

# Observational study for laryngeal mask anesthesia combined with nerve block in internal fixation for rib fractures

Jun Cao (✉ [18930173661@189.cn](mailto:18930173661@189.cn))

Shanghai Sixth People's Hospital <https://orcid.org/0000-0002-2645-9245>

Junfeng Zhang

Shanghai Sixth Peoples Hospital

Xiaoyun Gao

Shanghai Sixth Peoples Hospital

Xiaoli Zhang

Shanghai Sixth Peoples Hospital

Jing Li

Shanghai Sixth Peoples Hospital

---

## Research article

**Keywords:** Laryngeal mask anesthesia; Non-tracheal intubation; Thoracic paravertebral block; Erector spinae plane block; Rib fractures.

**Posted Date:** November 11th, 2019

**DOI:** <https://doi.org/10.21203/rs.2.17107/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 July 15th, 2020. See the published version at <https://doi.org/10.1186/s12871-020-01082-y>.

# Abstract

To evaluate the safety and effectiveness of laryngeal mask(LMA) anesthesia combined with nerve block in rib fractures internal fixation, twenty patients with unilateral isolated rib fractures were observed during the anesthesia prospectively. Methods Thoracic paravertebral block(TPB) and/or erector spinae plane block(ESPB) were carried out before LMA anesthesia. The vital signs(HR, BP, SpO<sub>2</sub>) and parameters of breath were recorded during the operation. The arterial blood gas analysis and chest radiograph were performed preoperatively and on the next day after operation. Patient-controlled analgesia contained with 500mg of tramadol and 16mg of lornoxicam was routinely used after the operation, and 50mg of flurbiprofen was infused intravenously Bisindie in the ward. Postoperative nausea and vomiting(PONV) within 48 hours after surgery and NRS pain score at 6(T1), 12(T2), 24(T3) hours after surgery were assessed as well. Results Thirteen males and seven females(mean age 54 years) were enrolled in this trial. 6(30%) had a flail chest, 9(45%) had Haemothorax, 2(10%) had a pulmonary contusion. The vital signs and spontaneous breathing were kept stable. End-tidal carbon dioxide concentration(EtCO<sub>2</sub>) was acceptable(no more than 63 mmHg in all cases). PaO<sub>2</sub> of post-operation was significantly increased than that of pre-operation( $P < 0.001$ ), PaCO<sub>2</sub> of pre-operation and post-operation had no significant difference. NRS at T3 was significantly lower than that at T1 and T2( $p < 0.001$ ), while the score at T2 was slightly lower than that at T1 ( $p < 0.005$ ). Furthermore, no one suffered from PONV. Conclusions We demonstrated that laryngeal mask anesthesia combined with nerve block was feasible in the internal fixation for rib fractures.

## Background

Rib fracture is one of the most common injuries following blunt trauma, occurring in approximately 10% of all trauma patients. Currently, most scholars believe that surgical stabilization of rib fractures should be considered in all patients with flail chest and patients with multiple, severe displaced fractures.<sup>1</sup> The advantage is that it can relieve pain, shorten the duration of mechanical ventilation, decrease the incidence of pneumonia, and decrease the length of both intensive care unit and hospital stay. In the past, general anesthesia with endotracheal intubation(ETI) was used in this operation. But it may cause ventilator-associated lung injury (VALI), and also caused postoperative agitation, cognitive impairment, nausea and vomiting frequently.<sup>2</sup> Besides, the patients may suffer from delayed awakening or even re-intubation due to residual general anesthetics.<sup>3</sup> Recently, a non-intubation technique, such as LMA anesthesia combined with nerve block, can lead to ameliorative analgesia and reduction of the general anesthetics dosage at utmost and it provides a more stable airway and facilitates oxygenation.<sup>4</sup> Therefore, the occurrence of complications induced by endotracheal intubation can be minimized by LMA anesthesia.

Although the non-intubation technique has been reported in thoracic surgery, it is only found in pleural and pulmonary surgery. There are some differences in the rib surgery, include: 1. The surgery site is on the chest wall, not involving the viscera. 2. There is no need for one-lung ventilation, 3. Respiratory function is

affected since the injury, and its recovery depends greatly on thoracic pain relief. Theoretically, LMA anesthesia combined with nerve block is more suitable for rib internal fixation. In absence of such reports, we prospectively enrolled 20 patients with rib fractures internal fixation and hypothesized that LMA anesthesia combined with nerve block can be applied safely and effectively in this surgery.

## Methods

### Participants

This prospective, observational study was approved by the Ethics Committee of Shanghai Sixth People's Hospital(2019-53) and was registered at [www.chictr.org.cn](http://www.chictr.org.cn)(ChiCTR1900023763). Twenty patients from June to August 2019, scheduled for surgical reduction and fixation of unilateral isolated rib fractures in our hospital, were enrolled in this study. The informed consent was signed by all patients. Inclusion criteria: 1. ASA I and II; 2. aged 18–70 years; 3. BMI<30; 4. Preoperative PaO<sub>2</sub> > 60mmHg; 5. Preoperative PaCO<sub>2</sub> < 50mmHg. Exclusion criteria: 1. Difficult airway; 2. Esophageal reflux; 3. Myasthenia gravis; 4. Abnormal coagulation system; 5. Gastrointestinal tract ulcer or hemorrhage; 6. Allergy to anesthesia-related drugs; 7. Asthma or chronic obstructive emphysema; 8. Pregnant women; 9. The patients presented with major thoracic vascular injuries.

### Procedures

Vital signs were routinely monitored since the patient entered the operating room, and Lactated Ringer's solution was infused from the peripheral vein of the forearm.

Ultrasound-guided TPB was performed using an S-Nerve™ Ultrasound System (Fujifilm SonoSite Inc. Bothell, WA, USA) by two anesthesiologists in charge of block procedure, and the transversal Inferior Articular Process(IAP) approach was applied.<sup>6</sup> The patient was placed in a lateral decubitus position. A convex array probe (5-2 MHz; C60x; Fujifilm SonoSite Inc. Bothell, WA, USA) was used to visualize the vertebral lamina, internal intercostal membrane and parietal pleura for prescanning (Figure 1). a 22-gauge, 8-cm puncture needle (KDL medical apparatus and instruments Co. Wenzhou, China) was inserted into the thoracic paravertebral space(TPVS) from the lateral side. 20-30ml of 0.375% ropivacaine was injected with no air or blood aspiration. The injection point of TPVS was selected according to the fracture rib segments requiring surgery (hereinafter referred to as the "surgical segments"). If the surgical segments were not more than 4 consecutive ribs, the injection point was selected at the TPVS of the second fractured rib, and 20ml of 0.375% ropivacaine was injected at this single point. If the surgical segments were more than 4 consecutive ribs, the injection points were selected at the TPVS of the second and fifth fractured ribs, and 15 ml of 0.375% ropivacaine was injected at each point. In the case of posterior rib fractures, ESPB was combined to reinforce the regional anesthesia effect in patient's back. 20ml of 0.375% ropivacaine was injected between the transverse process of the fifth thoracic vertebral and erector spinae muscle on the injured side, by the cross-sectional in-plane approach under ultrasound.

Nerve block effect was evaluated in 15 minutes after nerve blockade, the blocked dermatomes of sensory loss were measured by acupuncture and rubbing with alcohol gauze. If the pain disappeared during deep breath and powerful cough, and the incision was within the area of reduced cold or pinprick sensation, it is considered that nerve block effect is complete, and the LMA anesthesia can be performed on the patient as an observational object. Otherwise, general anesthesia with endotracheal intubation was directly adopted and the patient was excluded from the observational objects.

The patients were inducted with administration of sufentanil 0.1ug/kg, propofol 3mg/kg and rocuronium 0.3mg/kg successively. An appropriate type of LMA Supreme™(Teleflex Medical Co. Westmeath, Ireland) was inserted. After the right position of the LMA was confirmed, mechanical ventilation was used with PCV-VG mode. Tidal volume(Vt) was set as 6ml/kg, breathe rate(BR) was 12 times/minute, and the I/E ratio was 1:2. Meanwhile, a 14# gastric tube was advanced through the gastric drainage channel at the depth of 30cm to prevent gas from spilling into the esophagus during positive pressure ventilation.

During the operation, the oxygen concentration was 50%, and the flow rate was 2L/minute. Sevoflurane concentration was adjusted according to BP and HR, and the MAC value was adjusted between 0.7 and 1.2. Spontaneous breathing was maintained when it had recovered. Sufentanil 0.03 ug/kg would be administrated if HR was 20% faster than the basic value or RR was more than 20 times/minute because of the surgical stimulation. Phenylephrine and atropine would be administrated if necessary. At 15 minutes before the end of the surgery, sevoflurane inhalation was ceased and 50mg of flurbiprofen was infused intravenously.

During the operation, the patient would be converted to endotracheal intubation anesthesia In the following cases: 1. the surgical field was difficult to be exposed on account of muscular tension, 2. the LMA couldn't be placed in the right position, 3. hemodynamic instability occurred, 4. saturation of pulse oxygen is less than 90%, 5. EtCO<sub>2</sub> was more than 70mmHg.

Patient-controlled analgesia (infusion rate 2ml/h, total volume 100ml) was routinely used after operation. The analgesics contained with 500mg of tramadol and 16mg of lornoxicam. 50mg of flurbiprofen was infused intravenously Bisindie in the ward. If the patient's NRS was more than 4, intramuscular injection 50mg of pethidine would be used as a remedy.

## **Data Collection**

BP, HR, SpO<sub>2</sub>, duration of induction to spontaneous breathing recovered, and Vt, BR, EtCO<sub>2</sub> during spontaneous breathing were recorded. We also gathered dosages of sufentanil and vasoactive drugs used, and degree of surgeon's satisfaction, cases of converted to ETI during the operation. Another investigator recorded the postoperative extubation time and the events of agitation or hoarseness since patients were transferred to the PACU. PONV within 48 hours after surgery and NRS pain score(Table 1) at 6(T1), 12(T2), 24(T3) hours after surgery were assessed as well. The arterial blood gas analysis and chest radiograph were performed preoperatively and on the next day after surgery.

**TABLE 1. Numerical Rating Scale of Pain(NRS) in our department**

Degree of pain	Description	Score			
No pain	No pain	0			
Mild pain	No pain in the supine position	Turn over Pain	Cough No pain	Deep breath No pain	1
		Pain	Pain	No pain	2
		Pain	Pain	Pain	3
Moderate pain	Feel pain in supine position	Intermittent pain			4
		Sustained pain			5
		Serious pain			6
Severe pain	Toss and turn	Sleeplessness			7
		Sweating			8
		unbearable			9
		Living death			10

### Statistical Analysis

SPSS19.0 software was used for statistical analysis. Quantitative variables are expressed as means  $\pm$  SD, The results of arterial blood gas analysis which measured pre/post-operatively were compared using the t-test. Categorical variables are expressed as quantitative value or percentage. The correlation of hypotension with injection points, combining ESPB, flail chest, haemothorax was evaluated using the chi-square test or Fisher's exact test.  $P < 0.05$  was considered to be statistically significant.

### Results

Twenty patients were enrolled in this study, and their characteristics are shown in Table 2. 8 cases (40%) received TPB by single-point injection, the rest of 12 cases (60%) received TPB by two-points injection. ESPB was combined in 13 cases (65%). All of the cases had perfect blockage effect, and received LMA anesthesia.

**TABLE 2. Demographics and clinical characteristics of the patients**

Variable	N	Mean	%
Sex(male/female)	13/7		
Age(y)	35-70	54.15 $\pm$ 8.67	
BMI(kg/m <sup>2</sup> )	19.1-29.7	24.29 $\pm$ 2.75	
Flail chest	6		30
Haemothorax	9		45
Pulmonary contusion	2		10

During the operation, MAP in 8 patients (40%) was less than 60 mmHg and needed to be maintained by phenylephrine(Figure 2). HR of patients was in range of 47-98 beats per minute. SpO<sub>2</sub> in all cases remained above 95% during the operation, except one patient's SpO<sub>2</sub> transiently decreased to 87%, but

recovered to 98% within 5 minutes. The recovery time of spontaneous breathing was  $27.25 \pm 19.43$  minutes. The range of  $V_t$ , BR and  $EtCO_2$  during spontaneous breathing are showed in Figure 3. In one case,  $EtCO_2$  exceeded 60 mmHg, which ranged from 57 to 63 mmHg.

In each case, the dose of sufentanil was 5-17( $9.9 \pm 3.3$ )  $\mu\text{g}$ . Eight patients (40%) required phenylephrine, and the dose was 80-300( $200 \pm 76$ )  $\mu\text{g}$ . The number of phenylephrine used in different groups is shown in Table 3. No one was administrated atropine. The duration of operation was 30-110( $70 \pm 21$ ) minutes. Neither slight muscle twitching caused by high-frequency electrotome, nor thoracic fluctuation of breathing impeded the surgeon's operation. No one was converted to ETI anesthesia due to the poor position of LMA or insufficient ventilation. The surgeons were satisfied with the anesthesia in all cases. Thoracic drainage tubes were placed in 9 cases (45%) according to the demands of surgery.

**TABLE 3. Crosstabs of hypotension with various factors**

Variable	Phenylephrine		P
	(n=8)	(n=12)	
Injection point count			0.648
1- point	4	8	
2- point	4	4	
Combining ESPB	8	5	0.015 *
Flail chest	4	2	0.161
Haemothorax	4	5	1.000

\*  $p < 0.05$  Showed a significant difference

The time to extubation was 1-11 minutes, with an average of  $6 \pm 3$  minutes. None of the patients had agitation or sore throat after anesthesia. The  $SpO_2$  was higher than 96% throughout recovering (oxygen flow rate 3 L/minute).

Postoperative NRS at T1, T2, T3 was  $3 \pm 1$ ,  $2 \pm 2$ , 0 respectively. The highest score was 5 in four cases (20%) of the study. Two of them had 5 score of NRS at 6 hours after surgery, the other two cases had 5 score at 12 hours postoperatively. All four patients received an intramuscular injection of pethidine 50 mg once as a remedy, and pain relieved. NRS at T3 was significantly lower than that at T1 and T2 ( $p < 0.001$ ), while the score at T2 was slightly lower than that at T1 ( $p < 0.005$ ) (Figure 4). PONV didn't occur within 48 hours after surgery in all cases.

Blood gas analysis shows that  $PaO_2$  of post-operation has significantly risen than that of pre-operation,  $P < 0.001$ . Nevertheless, There was no significant difference in  $PaCO_2$  between pre-operation and post-operation (Figure 5).

## Discussion

It was well known that rib fractures with flail chest and multiple, severe displaced fractures could make patients apnea. Surgical treatment is conducive to the early recovery of such patients. The concerns for anesthesiologists are not only guaranteeing the oxygenation during the operation but also the successful extubation after the surgery. LMA anesthesia combined with nerve block is priority to ETI anesthesia. In 2012, Ambrogi<sup>4</sup> had reported the successful use of LMA anesthesia for lung parenchymal resections. However, the surgery of rib fractures is different from VATS. Anesthesiologists should take account of the nerve block effect of surgical segments and the reduction of chest wall muscle twitching when the incision was separated.

The thoracic nerves are responsible for the sensation of the ribs and skin, and their distributions are consistent with the ribs. This is the theoretical basis for the application of epidural anesthesia in chest surgery. However, thoracic epidural anesthesia produces bilateral trunk block and thoracic sympathetic block, causes hypotension frequently. It's also associated with serious complications, such as epidural hematoma and neuropathy. Furthermore, it has contraindication of abnormal coagulation. Therefore, a variety of nerve blocks are used clinically as alternatives to epidural anesthesia, such as serratus anterior plane block(SAPB), intercostal nerve block(INB), ESPB and TPB. however, there are some limitations to the above three methods. The local anesthetic of SAPB is distributed along the midaxillary line which is mostly close to the surgical incision, which would cause the muscle swelling and impact the surgical vision. INB requires multipoint injection, which makes the patient more painful and increases the risk of inadvertent intercostal vessels or pleura puncture. ESPB is a blockade of Intermuscular fascia, the incidence of complete block to achieve the disappearance of pain and temperature sensation is only 1/3.<sup>5</sup> TPB has the advantage of certain effect which even equals to unilateral epidural anesthesia, and can be performed precisely by ultrasound-guidance. Thus we choose TPB as a part of anesthesia in our study.

The intercostal(IC) approach and the paralaminar(PL) approach are two most frequent approaches of TPB. According to our experience, A single injection of 0.375% ropivacaine 20ml via PL approach could block 4-5 segments of the sensory dermatome, which was consistent with Yasuko Take's conclusion.<sup>6</sup> They found that the blocked dermatomes of sensory loss were wider in group PL vs group IC after 20 ml of 0.5% ropivacaine was injected, median number of blocked dermatomes was 3 in group IC and 4 in group PL. Our approach of TPB has the same transversal cross-sectional image as Taketa's PL approach, and is also consistent with the transversal IAP approach described by Krediet, et al.<sup>24</sup> Unlike them, our puncture needle is inserted oblique to the skin from the lateral of the probe and advanced into the TPVS beyond the IAP. Based on our pilot experiment, we found that the block area toward caudal was more extensive than it toward cephalic. That's the reason we chose the inject point of TPB at the second surgical segment from cephalic when the surgical segments were not more than 4 consecutive ribs. Besides, the PL approach was regarded as a better approach to block the dorsal ramus of thoracic nerves,<sup>7</sup> so it was beneficial to postoperative analgesia for posterior costal fracture surgery. Finally, we think that ESPB is necessary to ensure the block effect of incision for posterior costal surgery. Because it

can produce sensory blockade over the posterior as well as anterolateral thorax, and apply more effective analgesia for posterior rib fractures compared with SAPB.<sup>18</sup>

The dosage of sufentanil during the surgery in each patient ranged from 5 to 17(9.9 ±3.3) µg. It both kept BR at 15±3 breaths per minute, and achieved an acceptable effect of postoperative analgesia. In the result of our study, the 6th hour after the operation was generally the time point at which patients felt painful obviously. This was consistent with the duration of TPB postoperative analgesia(303.97±76.08 minutes) reported by Das S, et al.<sup>8</sup> On account of the use of PCIA and intravenous infusion of lornoxicam as basic analgesia after operation, most patients had pain in an acceptable extent, except 4 patients (20%) with an NRS score of 5, occurred at 6 hours and 12 hours after operation respectively. They all received once rescue of pethidine. It indicated the multi-mode analgesia protocol was effective for rib surgery postoperatively. This result also suggests that we may achieve better postoperative analgesia by TPB catheterization in our future work, as reported by Ge Yeying.<sup>9</sup>

TPB may block the sympathetic ganglia of the corresponding segments, and lower the patients' BP. Theoretically, the incidence of hypotension is positively related with the number of blocked segments. However, in our study, we found that the need for phenylephrine in the operation was not relative to the number of TPB inject points. It was consistent with the conclusion that a single TPB wouldn't lower the blood pressure reported by other previous authors.<sup>19,20</sup> But there was a significant correlation between the need for phenylephrine and ESPB combined. We could not clearly explain this event yet and will confirm and elaborate it in the future research.

We used one ED95 of rocuronium during induction to reduce muscle twitching . Since the innervating nerves of the serratus anterior muscle and latissimus dorsi muscle originate from the cervical spinal cord, TPB is ineffective in blocking these two groups of muscles. We found this dose can satisfy the surgeons when they exposed the wound. Gleen S.Murphy et al.<sup>10</sup> pointed out that the residual effect of muscle relaxants was one of the causes of postoperative respiratory failure, critical respiratory events observed in 18.0% patients undergoing thoracic procedures. Althausen PL.<sup>11</sup> reported the incidence of re-intubation after surgical stabilization of flail chest was 4.55%(1/22). In this study, all 20 patients recovered spontaneous breathing during the operation and could cough powerfully after extubation, no one needed for re-intubation. Obviously, this result was attributed to the selection of patients and the small sample size. We expect that LMA anesthesia can show this advantage with further research.

Most of the patients with rib fractures have apnea caused by the injury. However, the satisfactory effect of TPB can improve the oxygenation of the patients. Because respiratory amplitude was increased when the patients didn't feel pain.<sup>12</sup> We set oxygen concentration as 50% to reduce the risk of atelectasis caused by high oxygen concentration.<sup>13</sup> Our results showed that SpO<sub>2</sub> of all patients was 99.08±1.30 % during the operation, including 3 patients whose oxygen saturation was lower than 93% before the operation. The minimum value of oxygen saturation during operation was 87% which occurred transiently in one case. His preoperative chest CT showed a large amount of pleural effusion on the affected side of

the chest cavity with incomplete atelectasis and consolidation of inferior lobe. The decline of SpO<sub>2</sub> was attributable to obvious decrease of tidal volume caused by sufentanil. But it rose to 98% in a few minutes and kept at 100% till the end of surgery.

Carbon dioxide retention occurred in different degrees during spontaneous breathing in 20 patients. The EtCO<sub>2</sub> of most of the patients was below 45mmHg at the end of the surgery, except one patient, his EtCO<sub>2</sub> reached the highest value of 63mmHg in our research. All patients were extubated within 1-11(6±3) minutes after surgery, and remained awake without drowsiness after extubation, including the patient with the highest EtCO<sub>2</sub> level. Their PaCO<sub>2</sub> checked on the second day after surgery was also in the normal range. Permissive hypercapnia has been accepted early, O' Toole<sup>14</sup> believed that hypercapnia could produce an anti-inflammatory effect by inhibiting NF-κB. And other scholars thought that hypercapnia had a protective effect on VILI.<sup>15,16</sup> Hypercapnia can also improve pulmonary compliance through a non-surfactants mechanism, and enhance pulmonary vascular resistance by strengthening hypoxic pulmonary vasoconstriction to reduce pulmonary shunt.<sup>17</sup> In summary, the patient's normal tidal volume and frequency during spontaneous breathing can meet the needs of intraoperative ventilation in this study. The perfect nerve block effect is the premise for the patient to breathe smoothly, because it can reduce the requirements of sufentanil which is responsible for respiratory inhibition, while sevoflurane itself does not produce obvious respiratory inhibition during the operation.

Postoperative pulmonary complications (PPCs) were always been concerned in thoracic surgery. Recruitment maneuver and suctioning airway secretion might be beneficial to the patients during ETI anesthesia. The sealing of the LMA is not as reliable as endotracheal catheter. But according to Russo's report,<sup>21</sup> the leak pressure of LMA supreme<sup>TM</sup> was 27.1 ± 5.2 cmH<sub>2</sub>O. So the LMA we used could meet the needs of the recruitment maneuver in general. Deserved to be mentioned, the LMA anesthesia combined with nerve block can shorten the time to extubation and apply a good analgesic effect to promote postoperative cough and sputum. In particular, the early recovery of spontaneous breath during operation reduces the interference of pulmonary function during mechanical ventilation. Because positive pressure ventilation not only changes the pressure gradient of the thoracic cavity and interferes with the distribution of intrapulmonary ventilation, but also leads to the imbalance of V/Q ratio with excessive or inadequate tidal volume. Besides, barotrauma and volume injury caused by mechanical ventilation can also cause VALI. All of the above show that spontaneous breath is beneficial to lung protection. Noda.<sup>22</sup> concluded that patients of VATS with spontaneous breath had a significantly reduced incidence of postoperative respiratory complications including pneumonia and ARDS compared to ETI anesthesia.

In general, the deterioration of pulmonary function of thoracic surgery without lobe resection maximizes at 12 to 48 hours after surgery. It reflects in the decrease of PaO<sub>2</sub> and increase of PaCO<sub>2</sub>. Therefore, we performed blood gas analysis on the second day after surgery. It was found that the postoperative PaO<sub>2</sub> in 20 patients was improved compared with the preoperative PaO<sub>2</sub> (p<0. 001). And no pneumonia was found by chest X-ray after surgery. It seemed that the LMA anesthesia wouldn't increase the incidence of

PPCs after rib fractures surgery, but it was limited by the small sample size. We will focus on it in our follow-up study.

Previous literature was retrospectively assessed for any complication of TPB, contained pleural punctures, pneumothorax, hypotension, bradycardia as well as signs and symptoms of local anesthetic toxicity. Incidence of pleural puncture was 0.6%, pneumothorax 0.26% and suspected toxicity from the local anesthetic 0.17%.<sup>23</sup> It showed that the incidence of TPB complications was low, and ultrasound-guidance could make the procedure safer. We adopt two-person operation mode, one physician operate the ultrasound probe and needle, the other person performed the aspiration and injection. Color Doppler ultrasound was used to confirm that there were no vessels in the path of the needle. None of the above complications occurred in 20 patients.

## Conclusions

In the present study, all patients had stable circulation and breathing, good oxygenation and acceptable EtCO<sub>2</sub>. The wound was well exposed and the vision was clear, and the surgeons were satisfied. The patients had smooth extubation, high quality of resuscitation, powerful cough and sputum, acceptable postoperative analgesia. Neither throat discomfort such as hoarseness, or PONV was observed. Therefore, we demonstrated that LMA anesthesia combined with nerve block anesthesia can be applied in the internal fixation for rib fractures safely and effectively.

## Abbreviations

laryngeal mask (airway): LMA

thoracic paravertebral block: TPB

erector spinae plane block: ESPB

heart rate: HR

blood pressure: BP

pulse oxygen saturation: SpO<sub>2</sub>

postoperative nausea and vomiting: PONV

numerical rating scale: NRS

end-tidal carbon dioxide concentration: EtCO<sub>2</sub>

partial pressure of artery oxygen: PaO<sub>2</sub>

partial pressure of artery carbon dioxide: PaCO<sub>2</sub>

endotracheal intubation: ETI

ventilator-associated lung injury: VALI

body mass index: BMI

Inferior Articular Process: IAP

thoracic paravertebral space: TPVS

pressure controlled ventilation-volume guaranteed: PCV-VG

tidal volume: Vt

breathe rate: BR

inspiratory/expiratory: I/E

minimum alveolar concentration: MAC

serratus anterior plane block: SAPB

intercostal nerve block: INB

intercostal: IC

paralaminar: PL

95% effective dose: ED95

Postoperative pulmonary complications: PPCs

## **Declarations**

### **Ethics approval and consent to participate**

This prospective, observational study was approved by the Ethics Committee of Shanghai Sixth People's Hospital, No. 2019-53.

### **Consent for publication**

The informed consent was signed by all patients. Meanwhile, consent for publication have been obtained from them.

### **Availability of data and material**

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

### **Competing interests**

The authors declare that they have no competing interests.

### **Funding**

Not applicable

### **Authors' contributions**

This study was designed by Jun Cao and Junfeng Zhang and was conducted by Jun Cao, Xiaoyun Gao, Xiaoli Zhang. Xiaoyun Gao and Jing Li were responsible for all data collection. Data was analyzed by Jun Cao.

### **Acknowledgements**

Not applicable

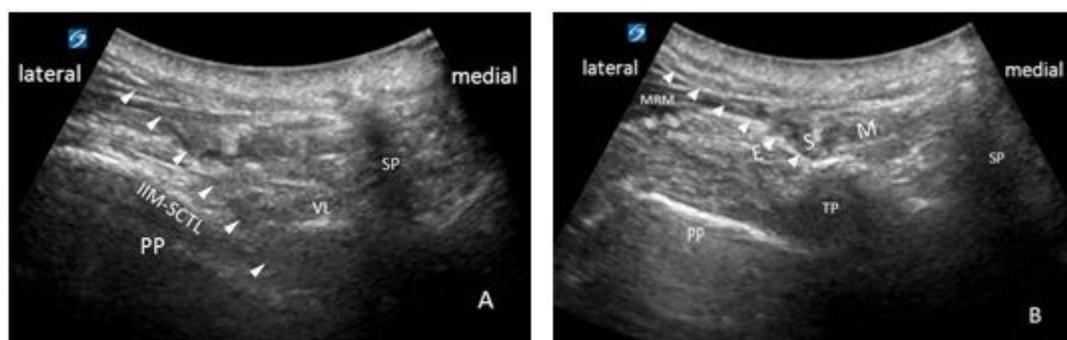
## **References**

1. Fredric M. Pieracci, et al. Consensus statement: Surgical stabilization of rib fractures rib fracture colloquium clinical practice guidelines. *Injury*. 2017 Feb;48(2):307-321.
2. Zhihua Guo, Weiqiang Yin, Hui Pan, et al. Video-assisted thoracoscopic surgery segmentectomy by non-intubated or intubated anesthesia: a comparative analysis of short-term outcome. *J Thorac Dis* 2016;8(3):359-368.
3. Murphy GS, Szokol JW, Avram MJ, et al. Postoperative residual neuromuscular blockade is associated with impaired clinical recovery. *Anesth Analg* 2013;117:133-41.
4. Ambrogi MC, Fanucchi O, Gemignani R, et al. Video-assisted thoracoscopic surgery with spontaneous breathing laryngeal mask anesthesia: preliminary experience. *J Thorac Cardiovasc Surg*. 2012;144:514-515.
5. Ban C.H. Tsui, Ahtziri Fonseca, Farrukh Munshey, et al. The erector spinae plane (ESP) block: A pooled review of 242 cases. *Journal of Clinical Anesthesia* 53 (2019) 29–34.
6. Yasuko Taketa, Yumi Irisawa, Taro Fujitani. Comparison of analgesic efficacy between two approaches of paravertebral block for thoracotomy: A randomised trial. *Acta Anaesthesiol Scand*. 2018;62:1274–1279.
7. Thomas Collin, Julie Cox. Innervation of the chest wall. Chapter 53. *Gray's Anatomy: The Anatomical Basis of Clinical Practice*, 41st edn. In: Jonathan D Spratt, Standing S, eds. Amsterdam, The Netherlands: Elsevier;2015:944-945.

8. Das S, Bhattacharya P, Mandal MC, et al. Multiple-injection thoracic paravertebral block as an alternative to general anaesthesia for elective breast surgeries: A randomised controlled trial. *Indian J Anaesth* 2012; 56:27–33.
9. Ge Yeying, Yuan Liyong, Chen Yuebo, et al. Thoracic paravertebral block versus intravenous patient-controlled analgesia for pain treatment in patients with multiple rib fractures. *Journal of International Medical Research* 2017, Vol.45(6)2085–2091.
10. Gleen S. Murphy et al. Residual Neuromuscular Blockade and Critical Respiratory Events in the Postanesthesia Care Unit. *Anesth Analg* 2008;107:130 –7.
11. Althausen PL, Shannon S, Watts C, et al. Early surgical stabilization of flail chest with locked plate fixation. *J Orthop Trauma*. 2011 Nov;25(11):641-7.
12. Bataille B, Nucci B, De Selle J, Mora M, Moussot PE, Cocquet P, Silva S. Paravertebral block restore diaphragmatic motility measured by ultrasonography in patients with multiple rib fractures. *J Clin Anesth*. 2017 Nov;42:55-56.
13. Koo CH, Park EY, Lee SY, Ryu JH. The Effects of Intraoperative Inspired Oxygen Fraction on Postoperative Pulmonary Parameters in Patients with General Anesthesia: A Systemic Review and Meta-Analysis. *J Clin Med*. 2019 Apr 28;8(5).
14. O' Toole D, Hassett P, Contreras M, et al. Hypercapnic acidosis attenuates pulmonary epithelial wound repair by an NF- $\kappa$ B dependent mechanism[J]. *Thorax*, 2009, 64(11):976- 982.
15. Sinclair SE, Kregenow DA, Lamm WJ, et al. Hypercapnic acidosis is protective in an in vivo model of ventilator-induced lung injury[J]. *Am J Respir Crit Care Med*, 2002, 166(3):403-408.
16. Broccard AF, Hotchkiss JR, Vannay C, et al. Protective effects of hypercapnic acidosis on ventilator-induced lung injury. *Am J Respir Crit Care Med*, 2001, 164(5):802- 806.
17. Jonathan M, Eddy F. Carbon Dioxide in the Critically Ill: Too Much or Too Little of a Good Thing? [J]. *Respir Care*, 2014, 59(10):1597-1605.
18. Luftig J, Mantuani D, Herring AA, et al. Successful emergency pain control for posterior rib fractures with ultrasound-guided erector spinae plane block. *Am J Emerg Med*. 2018 Aug;36(8):1391-1396.
19. Amer Harky, Ciaran Grafton Clarke, Ashok Kar, Mohamad Bashir. Epidural analgesia versus paravertebral block in video-assisted thoracoscopic surgery. *Interactive CardioVascular and Thoracic Surgery*, Volume 28, Issue 3, March 2019, Pages 404–406.
20. Onishi E, Murakami M, Nishino R, et al. Analgesic Effect of Double-Level Retrolaminar Paravertebral Block for Breast Cancer Surgery in the Early Postoperative Period: A Placebo-Controlled, Randomized Clinical Trial. *Tohoku J Exp Med*. 2018 Jul;245(3):179-185.
21. Sebastian G Russo, Stephan Cremer, Tamara Galli, et al. Randomized comparison of the i-gel™, the LMA Supreme™, and the Laryngeal Tube Suction-D using clinical and fiberoptic assessments in elective patients. *BMC Anesthesiol*. 2012; 12: 18.
22. Noda M, Okada Y, Maeda S, et al. Is there a benefit of awake thoracoscopic surgery in patients with secondary spontaneous pneumothorax? *J Thorac Cardiovasc Surg* 2012;143:613-6.

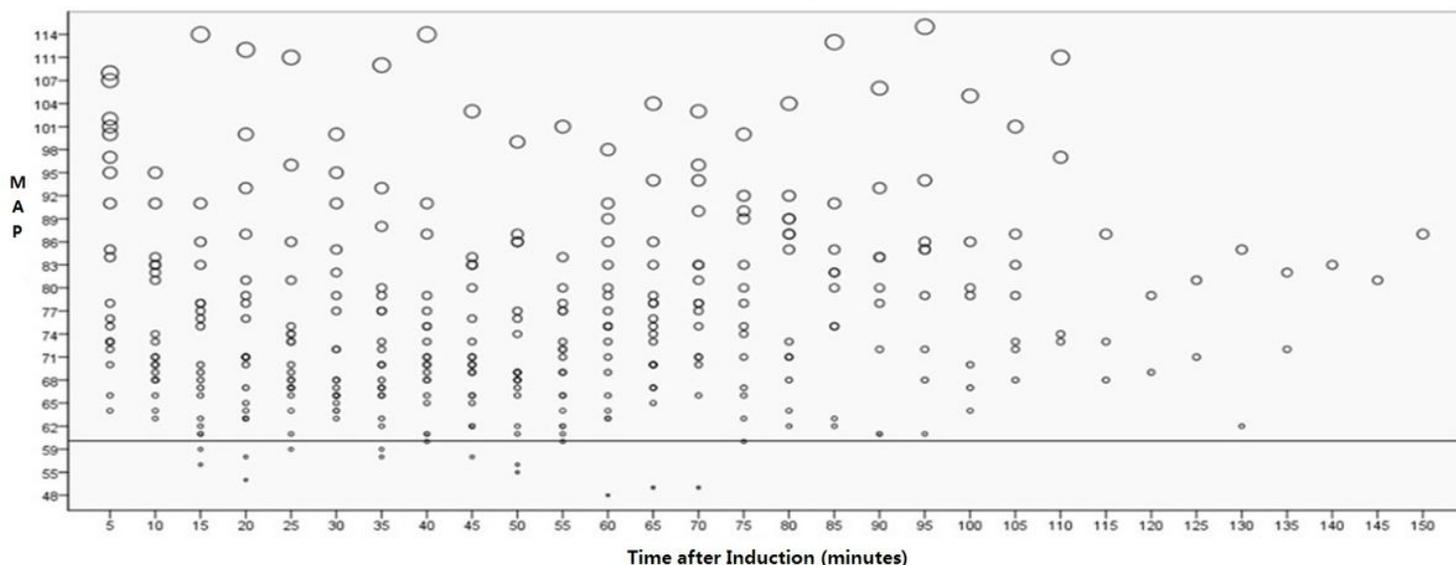
23. Michael E. Kelly BA, Daniel Mc Nicholas, James Killen, Joey Coyne, Karl J. Sweeney MD, John McDonnell. Thoracic paravertebral blockade in breast surgery: Is pneumothorax an appreciable concern? A review of over 1000 cases. *Breast J.* 2018;24:23–27.
24. Krediet AC, Moayeri N, van Geffen GJ, et al. Different Approaches to Ultrasound-guided Thoracic Paravertebral Block: An Illustrated Review. *Anesthesiology.* 2015 Aug;123(2):459-74.

## Figures



**Figure 1**

Ultrasound-guided cross-sectional in-plane approach. A, The image of TPB. B, The image of ESPB. Arrowheads indicate the needle. PP, Parietal Pleura; VL, Vertebral Lamina; TP, Transverse Process; SP, Spinae Process; IIM-SCTL, Internal Intercostal Membrane, and Superior Costotransverse Ligament; ESM, Erector Spinae Muscle; MRM, Musculus Rhomboideus Major.



**Figure 2**

Scatterplot of all patients' MAPs acquired every five minutes during the anesthesia.

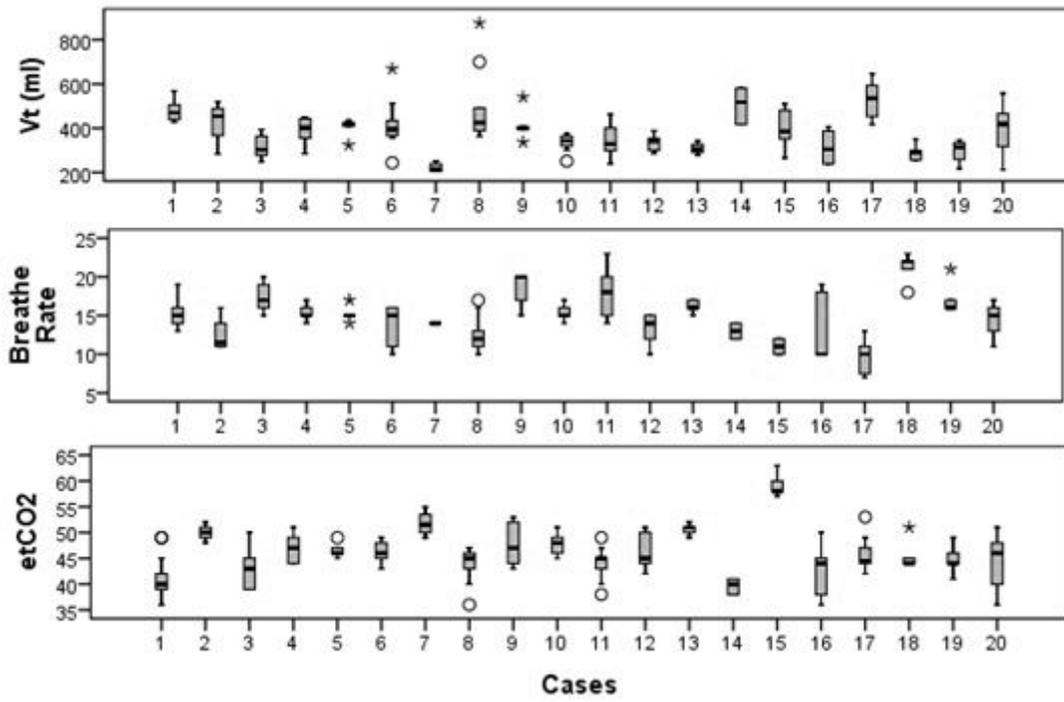


Figure 3

Boxplot of respiratory parameters(Vt, BR and EtCO2) during spontaneous breathing.

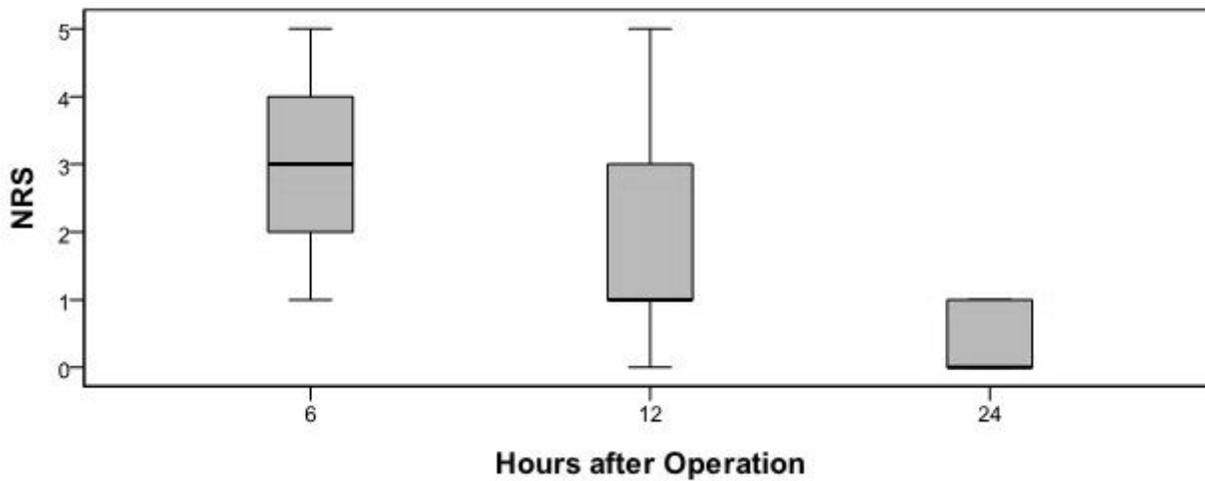
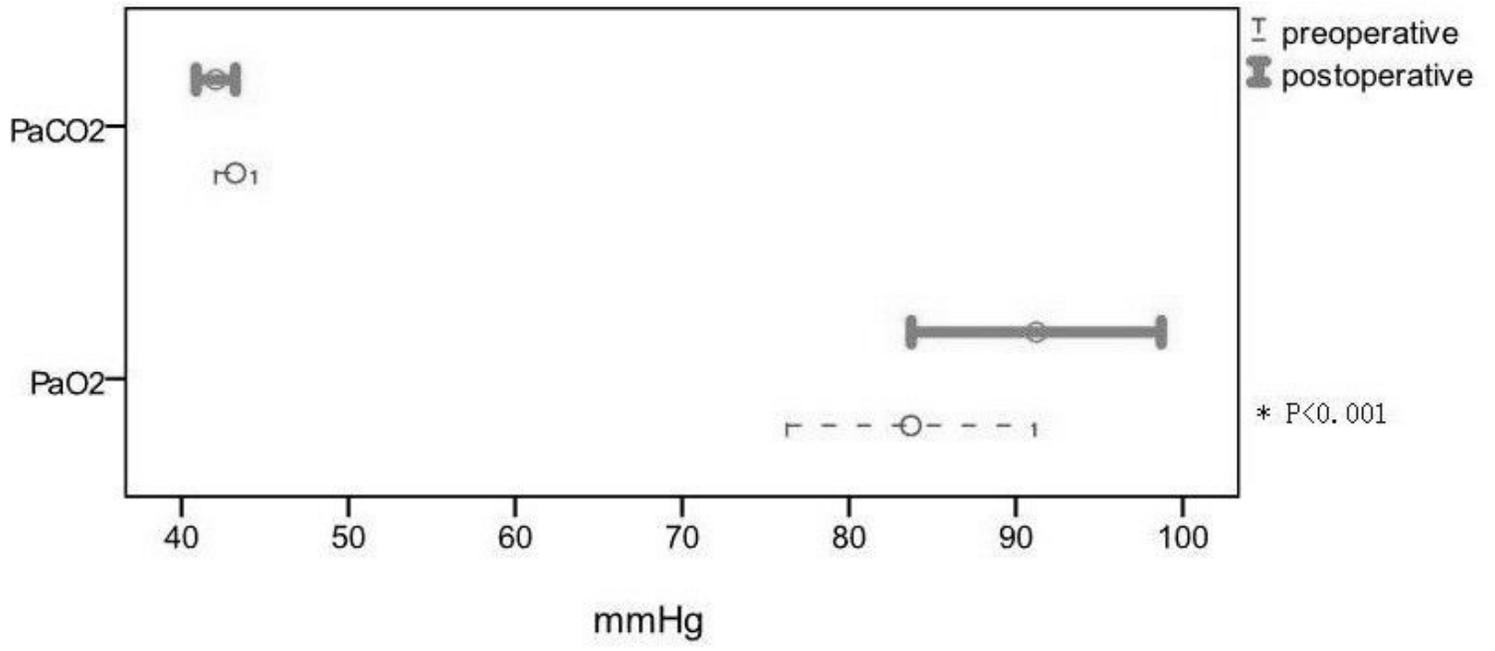


Figure 4

Boxplot of patients' NRS at 6, 12, 24 hours postoperatively.



**Figure 5**

Blood gas analysis(PaO2 and PaCO2) of pre-operation and post-operation.