Feasibility of laryngeal mask anesthesia combined with nerve block in adult patients undergoing internal fixation of rib fractures: a prospective observational study

CURRENT STATUS: Under Review

BMC Anesthesiology  •  BMC series

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Subject Areas

Prescreen

10.21203/rs.2.17107/v3
Anesthesiology & Pain Medicine

Keywords

erector spinae plane block, laryngeal mask anesthesia, non-tracheal intubation, rib fractures, thoracic paravertebral block
Abstract

Background: Laryngeal mask airway (LMA) anesthesia with nerve block seems a promising alternative to traditional general anesthesia with endotracheal intubation (ETI), and was applied in kinds of surgeries but not in rib fracture surgery. We developed a protocol for LMA anesthesia technique and evaluated its feasibility for internal fixation of rib fractures.

Methods: Twenty patients undergoing unilateral rib fracture surgery were enrolled. Thoracic paravertebral block (TPB) and/or erector spinae plane block (ESPB) were performed before LMA anesthesia. Heart rate (HR), blood pressure (BP), pulse oximetry (SpO₂) and respiratory parameters were measured. Arterial blood gas analysis and chest X-ray were performed preoperatively and on the day after the operation. All patients received postoperative continuous analgesia (PCA) with 500mg of tramadol and 16mg of lornoxicam, and intravenous 50mg flurbiprofen twice a day. The numerical rating scale (NRS) pain score at 6(T1), 12(T2), 24(T3) hours after surgery and postoperative nausea and vomiting (PONV) within 48 h after surgery were assessed as well. We also recorded the incidence of perioperative reflux, aspiration, and nerve block related complications.

Results: Thirteen men and 7 women (age 35-70 years) were enrolled. Six (30%) had a flail chest, 9 (45%) had haemothorax and/or pneumothorax, and 2 (10%) had pulmonary contusions. Vital signs and spontaneous breathing were stable during the surgery. End-tidal carbon dioxide concentrations (EtCO₂) were within an acceptable range (≤ 63mmHg in all cases). The postoperative partial pressure of arterial oxygen (PaO₂) was higher than the preoperative value (91.2±16.0 vs. 83.7±15.9 mmHg, p =0.004). The preoperative and postoperative partial pressure of arterial carbon dioxide (PaCO₂) were 42.1±3.7 and 43.2±3.7 mmHg (p =0.165), respectively. NRS at T1, T2, and T3 were 3±1, 2±2, and 0, respectively. None suffered from PONV, regurgitation, aspiration and nerve block related complications.

Conclusions: The technique of laryngeal mask anesthesia combined with nerve block was feasible for internal fixation of rib fractures.

Background

Rib fracture is one of the most common injuries following blunt trauma, occurring in approximately 10% of all trauma patients. Surgical stabilization of rib fractures has been shown to be extremely beneficial in those patients with flail chest and multiple severe displaced fractures and should be strongly considered in this patient population[1]. In the past, general anesthesia with ETI was considered mandatory for rib surgery. However, it might cause ventilator-induced lung injury (VILI)[3], postoperative agitation, cognitive impairment[4], nausea, and frequent vomiting. Patients might also suffer from delayed awakening or even re-intubation due to residual general anesthetics[11]. Currently, enhanced recovery after surgery (ERAS) protocol is well established as the best care. LMA anesthesia combined with nerve block, has an advantage of early extubation, and is a critical part of ERAS and has been occasionally applied in thoracic surgery[2]. Nevertheless, this technique had not yet been applied in rib fracture surgery. It was unknown whether it would be comfortable in rib fracture surgery since these patients usually suffer from dyspnea due to complications such as hemothorax, pneumothorax, atelectasis, and paradoxical breathing[22]. Therefore, we design this prospective observational study to evaluate the feasibility of the technique in adult patients undergoing internal fixation of rib fractures.

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 (ChiCTR1900023763). From June to August 2019, 20
patients scheduled for surgical reduction and fixation of unilateral isolated rib fractures in our hospital, were enrolled in this study. Informed consent was obtained from all patients. The inclusion criteria were American Society of Anesthesiologists physical status I and II, age 18–70 years, body mass index (BMI) <30, preoperative PaO$_2$ > 60mmHg, and preoperative PaCO$_2$ < 50mmHg. The exclusion criteria were difficult airway, esophageal reflux, myasthenia gravis, abnormal coagulation system, gastric ulcer or hemorrhage, allergy to anesthesia-related drugs, asthma or chronic obstructive emphysema, major thoracic vascular injuries, and pregnant women.

**Procedures**

All patients fasted for at least 8 h. BP, SpO$_2$, and electrocardiography were performed when the patients were admitted into the operating room.

Ultrasound-guided TPB was performed using the S-Nerve™ Ultrasound System (Fujifilm SonoSite Inc. Bothell, WA, USA). The patient was placed in the lateral decubitus position. The transversal Inferior Articular Process (IAP) in-plane approach was applied. 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 (Figure 1A). A 22 gauge, 8cm puncture needle (KDL medical apparatus and instruments Co. Wenzhou, China) was inserted into the thoracic paravertebral space (TPVS) from the lateral side. Ropivacaine 0.375% (20-30ml) was injected with no air or blood aspiration.

The injection points of TPVS were selected according to the fractured rib segments requiring surgery (hereinafter referred to as "surgical segments"). If the surgical segments did not have more than 4 sequential ribs, 20ml of ropivacaine was injected into the TPVS of the second fractured rib, referred to as a single-level block. If the surgical segments had more than 4 sequential ribs, 15 ml of ropivacaine was injected into the TPVS of the second and fifth fractured ribs, referred to as a double-level block. We adopted a two-person mode in TPB: one physician operated the ultrasound probe and needle while the other performed the injection and aspiration. Color Doppler ultrasound was initially used to ensure that there were no vessels in the pathway of the needle insertion while approaching the TPVS.

In the case of posterior rib fractures, ESPB was performed to enhance the regional effect of the patient’s back and to supply more effective analgesia of posterior rib fractures as well.$^{[19]}$ Ropivacaine 0.375% (20ml) was injected between the fifth thoracic vertebral transverse process and erector spinae muscle (ESM) on the operative side using the transversal in-plane approach under ultrasound guidance (Figure 1B).

The effect of the regional block was evaluated 15 min after nerve blockade, and the dermatomes of sensory loss were measured by acupuncture and rubbing with alcohol gauze. If the patient felt no pain while deep-breathing and vigorous coughing, and the range of reduction area of cold or pinprick sensation covered the incision, we considered the regional effect to be satisfactory. The patient was then given LMA anesthesia and was included in this study. Otherwise, the patient was administered ETI anesthesia and excluded from the observational analysis.

Anesthesia was induced with 0.1µg/kg sufentanil, 3mg/kg propofol and 0.3mg/kg rocuronium successively. We inserted an LMA Supreme™ (Teleflex Medical Co. Westmeath, Ireland) and ensured the LMA was correctly positioned. Mechanical ventilation commenced with a pressure control ventilation-volume guaranteed mode, at 6 ml/kg and respiratory rate(RR) of 12 breaths/min. The inspiratory to expiratory ratio was 1:2. A 14# gastric tube was placed for drainage of the fluid and/or gas that might escape into the stomach during positive pressure ventilation.

Anesthesia was maintained with sevoflurane at 0.7-1.2 age-adjusted minimum alveolar concentration (MAC) in 50% oxygen in air mixture depending on the hemodynamic responses to surgical intervention. Spontaneous breathing was maintained after recovery. A supplementary dose of 0.03 µg/kg sufentanil was allowed if the HR was 20% faster than the basic value, or RR was more than 20 breaths/min for surgical stimulation. Phenylephrine and atropine were injected if necessary. Sevoflurane inhalation was withdrawn and 50mg flurbiprofen was infused intravenously at 15 min before the end of the surgery. The muscle relaxant antagonist and neuromuscular blockade monitoring were not used in this study and all patients were allowed to recover on their own.
The patient was converted to ETI anesthesia as one of the following occurred: 1. The surgical field was difficult to expose because of muscular tension. 2. The LMA could not be placed in the correct position after three attempts. 3. Hemodynamic instability occurred. 4. The SpO$_2$ was less than 90% or the concentration of EtCO$_2$ was more than 70 mmHg.

PCA (infusion rate 2 ml/h, total volume 100 ml) containing 500 mg tramadol and 16 mg lornoxicam was routinely administered to all patients. The 50 mg flurbiprofen was infused intravenously twice a day. If the patient's NRS was >4, an analgesia rescue of 50 mg pethidine was administered intramuscularly.

**Data Collection**

Vital signs during the anesthesia, tidal volume (Vt), RR, and EtCO$_2$ during spontaneous breathing were recorded. The time to removal of LMA and the events of agitation or hoarseness in the Post-Anesthesia Care Unit (PACU) were also recorded. Preoperative and postoperative arterial blood gas analysis and chest X-ray were routinely obtained.

Postoperative nausea and vomiting (PONV) within 48 h after surgery and NRS pain score were assessed at 6(T1), 12(T2), and 24(T3) hours after surgery. We also recorded dosages of sufentanil and vasoactive drugs administered and the cases that were converted to ETI during the operation. The perioperative complications such as regurgitation, aspiration, and injuries relating to nerve block were recorded as well.

**Statistical analysis**

SPSS 19.0 software was used for statistical analysis. The sample size was calculated based on the change of PaO$_2$. Seventeen patients were required to detect a mean difference of 10 mmHg and standard deviation of 10 mmHg, power of 0.8, and α-value of 0.05. We factored in a 15% dropout rate and enrolled 20 patients. Quantitative variables were expressed as mean±SD. Categorical variables were expressed as quantitative values or in percentage. The results of arterial blood gas analysis that were measured pre- and post-operatively, were compared using the Student's t-test. $p < 0.05$ was considered statistically significant.

**Results**

Twenty patients were enrolled in this study, and their characteristics are shown in Table 1. Eight (40%) patients received single-level TPB, while the remaining 12 (60%) patients received double-level TPB. ESPB was combined in 13 (65%) patients. All the patients had a satisfactory blockade and received LMA anesthesia. None of the patients were converted to ETI anesthesia due to the poor position of the LMA or insufficient ventilation. A flow chart of patients recruited for the study is depicted in Figure 2.

Most of the patients’ mean arterial pressures (MAP) were stable. Eight (40%) patients had MAPs less than 60 mmHg and were treated by phenylephrine. The dosage of phenylephrine was 80-300 (200±76) μg. Patients’ SpO$_2$ before anesthesia was 96±3.6% and remained above 95% (99.1±1.3%) during the operation, except for one patient. His SpO$_2$ declined from 100% to 87% transiently but recovered to 98% within 5 min. The duration from LMA insertion to spontaneous breathing recovery was 27.25±19.43 min. Vt, RR, and EtCO$_2$ during spontaneous breathing were in the range of 205-875 ml, 7-23 breaths/min, 36-63 mmHg, respectively. One patient’s EtCO$_2$ exceeded 60 mmHg, ranging from 57 mmHg to 63 mmHg.

The time to removal of LMA was 1-11 (6±3) min. None of the patients had agitation or sore throat after anesthesia. Perioperative regurgitation, aspiration and nerve block related complications were not observed in any of the patients.

The postoperative PaO$_2$ was significantly improved compared with its preoperative value (91.2±16.0 vs. 83.7±15.9 mmHg, p=0.004). Nevertheless, there was no significant difference between preoperative and postoperative PaCO$_2$ (42.1±3.7 vs. 43.2±3.7 mmHg, p=0.165). The dosage of sufentanil was 5-17 (9.9±3.3) μg.
Atropine was not required for any patient.

The postoperative NRS values at T1, T2, and T3 were 3±1, 2±2, and 0, respectively. In this study, the highest score was 5 in 4 patients (20%). Two of them had a score of 5 at 6 h and the other 2 at 12 h after surgery. All 4 patients received one intramuscular injection of 50mg pethidine as analgesia rescue, and the pain was relieved. PONV did not occur within 48 hours after surgery in all cases.

Neither slight muscle twitching caused by high-frequency electrotome, nor thoracic excursion during breathing impeded the surgeons' operation. The surgeons were satisfied with the anesthesia in all cases.

Discussion

In this study, our results showed that the LMA anesthesia combined with nerve blocks such as TPB and ESPB could offer a satisfactory analgesia, stable hemodynamic function, good oxygenation, acceptable EtCO₂, and thereby a smooth recovery.

Although thoracic epidural anesthesia is a golden standard for thoracic analgesia, it can frequently induce hypotension. It is also associated with serious complications, such as epidural hematoma and neuropathy[5]. Therefore, a variety of nerve blocks as alternatives to epidural anesthesia, such as serratus anterior plane block (SAPB), intercostal nerve block (INB), and ESPB. Nevertheless, there are some limitations to the above-mentioned methods. The local anesthetic of SAPB is distributed along the midaxillary line near the surgical incision, which may impede the surgeon from transecting the muscular layers. INB requires multi-injection, which subjects the patient to more pain and increases the risk of inadvertent intercostal vessels or pleural puncture. ESPB is administered in the intermuscular space, the incidence of a complete block is only 1/3[6]. TPB can provide reliable effect which might be equivalent to unilateral epidural anesthesia with less hemodynamic depression. Therefore, we chose TPB for inducing local anesthesia in our study. Meanwhile, all patients maintained steady hemodynamic functions by occasional administration of phenylephrine. The intercostal (IC) and paralaminar (PL) approaches are commonly used in TPB. Yasuko Taketa et al.[7] considered that a single injection of 20ml ropivacaine 0.375% via the PL approach could acquire 4-5 dermatomes of sense blockade. They found that the blocked dermatomes of sensory loss in PL group were more than in IC group. The average of blocked dermatomes was 3 in IC group and 4 in PL group, respectively. In addition, the PL approach was regarded as a better choice to block the dorsal ramus of the thoracic nerves[8]. It seems TPB through PL approach would obtain a wider block effect compared to IC approach and should be applied preferentially. Our approach of TPB is the same as Taketa's PL approach and is also consistent with the transversal IAP approach described by Krediet et al.[20] Moreover, we chose the TPVS of the second fractured rib for injection when the surgical segments were not more than 4 sequential ribs because we found that the blocked area to the caudal area was more extensive than that to cephalic in our pilot experiment.

In our study, the analgesic effect of nerve block was sufficient and maintained about 6 hours after the operation. This was consistent with the duration of postoperative analgesia of TPB (303.97±76.08 min) reported by Das et al.[9] Because of PCA and intravenous infusion of flurbiprofen, most patients felt pain acceptably. This indicated that the multi-mode analgesia protocol was effective and necessary for postoperative analgesia. This result also suggests that we may achieve better postoperative analgesia by TPB catheterization in our future work, as reported by Ge Yeying[10].

Most patients with rib fractures experienced dyspnea. The satisfactory effect of TPB could improve patient oxygenation because respiratory amplitude increases when the patients do not feel pain[13]. The patients' Vt and RR during spontaneous breathing can meet the needs of intraoperative oxygenation, even in LMA anesthesia with 50% oxygen. Koo et al. concluded that an oxygen concentration of 50% could decrease the risk of atelectasis caused by high oxygen concentration[14]. Our results showed that all patients maintained their SpO₂ at good level during the operation, including 3 patients whose preoperative SpO₂ was lower than 93%. The minimum SpO₂ was 87%, which occurred transiently in one case. Preoperative chest CT showed a large amount
of pleural effusion, incomplete atelectasis, and consolidation of the inferior lobe on the injured thorax. The decline in SpO₂ was attributed to a notable decrease in tidal volume caused by sufentanil. However, it increased to 98% in a few min and remained at 100% until the end of surgery.

In thoracic surgery, postoperative pulmonary complications (PPCs) are problems that should be addressed. Recruitment maneuver and airway suction might be beneficial to patients during ETI anesthesia. The leak pressure of the LMA Supreme™ was 27.1 ± 5.2 cmH₂O according to Russo’s report[21]. Thus, the LMA Supreme™ could settle for recruitment maneuver during anesthesia. Early extubation and good analgesia in our study promoted patients to have enough strength to cough and expectorate postoperatively, also beneficial to lung recruitment. In particular, the early recovery of spontaneous breathing reduced pulmonary problems associated with mechanical ventilation. 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 an imbalance in the ventilation/perfusion (V/Q) ratio with excessive or inadequate tidal volume. Barotrauma and volume injury caused by mechanical ventilation can also cause VILI. The information above indicates that spontaneous breathing might be beneficial to lung protection. In our study, the postoperative PaO₂ was improved compared to the preoperative PaO₂. No pneumonia was found in the chest X-ray after surgery.

The patients showed carbon dioxide retention in different degrees during spontaneous breathing. The EtCO₂ of most patients was below 50 mmHg at the end of surgery. The highest EtCO₂ value in our study was 63 mmHg, and occurred in a male patient. His final EtCO₂ was 58 mmHg when the surgery ended. All patients were fully awake after extubation. Their PaCO₂ values checked on the second day after surgery were all within the normal range. The concept of permissive hypercapnia has been accepted for a long time. O’Toole et al.[15] believed that hypercapnia could produce an anti-inflammatory effect by inhibiting nuclear factor-kappa B (NF-kB). Other scholars thought that hypercapnia had a protective effect on VILI[16,17]. Hypercapnia can also improve pulmonary compliance by a non-surfactant mechanism and enhance pulmonary vascular resistance by strengthening hypoxic pulmonary vasoconstriction to decrease pulmonary shunt[18].

The serratus anterior and latissimus dorsi muscles were innervated by the long thoracic and thoracodorsal nerves, respectively. TPB can not paralyze these muscles. We found that one ED₉₅ of rocuronium could weaken muscle twitching when the surgeons transected the muscles using a high-frequency electrotome. Murphy et al. [11] pointed out that the residual effect of muscle relaxants was one of the causes of postoperative respiratory failure and critical respiratory events observed in 18.0% of patients undergoing thoracic surgeries. Althausen et al. reported that the incidence of re-intubation after surgical stabilization of the flail chest was 4.55%(1/22)[12].

The half dosage of muscular relaxants for ETI anesthesia in our study facilitated the patients to recover spontaneous breathing during surgery. So we did not monitor neuromuscular blockade or administer muscle relaxant antagonists to any of the patients. Besides, they maintained a good level of cough strength after extubation, and did not need re-intubation.

There were several limitations to this study. Due to the small sample size, the capacity to evaluate the potential risks such as regurgitation, aspiration, and nerve block related complications is limited. The patient selection and lack of a control group also attributed to the limitations. Since the initial focus was on whether the anesthetic technique could meet the needs of rib surgery. We excluded patients with difficulty extubation conditions such as respiratory failure, obesity, difficult airway, myasthenia gravis, asthma, and chronic obstructive emphysema. Although early extubation occurred and PPCs such as pneumonia and acute respiratory distress syndrome were not observed, these findings are not sufficient enough to declare superiority when compared with ETI anesthesia. The results in our study might provide a basis for further randomized controlled trials to access safety and effectiveness of this anesthesia technique.

**Conclusions**

We demonstrated that LMA anesthesia combined with nerve block anesthesia can be feasibly applied in internal
fixation of rib fractures. This practice could provide stable hemodynamic and respiratory function, and an advantage for smooth recovery.

**List Of Abbreviations**

LMA: Laryngeal mask airway;  
TPB: Thoracic paravertebral block;  
ESPB: Erector spinae plane block;  
HR: Heart rate;  
BP: Blood pressure;  
SpO₂: Pulse oxygen saturation;  
PCA: Postoperative continuous analgesia;  
NRS: Numerical rating scale;  
EtCO₂: End-tidal carbon dioxide concentration;  
PaO₂: Partial pressure of arterial oxygen;  
PaCO₂: Partial pressure of arterial carbon dioxide;  
ETI: Endotracheal intubation;  
VILI: Ventilator-induced lung injury;  
BMI: Body mass index;  
IAP: Inferior Articular Process;  
TPVS: Thoracic paravertebral space;  
PONV: Postoperative nausea and vomiting;  
Vt: Tidal volume;  
RR: Respiratory rate;  
MAC: Minimum alveolar concentration;  
SAPB: Serratus anterior plane block;  
INB: Intercostal nerve block;  
IC: Intercostal;  
PL: Paralaminar;  
ED₉₅: 95% effective dose;  
PPCs: Postoperative pulmonary complications
Declarations

Ethics approval and consent to participate

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 (ChiCTR1900023763). Informed consent was obtained from all patients.

Consent for publication

Not applicable

Availability of data and material

The datasets used and analyzed 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 JC and JFZ, and was conducted by JC, XYG, XLZ. XYG and JL collected the data. JC analyzed the data and drafted the manuscript. All authors read and approved the final manuscript.

Acknowledgments

Not applicable

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Table 1. Demographics and clinical characteristics of the patients
| Variable                                           | N    | Mean        | %   |
|---------------------------------------------------|------|-------------|-----|
| Sex(male/female)                                  | 13/7 |             |     |
| Age(y)                                            | 35-70| 54.15±8.67  |     |
| BMI(kg/m²)                                        | 19.1-29.7| 24.29±2.75 |     |
| Flail chest                                       | 6    | 30          |     |
| Hemothorax or/and pneumothorax                    | 10   | 50          |     |
| Atelectasis                                       | 5    | 25          |     |
| Pulmonary contusion                               | 2    | 10          |     |
| Thoracic drainage placed in surgery               | 9    | 45          |     |
| Duration of surgery (min)                         |      | 70±21       |     |

Figures
Ultrasound-guided transversal 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.
Myasthenia gravis
Gastric ulcer or hemorrhage
Asthma or chronic obstructive emphysema
The patients presented with major thoracic vascular...

Consented (20)

Without posterior rib fractures (7)

Received TPB (7)

Nerve block effect was cons...

Administered anesthesia wit...
FIGURE 2. Flow chart of patients in the study.

Figure 2
Flow chart of patients in the study.