraoperative bleeding, lower the incidence rates of cardiovascular and cerebrovascular events [14]. In our study, all patients recovered rapidly with satisfactory postoperative analgesia, which supported the further application of preemptive analgesia in CWS.

Compared with video-assisted thoracoscopic surgery, division of thoracic muscles in CWS is more extensive. Although muscle-sparing incisions and minimized approaches can preserve muscles in the maximum extent, dividing muscles is still inevitable in CWS. Mechanical ventilation was necessary in all patients during the first half part of operation since muscles relaxants were used, which made satisfactory oxygenation easy to maintain. Abdominal distention is a major complication after operation, which was usually caused by the air leakage around laryngeal mask. None patients developed abdominal distention in this study, which may attribute to appropriate choice of laryngeal mask size and anesthesiologist with well-experienced anesthesia skill. During the second half part of operation, satisfactory oxygenation was also maintained in all patients. Intact parietal pleura in major cases and short operation time may contribute to above results.

VARP is a new technique for CWS allows for an extrathoracic approach using standard plating assisted
er recovery. Previous study reported their experience of

performing VARP technique and concluded that it was feasible in the cadaver model [11]. Our study firstly reported our experience of using VARP technique in patients with multiple rib fractures with satisfactory results, which supports application in the general patient population to further define the patient indications.

Although no study has been performed before, non-intubated CWS is tended to be safer than video-assisted thoracoscopic surgery. Firstly, CWS usually does not involve intrathoracic procedures, which might avoid triggering coughing in spontaneously breathing patients. Our experience in this study showed no patient developed cough in non-intubated CWS. Secondly, hypoxemia and hypercapnia is not likely to be happened in patients without open pneumothorax. Since the parietal pleura were intact in most cases of CWS, it is easily to maintain satisfactory oxygenation during surgery. The satisfactory intraoperative results showed non-intubated CWS in carefully selected patients was safe and feasible.

Although muscles relaxants were used in all patients, the dosage of muscles relaxants in this study was obviously lower than general anesthesia intubation (10 mg vs. 50 mg). Previous study showed that residual neuromuscular blockade after anesthesia is a cause of increased pulmonary complications such as oxygen desaturation, postoperative pneumonia, airway obstruction, and reintubation [15]. Therefore, it is reasonable to speculate that non-intubated CWS can reduce pulmonary complications even without a control group in this study. Since dividing or dissecting muscles is inevitable in CWS, low dosage of muscles relaxants may make the whole procedure more difficult. The mean operation time was 87.5 minutes, which seemed to suggest that operation procedure was not getting difficult under non-intubated anesthesia. Basing on our experience, we did find that operation procedure was getting difficult in patients with posterior rib fractures due to the muscle tremor during muscles dissecting, which suggested posterior rib fractures might not be the perfect candidate of non-intubated CWS.

There were inevitable certain several limitations in this study. Firstly, the number of included patients was relatively small. Secondly, a control group who received CWS under intubated general anesthesia was lacked to compare the differences with non-intubated anesthesia. Considering this technique had not been performed before, this study had to be designed as a single arm with small sample to verify the safety and feasibility of this technique. However, the results of this study do support further study including a control group with large sample size.

In our study, all patients showed tolerable postoperative pain, postoperative nausea and vomiting, early postoperative fasting time, low morbidity. With satisfactory results in our study, a prospective study comparing non-intubated anesthesia and general intubated anesthesia in CWS would be helpful to further elucidate the safety and value of non-intubated anesthesia.

Conclusion

In conclusion, non-intubated CWS is safe and feasible in carefully selected patients. Further study with large sample size is warranted to verify the advantage and disadvantage of non-intubated CWS.

Abbreviations

CWS: chest wall stabilization;

VATS: video-assisted thoracoscopic surgery;

VARP: video-assisted rib plating;

ASA: American society of anesthesiologists;

BMI: body mass index;

PONV: postoperative nausea and vomiting;

VAS: visual analog scale;

IOC: index of consciousness;

MIPO: minimally invasive plate osteosynthesis;

BP: blood pressure;

HR: heart rate;

Declarations

Ethical Approval and Consent to participate

The study was approved by Ethics Committee of Shanghai Jiao Tong University Affiliated Sixth People's Hospital.

Consent for publication

Not applicable.

Availability of supporting data

The data that support the findings of this study are available from Shanghai Jiao Tong University Affiliated Sixth People's Hospital and are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

Author contributions

Zhao WG, Chen YL conceived and designed the study. Zhao WG, He WW and Zhao YH collected and assembled data. Zhao WG performed data analysis and interpretation. Yang Y contributed to manuscript writing. All authors read and approved the final version of the manuscript.

Acknowledgements

Not applicable

References

1. de Campos JR, White TW. Chest wall stabilization in trauma patients: why, when, and how? *J Thorac Dis.* 2018;10:951–62.
2. Chien CY, Chen YH, Han ST, et al. The number of displaced rib fractures is more predictive for complications in chest trauma patients. *Scand J Trauma Resusc Emerg Med.* 2017;25:19.
3. Zhong T, Wang W, Chen J, et al. Sore throat or hoarse voice with bronchial blockers or double-lumen tubes for lung isolation: a randomised, prospective trial. *Anaesth Intensive Care.* 2009;37:441–6.
4. Murphy GS, Szokol JW, Avram MJ, et al. Postoperative residual neuromuscular blockade is associated with impaired clinical recovery. *Anesth Analg.* 2013;117:133–41.
5. Hung MH, Hsu HH, Chen KC, Chan KC, Cheng YJ, Chen JS. Nonintubated thoracoscopic anatomical segmentectomy for lung tumors. *Ann Thorac Surg.* 2013;96:1209–15.
6. Cui F, Liu J, Li S, et al. Tubeless video-assisted thoracoscopic surgery (VATS) under non-intubated, intravenous anesthesia with spontaneous ventilation and no placement of chest tube postoperatively. *J Thorac Dis.* 2016;8:2226–32.
7. Hwang J, Shin JS, Son JH, et al. Non-intubated thoracoscopic bullectomy under sedation is safe and comfortable in the perioperative period. *J Thorac Dis.* 2018;10:1703–10.
8. Pompeo E, Tacconi F, Mineo D, Mineo TC. The role of awake videoassisted thoracoscopic surgery in spontaneous pneumothorax. *J Thorac Cardiovasc Surg.* 2007;133:786–90.
9. Mineo TC, Sellitri F, Tacconi F, Ambrogi V. Quality of life and outcomes after non-intubated versus intubated video-thoracoscopic pleurodesis for malignant pleural effusion: comparison by a case-matched study. *J Palliat Med.* 2014;17:761–8.
10. Wen Y, Liang H, Qiu G, et al. Non-intubated spontaneous ventilation in video-assisted thoracoscopic surgery: a meta-analysis. *Eur J Cardiothorac Surg.* 2020;57:428–37.
11. Diaz JJ, Azar FK. Minimally invasive chest wall stabilization: a novel surgical approach to video-assisted rib plating (VARP). *Trauma Surg Acute Care Open.* 2019;4:e000366.
12. Hung MH, Hsu HH, Chen KC, Chan KC, Cheng YJ, Chen JS. Nonintubated thoracoscopic anatomical segmentectomy for lung tumors. *Ann Thorac Surg.* 2013;96:1209–15.
13. Richardson P, Mustard L. The management of pain in the burns unit. *Burns.* 2009;35:921–36.

14. Kissin I. Preemptive analgesia. *Anesthesiology*. 2000;93:1138–43.

15. Cammu G. Residual Neuromuscular Blockade and Postoperative Pulmonary Complications: What Does the Recent Evidence Demonstrate? *Curr Anesthesiol Rep*. 2020; 1–6.

Figures

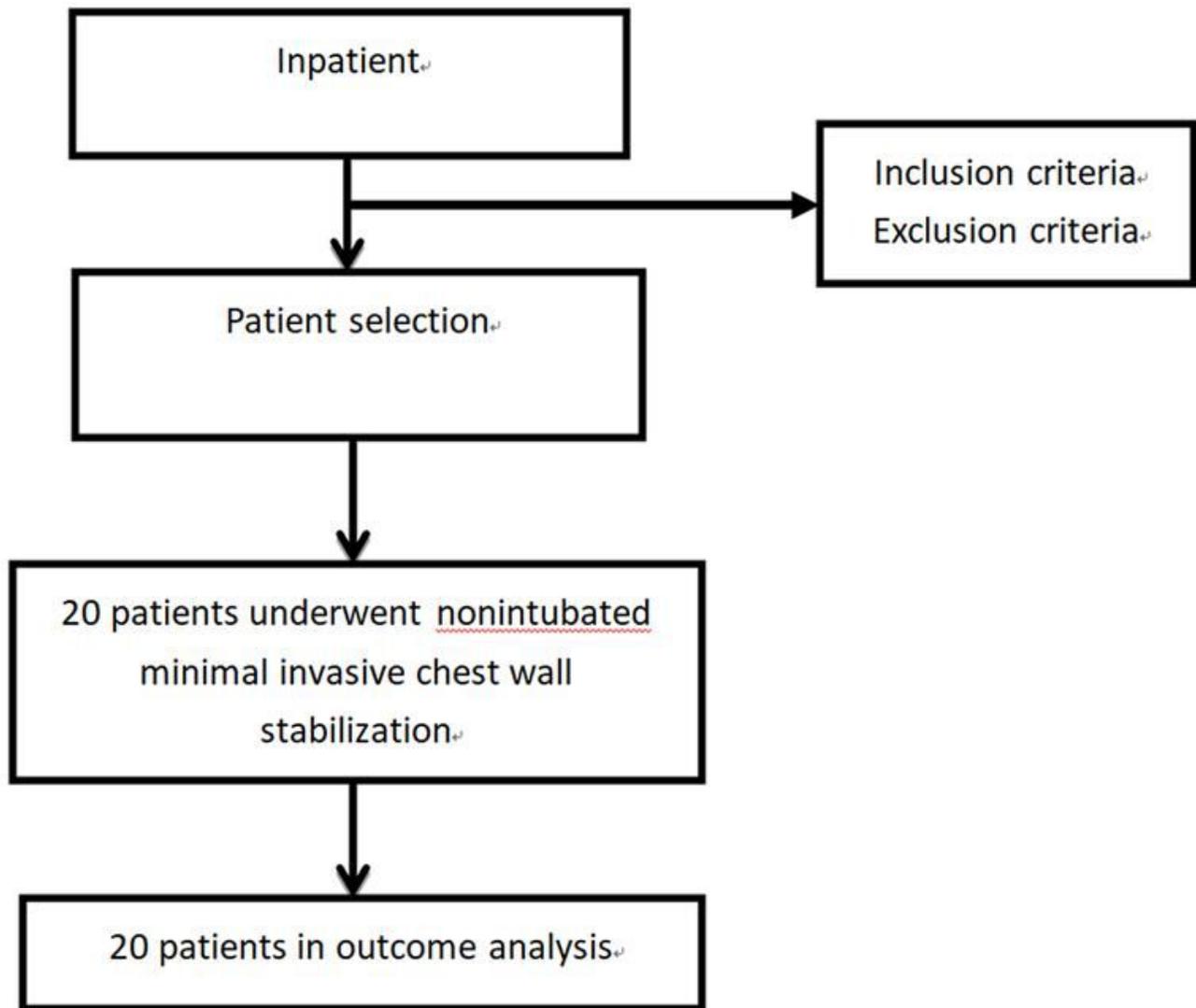


Figure 1

Flow chart of 20 patients screened in this study.



Figure 2

Paravertebral block before anesthesia induction.



Figure 3

Operative views of a patient undergoing non-intubated minimally invasive chest wall stabilization.



Figure 4

Chest computer tomography and three-dimensional reconstruction of the ribs.



Figure 5

The incision of minimally invasive chest wall stabilization.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [vedio1.mp4](#)