Clinical Report

Journal of INTERNATIONAL MEDICAL RESEARCH

Journal of International Medical Research
2017, Vol. 45(6) 2085–2091

DOI: 10.1177/0300060517710068
journals.sagepub.com/home/imr
SAGE

Thoracic paravertebral block versus intravenous patient-controlled analgesia for pain treatment in patients with multiple rib fractures

Ge Yeying[1], Yuan Liyong[1], Chen Yuebo[1], Zhang Yu[1], Ye Guangao[1], Ma Weihu[2] and Zhao Liujun[2]

Abstract

Objectives: To assess the effect of thoracic paravertebral block (PVB) on pain management and preservation of pulmonary function compared with intravenous, patient-controlled analgesia (IVPCA) in patients with multiple rib fractures (MRFs).

Methods: Ninety patients with unilateral MRFs were included in this prospective study and randomly assigned to the TPVB or IVPCA group. The visual analogue scale (VAS) pain score, blood gas analysis, and bedside spirometry were measured and recorded at different time points after analgesia.

Results: TPVB and IVPCA provided good pain relief. VAS scores were significantly lower in the TPVB group than in the IVPCA group at rest and during coughing ($P < 0.05$). Patients in the TPVB group had a higher PaO_2 and PaO_2/FiO_2 and lower $P_{(A–a)}O_2$ compared with the IVPCA group ($P < 0.05$). Moreover, patients in the TPVB group showed higher FVC, FEV1/FVC, and PEFR, and fewer complications than did the IVPCA group ($P < 0.05$).

Conclusion: TPVB is superior to IVPCA in pain relief and preservation of pulmonary function in patients with MRFs.

Keywords

Paravertebral block, multiple rib fractures, analgesia, pulmonary function

Date received: 19 February 2017; accepted: 25 April 2017

Introduction

Rib fractures are the most common of all chest injuries and occur in up to 80% of patients with blunt chest trauma.[1] Multiple rib fractures (MRFs) cause severe pain,

[1]Department of Anesthesiology, Ningbo 6th Hospital, Ningbo 315040, China
[2]Department of Orthopeadic Surgery, Ningbo 6th Hospital, Ningbo 315040, China

Corresponding author:
Ge Yeying, Department of Anesthesiology, Ningbo 6th Hospital, Ningbo 315040, China.
Email: geyeying59198@163.com

which may adversely affect coughing and deep breathing. Pain relief is important for preventing complications, including atelectasis, chest infection, and respiratory failure.[2] These complications, if severe, may be more harmful than the injury itself, and can be life-threatening.

Paravertebral block (PVB), through injecting a local anaesthetic agent close to where the spinal nerves exit the intervertebral foramina, can provide high-quality ipsilateral, segmental, somatic, and sympathetic nerve blockade. PVB is a successful regional method for amelioration of pain in patients undergoing esophagectomy,[3] breast surgery,[4] thoracotomy,[5] cardiac surgery,[6] hepatectomy,[7] inguinal herniorrhaphy,[8] percutaneous nephrolithotomy,[9] and nephrectomy.[10] Thoracic paravertebral block (TPVB) has also been used for pain relief of MRFs.[11–13] Differences in the efficacy and safety between TPVB and traditional analgesia for MRFs, including thoracic epidural analgesia (TEA) and intravenous analgesia, need to be considered. Mohta et al.[14] showed that TPVB was as effective as TEA for pain treatment in patients with unilateral MRFs. However, comparison between TPVB and intravenous analgesia in patients with MRF has rarely been reported. Therefore, this study aimed to assess the effect of TPVB on pain management and preservation of pulmonary function compared with intravenous patient-controlled analgesia (IVPCA) in patients with MRFs.

Materials and methods

Patients and procedures

The study was conducted at Ningbo 6th Hospital (Ningbo, China) between January 2015 and August 2016. The protocol was approved by the ethics committee of Ningbo 6th Hospital and written informed consent was obtained from each patient. This prospective, randomized study included 90 adult patients of either sex, having three or more unilateral fractured ribs. The exclusion criteria were as follows: age <18 or >70 years; severe head injury or unconsciousness; pathological obesity (body mass index ≥35); thoracic and abdominal visceral injuries; unstable cardiac status; severe liver or kidney disease; coagulopathy; spinal or pelvic fracture; infection at the puncture site; and allergy to local anaesthetics. The patients' characteristics are shown in Table 1.

Table 1. Demographic and morphometric characteristics of the participants.

Factors	TPVB group	IVPCA group	P
Age, y	39.1 ± 8.9	41.2 ± 9.7	NS
Sex, males/females	29/16	31/14	NS
Weight, kg	70.1 ± 10.9	72.3 ± 11.6	NS
Number of fractured ribs	3.9 ± 1.2	4.1 ± 1.4	NS
Abbreviated Injury Score	3.1 ± 0.8	3.0 ± 0.9	NS
Injury Severity Score	14.2 ± 5.1	13.7 ± 5.5	NS

On arrival to the anaesthetic room, intravenous access was established, and standard monitors were applied, including electrocardiography, noninvasive blood pressure, and pulse oximetry. All of the patients received oxygen via a nasal cannula to maintain $SpO_2 > 90\%$ blood oxygen saturation and none of them received mechanical ventilation. By using the sealed envelope technique, the patients were assigned randomly to the TPVB or IVPCA group. In the TPVB group, the patients were placed in the lateral decubitus position. A 7.5-MHz linear ultrasound probe (LOGIQ α-200 E, GE Healthcare, Waukesha, USA) was used to identify the spinous process, transverse process, pleura, superior costotransverse ligament, and the paravertebral space at the target vertebral level. After standard skin disinfection, a 20-gauge, 8-cm puncture needle (Pajunk GmbH Medizintechnologie, Geisingen, Germany) was inserted into the

paravertebral space under ultrasound guidance. This was performed using a lateral to medial in-plane needle insertion technique as previously described.[15,16] After negative aspiration for blood and cerebrospinal fluid, 15 ml of 0.5% ropivacaine was slowly injected. A 24-gauge, 30-cm catheter (Pajunk GmbH Medizintechnologie, Geisingen, Germany) was then inserted 3–4 cm beyond the needle tip. After negative aspiration for blood and cerebrospinal fluid, 15 ml of 0.5% ropivacaine was injected. The solution in the TPVB pump contained 250 mL of 0.2% ropivacaine, and the continuous infusion rate was set at 5 mL/h. The bolus dose was 5 mL and the lockout interval was 15 minutes. In the IVPCA group, sufentanil 2 μg/kg diluted in normal saline was used as the IVPCA solution and the volume was 100 mL. The continuous delivery dose was set at 2 mL/h. The bolus dose was 2 mL with a 15-minute lockout time. For each patient, oral acetaminophen (500 mg) was provided every 12 hours. Low-dose tramadol 1 mg/kg was administered when the visual analogue scale (VAS) score was greater than 4 as rescue analgesia.

Measurements and sample size calculation

Trained nurses who were blinded to the patient's treatment collected various data. Pain at rest and on coughing was estimated with the VAS pain score (0, no pain; 10, worst imaginable pain). Blood gas analysis was performed to measure arterial partial pressure of oxygen (PaO_2), arterial partial pressure of carbon dioxide ($PaCO_2$), PaO_2/Fraction of inspiration oxygen (FiO_2), and Alveolar - arterial oxygen partial pressure difference ($P_{(A-a)}O_2$.) These parameters were recorded pre-analgesia (T_0), at 60 minutes post-analgesia (T_1), and on post-analgesia days 1 (T_2), 2 (T_3), and 3 (T_4). Bedside spirometry (forced vital capacity (FVC), forced expiratory volume in one second (FEV1)/FVC, and the peak expiratory flow rate [PEFR]) was measured by using a ventilometer (CHEST HI-701; YILIAN Medicine, Shanghai, China) at T_0, T_1, and T_4. All anaesthesia-related adverse events were also recorded.

This study aimed to compare the efficacy and safety of TPVB as a method of pain relief following MRFs compared with IVPCA. The primary outcome measurement was the VAS score at rest. After a pilot study (6 patients per group), a 23% reduction was found in the TPVB group. The authors then estimated that the required minimum sample size would be 22 patients per group, with a significance level of 0.05 and a power of 90%. Finally, 90 patients were enrolled in this study (45 patients per group).

Statistical analysis

SPSS15.0 software was used for statistical analysis. Quantitative variables are expressed as means ± SD and were compared using the t test. Categorical variables are expressed as number (%) and were compared using the chi-square test. $P < 0.05$ was considered significant.

Results

A total of 90 patients were included in this study. The patients' characteristics are shown in Table 1. There were no significant differences in age, sex, body weight, number of fractured ribs, chest Abbreviated Injury Score, and Injury Severity Score between the two groups ($P > 0.05$).

There was a significant decrease in VAS scores at rest and during coughing at all time points after analgesia (T_1–T_4) compared with baseline values (T_0) in the TPVB and IVPCA groups (Table 2). The pain scores at rest at T_1 and T_2 were significantly lower in the TPVB group than in the IVPCA group. Additionally, a significant difference was found in pain scores were significantly lower during

Table 2. Mean VAS scores at rest and with coughing in the TPVB and IVPCA groups.

Time	TPVB group	IVPCA group
T_0 (rest)	7.6 ± 2.2	7.8 ± 2.1
T_0 (coughing)	7.9 ± 2.0	8.0 ± 2.2
T_1 (rest)	3.9 ± 1.3*	4.9 ± 1.5*#
T_1 (coughing)	4.5 ± 1.6*	5.6 ± 1.7*#
T_2 (rest)	3.4 ± 1.0*	4.1 ± 1.2*#
T_2 (coughing)	3.9 ± 1.1*	4.5 ± 1.3*#
T_3 (rest)	2.8 ± 0.9*	3.0 ± 1.0*
T_3 (coughing)	3.3 ± 0.8*	3.5 ± 0.9*#
T_4 (rest)	2.1 ± 0.5*	2.2 ± 0.6*
T_4 (coughing)	2.7 ± 0.6*	2.8 ± 0.7*#

*$P < 0.05$ compared with T_0; #$P < 0.05$ compared with the TPVB group.

coughing at all time points in the TPVB group compared with the IVPCA group.

Blood gas analysis showed that PaO_2 and PaO_2/FiO_2 were significantly increased, and $P_{(A-a)}O_2$ was significantly decreased at all time points (T_1–T_4) after TPVB compared with baseline values (T_0) (Table 3). In the IVPCA group, we observed increased PaO_2 and PaO_2/FiO_2, and decreased $P_{(A-a)}O_2$ only at the time points of T_2, T_3, and T_4 compared with baseline values. Furthermore, patients in the TPVB group had significantly higher PaO_2 and PaO_2/FiO_2 (T_2–T_4), and lower $P_{(A-a)}O_2$ (T_1–T_4) compared with the IVPCA group (Table 3).

The bedside pulmonary function test showed increased FVC, FEV1/FVC, and PEFR after analgesia (T_1 and T_4) in the TPVB and IVPCA groups compared with baseline values (T_0) (Table 4). Moreover, patients in the TPVB group showed higher FVC, FEV1/FVC, and PEFR compared with the IVPCA group at T_1 and T_4.

No serious anaesthesia-related complications or deaths occurred in either group. The incidence of pulmonary complications was significantly less in the TPVB group (n = 3, 6.7%) than in the IVPCA group (n = 9, 20%, $P < 0.05$). The incidence of nausea/vomiting and somnolence was also higher in

Table 3. Effects of TPVB and IVPCA on PaO_2, PaO_2/FiO_2, and $P_{(A-a)}O_2$.

	TPVB group					IVPCA group				
Factors	T_0	T_1	T_2	T_3	T_4	T_0	T_1	T_2	T_3	T_4
PaO_2 (mmHg)	65 ± 13	71 ± 15*	80 ± 17*#	88 ± 19*#	95 ± 20*#	67 ± 14	69 ± 14	73 ± 16*	80 ± 17*	87 ± 19*
PaO_2/FiO_2 (mmHg)	332 ± 43	385 ± 48*	411 ± 55*#	432 ± 59*#	446 ± 61*#	343 ± 47	361 ± 49	384 ± 51*	401 ± 58*	410 ± 67*
$P_{(A-a)}O_2$ (mmHg)	37 ± 4.2	26 ± 3.5*#	21 ± 2.7*#	18 ± 2.2*#	17 ± 2.3*#	38 ± 4.5	34 ± 4.4	30 ± 4.1*	23 ± 3.4*	21 ± 2.7*

*$P < 0.05$ compared with T_0; #$P < 0.05$ compared with the IVPCA group.

Table 4. Effects of TPVB and IVPCA on pulmonary function.

	TPVB group			IVPCA group		
Factors	T_0	T_1	T_4	T_0	T_1	T_4
FVC (L)	1.2 ± 0.2	$1.7 \pm 0.3^{*\#}$	$1.8 \pm 0.3^{*\#}$	1.2 ± 0.3	$1.5 \pm 0.2^{*}$	$1.6 \pm 0.3^{*}$
FEV1/FVC	0.60 ± 0.14	$0.71 \pm 0.18^{*\#}$	$0.79 \pm 0.16^{*\#}$	0.58 ± 0.12	$0.65 \pm 0.15^{*}$	$0.70 \pm 0.16^{*}$
PEFR (L/min)	165 ± 31	$241 \pm 53^{*\#}$	$267 \pm 58^{*\#}$	165 ± 31	$212 \pm 49^{*}$	$235 \pm 51^{*}$

$^{*}P < 0.05$ compared with T_0; $^{\#}P < 0.05$ compared with the IVPCA group.

the IVPCA group than in the TPVB group (nausea/vomiting, 28.9% vs 6.7%, $P < 0.05$; somnolence, 8.9% vs 0%, $P < 0.05$).

Discussion

Effective analgesia, which permits deep breathing and coughing, is one of the mainstays of management of patients with MRFs. The clinical analgesic methods for MRFs include TEA, TPVB, and intravenous analgesia. Analyses of the advantages and disadvantages of these different analgesic methods are helpful in clinical practice. TPVB is technically less complex than other methods, and there are few absolute contraindications.[17] Because there is no need for use of opioids, urinary retention and pruritis are not concerns with TPVB.[17] However, rapid absorption of local anaesthetic enables toxicity, especially if more than one catheter is place.[17] Previous studies have already shown the advantages of TPVB compared with TEA in patients with MRFs. PVB shows similar analgesic effects compared with epidural anaesthesia with fewer complications.[14] Therefore, our study focussed on analgesic efficacy, protection of respiratory function, and adverse effects of TPVB compared with IVPCA.

In our study, pain scores at rest (T_1 and T_2) and during coughing (T_1–T_4) were significantly lower in the TPVB group than in the IVPCA group. This finding indicated that TPVB may provide a better analgesic effect than IVPCA. These findings are consistent with the results of previous studies as follows. A previous study showed that paravertebral block was associated with improved postoperative pain relief compared with intravenous analgesia in patients undergoing herniorrhaphy.[18] TPVB is also superior to IVPCA in pain management after thoracotomy.[19] Additionally, TPVB is more efficacious for prolonging postoperative analgesia and reducing morbidity in patients undergoing elective unilateral breast surgery.[20]

Another interesting finding of our study is that there was a significant difference in postanalgesia pulmonary function between the TPVB and IVPCA groups. We observed higher FVC, FEV1/FVC, PEFR, PaO_2, and PaO_2/FiO_2, and lower $P_{(A-a)}O_2$ in the TPVB group compared with the IVPCA group. The incidence of pulmonary complications was significantly higher with IVPCA compared with TPVB. Bilgin et al.[21] also observed a significant reduction in FEV1 and FVC in the systemic analgesia group compared with the TPVB group 24 h and 48 h after thoracotomy. Two possible reasons could explain the advantages of TPVB in pulmonary function protection. First, in our study, TPVB was superior to IVPCA for analgesia, and resulted in lower pain scores, especially during coughing. Effective analgesia in the TPVB group is conducive to deep breathing and coughing, thereby improving lung function. Second, sufentanil, a synthetic opioid, was used in the IVPCA group. Respiratory depression is one of the most feared side effects of opioids.[22] For patients with MRFs, powerful opioids are depressants and suppress coughing, and may promote

respiratory complications even as they reduce pain.[17] Moreover, in the present study, IVPCA was associated with a significantly higher incidence of nausea and vomiting, another common side effect of opioid analgesics compared with TPVB.[23] Taken together, these results suggest that TPVB may be a safer analgesic method for MRFs than IVPCA.

There are some limitations of our study. First, we only collected data at a few time points to avoid disturbing the patients. Second, some parameters, such as blood pressure, heart rate, and respiratory rate, were not included in this study. Studies that contain more parameters need to be included in future studies.

In conclusion, our study shows that TPVB is superior to IVPCA in pain relief and preservation of pulmonary function for patients with MRFs. Large-scale, multicentre studies are required to confirm our results.

Declaration of Conflicting Interest

The authors declare that there is no conflict of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

References

1. Lin FC, Tsai SC, Li RY, et al. Factors associated with intensive care unit admission in patients with traumatic thoracic injury. *J Int Med Res* 2013; 41: 1310–1317.
2. Vasigh A, Jaafarpour M, Khajavikhan J, et al. The Effect of Gabapentin Plus Celecoxib on Pain and Associated Complications After Laminectomy. *J Clin Diagn Res* 2016; 10: UC04–UC08.
3. Zhang W, Fang C, Li J, et al. Single-dose, bilateral paravertebral block plus intravenous sufentanil analgesia in patients with esophageal cancer undergoing combined thoracoscopic-laparoscopic esophagectomy: a safe and effective alternative. *J Cardiothorac Vasc Anesth* 2014; 28: 966–972.
4. Gacio MF, Lousame AM, Pereira S, et al. Paravertebral block for management of acute postoperative pain and intercostobrachial neuralgia in major breast surgery. *Braz J Anesthesiol* 2016; 66: 475–484.
5. Yeung JH, Gates S, Naidu BV, et al. Paravertebral block versus thoracic epidural for patients undergoing thoracotomy. *Cochrane Database Syst Rev* 2016; 2: CD009121.
6. El-Morsy GZ, El-Deeb A, El-Desouky T, et al. Can thoracic paravertebral block replace thoracic epidural block in pediatric cardiac surgery? A randomized blinded study. *Ann Card Anaesth* 2012; 15: 259–263.
7. Chen H, Liao Z, Fang Y, et al. Continuous right thoracic paravertebral block following bolus initiation reduced postoperative pain after right-lobe hepatectomy: a randomized, double-blind, placebo-controlled trial. *Reg Anesth Pain Manag* 2014; 39: 506–512.
8. Fusco P, Cofini V, Petrucci E, et al. Unilateral paravertebral block compared with subarachnoid anesthesia for the management of postoperative pain syndrome after inguinal herniorrhaphy: a randomized controlled clinical trial. *Pain* 2016; 157: 1105–1113.
9. Li C, Song C, Wang W, et al. Thoracic paravertebral block versus epidural anesthesia combined with moderate sedation for percutaneous nephrolithotomy. *Med Princ Pract* 2016; 25: 417–422.
10. Baik JS, Oh AY, Cho CW, et al. Thoracic paravertebral block for nephrectomy: a randomized, controlled, observer-blinded study. *Pain Med* 2014; 15: 850–856.
11. Murata H, Salviz EA, Chen S, et al. Case report: ultrasound-guided continuous thoracic paravertebral block for outpatient acute pain management of multilevel unilateral rib fractures. *Anesth Analg* 2013; 116: 255–257.
12. Karmakar MK, Chui PT, Joynt GM, et al. Thoracic paravertebral block for management of pain associated with multiple fractured ribs in patients with concomitant

lumbar spinal trauma. *Reg Anesth Pain Med* 2001; 26: 169–173.
13. Karmakar MK, Critchley LA, Ho AM, et al. Continuous thoracic paravertebral infusion of bupivacaine for pain management in patients with multiple fractured ribs. *Chest* 2003; 123: 424–431.
14. Mohta M, Verma P, Saxena AK, et al. Prospective, randomized comparison of continuous thoracic epidural and thoracic paravertebral infusion in patients with unilateral multiple fractured ribs–a pilot study. *J Trauma* 2009; 66: 1096–1101.
15. Boretsky K, Visoiu M and Bigeleisen P. Ultrasound-guided approach to the paravertebral space for catheter insertion in infants and children. *Paediatr Anaesth* 2013; 23: 1193–1198.
16. Hall Burton DM and Boretsky KR. A comparison of paravertebral nerve block catheters and thoracic epidural catheters for postoperative analgesia following the Nuss procedure for pectus excavatum repair. *Paediatr Anaesth* 2014; 24: 516–520.
17. Ho AM, Karmakar MK and Critchley LA. Acute pain management of patients with multiple fractured ribs: a focus on regional techniques. *Curr Opin Crit Care* 2011; 17: 323–327.
18. Naja ZM, Raf M, El Rajab M, et al. Nerve stimulator-guided paravertebral blockade combined with sevoflurane sedation versus general anesthesia with systemic analgesia for postherniorrhaphy pain relief in children: a prospective randomized trial. *Anesthesiology* 2005; 103: 600–605.
19. Fortier S, Hanna HA, Bernard A, et al. Comparison between systemic analgesia, continuous wound catheter analgesia and continuous thoracic paravertebral block: a randomised, controlled trial of postthoracotomy pain management. *Eur J Anaesthesiol* 2012; 29: 524–530.
20. 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.
21. Bilgin M, Akcali Y and Oguzkaya F. Extrapleural regional versus systemic analgesia for relieving postthoracotomy pain: a clinical study of bupivacaine compared with metamizol. *J Thorac Cardiovasc Surg* 2003; 126: 1580–1583.
22. Jungquist CR, Correll DJ, Fleisher LA, et al. Avoiding Adverse Events Secondary to Opioid-Induced Respiratory Depression: Implications for Nurse Executives and Patient Safety. *J Nurs Adm* 2016; 46: 87–94.
23. Marrett E, Kwong WJ, Frech F, et al. Health Care Utilization and Costs Associated with Nausea and Vomiting in Patients Receiving Oral Immediate-Release Opioids for Outpatient Acute Pain Management. *Pain Ther* 2016; 5: 215–226.