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**Bilateral Transversus Thoracis Muscle Plane Block Provides Effective Analgesia
and Enhances Recovery After Open Cardiac Surgery**

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Abstract

Background: The mid-sternum is the main source of pain after open cardiac surgery. The aim of this study was to investigate the effect of bilateral transversus thoracis muscle plane (TTMP) blocks on open cardiac surgery.

Methods: Sixty patients were randomly divided into two groups: bilateral TTMP blocks (TP group) or no nerve block (CO group). The primary endpoint was perioperative sufentanil consumption. The secondary outcome measures included postoperative pain, flurbiprofen axetil administration, quality of sleep after extubation, time to extubation, time to the return of gastrointestinal function, time to drain removal, the Intensive Care Unit (ICU) stay time and hospital stay.

Results: The TP group reported significantly less sufentanil and flurbiprofen axetil consumption than the CO group. The CO group had higher Numerical Rating Scale (NRS) pain scores at 1, 2, 6, 12, 24 h after extubation both at rest and during movement than the TP groups. Compared to the CO group, time to extubation, time to the first bowel movement, ICU stay time and hospital stay were significantly decreased in the TP group. The TP group was rated as better in the quality of the two nights of sleep after extubation.

Conclusion: Bilateral TTMP blocks can provide good perioperative analgesia for patients undergoing open cardiac surgery and promote postoperative recovery.

Trial registration: This study was registered in the Chinese Clinical Trial Registry (ChiCTR2000032318) on 04/08/2019.

Key words: The transversus thoracis muscle plane block; The length of hospital stay; Sufentanil; Numerical Rating Scale ; Postoperative pain; Open cardiac surgery.

Introduction

Postoperative pain is severe in patients undergoing cardiac surgery, especially from the median sternotomy incision ^{1,2}. According to a previous study, 705 patients undergoing open cardiac surgery suffer from pain, scoring between 5.3 and 6.5 out of 10 24 hours postoperatively ². The mid-sternum is the main source of pain after cardiac surgery³. The current analgesia regimen with the use of oral and intravenous analgesics has a limited effect. Poor postoperative analgesia in patients undergoing cardiac surgery increased morbidity and a longer hospital stay than patients without pain ^{3,4}. High-dose opioids can provide good postoperative analgesia for patients undergoing heart surgery. However, opioids has some side effects, such as nausea and vomiting, pruritus, and respiratory depression, as well as increased risk of chronic pain⁵. Therefore, the implementation of neuraxial and paravertebral block techniques may be a superior choice^{6,7}.

Paravertebral block and thoracic epidural anesthesia (TEA) result in significantly low pain scores after open cardiac surgery ⁸. Epidural hematoma caused by postoperative coagulopathy and anticoagulation, hemodynamic instability and arterial or venous epidural puncture have limited the wide application of regional techniques in cardiac surgery patients ⁹. The effect of continuous infusion of local anesthetics on postoperative analgesia in cardiac surgery patients is mainly related to the

concentration of local anesthetics and the position of catheters, thus the application of this technology is limited¹⁰. So it seems that ultrasound-guided peripheral nerve block is the safest and the most effective method for postoperative analgesia in cardiac surgery patients.

The transversus thoracis muscle plane (TTMP) block is a newly developed technique^{11,12} that was first reported by Ueshima in 2015¹³. The TTMP block covers the anterior branches of intercostal nerves from T2 to T6 to provide effective analgesia in the internal mammary area¹⁴. Therefore, bilateral TTMP block may provide an effective analgesic alternative during median sternotomy in cardiac surgery patients. The purpose of this study was to observe whether bilateral TTMP blocks can provide good postoperative analgesia and promote postoperative rehabilitation for patients undergoing open heart surgery.

Methods

This randomized, double-blind study was approved by the ethics committee of our hospital, and it was registered in the Chinese Clinical Trial Registry (ChiCTR2000032318). Our study adheres to CONSORT guidelines.

Patients and design

This study included patients aged 18 to 70 years, American Society of Anesthesiologists physical status II-III, who underwent median open heart surgery. The exclusion criteria were patient refusal, hepatic or renal failure, unable to cooperate and communicate, ejection fraction<35%, allergy to ropivacaine, secondary

surgery, urgent surgery, hemodynamic instability and drug addiction.

Surgery and anesthesia

All patients received 200 ml carbohydrate loading before entering the operating room. General anesthesia was induced with 0.1 mg/kg midazolam, 0.3 mg/kg etomidate, 0.15 mg/kg cisatracurium and 0.6-1 µg/kg sufentanil. Then, endotracheal intubation was performed. Total intravenous anesthesia was maintained with propofol and cisatracurium, and the BIS was maintained between 45 and 55. The administration of sufentanil during surgery was decided according to clinical need. According to the demands of the patients, postoperative analgesia was performed with continuous infusion of sufentanil. If patients complained of additional pain (NRS score $\geq$ 4), 50 mg flurbiprofen axetil was injected i.v. at 6 h intervals. No other analgesic drugs were used in any of the patients during the perioperative period.

The patients undergoing cardiac surgery were randomly divided into two groups after providing written informed consent. Patients in the TP group underwent bilateral TTMP blocks after endotracheal intubation, whereas in the other group (the CO group), no nerve block was performed (the same volume of saline was injected as the TTMP block in the experimental group). All operations were performed by the same group of surgeons, and all patients were sent to ICU.

Randomization and blinding

All enrolled patients were randomly divided into TP group or CO group with either 0.4% ropivacaine or saline for using a computer generated random number table, and the group allocation was kept in the sealed envelope. The saline and ropivacaine were

prepared in the post anesthesia care unit by a nurse, the saline and ropivacaine solutions looked identical. The skilled anesthesiologist injected the liquid into TTMP within 20 min and he didn't know whether the liquid is ropivacaine or saline. Postoperative data collection was recorded by another researcher. The patients, surgeons, anesthesiologist, intensive care unit staff, nurses and other investigators were not aware of medication assignment. Thus this was a double-blind, randomized, controlled study.

Ultrasound-guided TTMP block

We used a real-time high-frequency linear ultrasound probe (Huasheng, Shenzhen, China) to perform bilateral TTMP blocks. After using ultrasonography to determine the anterior T4-T5 interspace, the ultrasound probe parallel to the rib was placed lateral to the sternal border¹⁵ so that we could find the pectoralis major internal muscle, intercostal muscle and transversus thoracis muscle. The TTMP was located between the two posterior muscles. The internal mammary artery and vein also passed through the TTMP, verifying this plane. Then, a 20-gauge, 70 mm needle (Tuoren, Henan, China) was inserted inline with the tip of the needle located in the TTMP, and 0.4% ropivacaine (20 ml) was injected into this plane. After 5 minutes, we used ultrasonography to observe whether the local anesthetic had spread between the costal cartilage and the transversus thoracis muscle in T2-6. If ropivacaine had spread poorly, we added local anesthetic in the corresponding plane to ensure an analgesic effect. The methods used on the other side of the TTMP blocks were the same. All nerve blocks were completed by the same skilled anesthesiologist within 15 minutes. The

possible complications of TTMP blocks in this study included ropivacaine allergy, pneumothorax, hematoma, infection and injury of the internal mammary artery and vein. The TTMP block was done as previously described¹⁶.

Study Parameters

The primary endpoint was perioperative sufentanil consumption. The secondary outcome measures included pain at rest and during coughing (exercise pain) at 1, 2, 6, 12, 24, and 48 h after extubation; 48-hour flurbiprofen axetil administration; quality of the two nights' of sleep after extubation; time to extubation; time to return of gastrointestinal function (including the first bowel movement and the first occurrence of flatus); time to drain removal; the Intensive Care Unit (ICU) stay time and hospital stay.

Postoperative pain was measured using the Numerical Rating Scale (NRS) score from 0 (no pain) to 10 (worst severe pain). The sleep quality assessment was performed with a 10-cm visual analogue scale (0= worst sleep quality, 10= best sleep quality). Data collection was recorded by an experimental assistant who was also blinded to the experimental grouping.

Statistical analysis

The calculation of the patient sample size was based on a pilot study (n=8 patients in each group), which compared the primary endpoint, *i.e.*, perioperative sufentanil consumption during open cardiac surgery. A sample size of 25 patients in each group was required with a type I error of $\alpha=0.05$, a type II error of $\beta=0.1$ and a power of

90%. Considering the possible surgical reasons for exclusion and the possibility of patient drop out during the study, we included 20% additional patients for the final sample size (n=30 in each group).

Pain intensity after extubation was compared between the TP group and CO group with repeated-measures (two-way) analysis of variance. Student's t test was used to assess intergroup differences with a normal distribution, whereas the Wilcoxon Mann-Whitney test was used to assess abnormally distributed data. A probability value of less than 5% was considered significant.

Results

Sixty-six patients were enrolled in our trial. Six patients were excluded for the following reasons: secondary surgery (two); ejection fraction<35% (two) and renal failure (two). Ultimately, a total of 60 patients were included in our study for data analysis, with 30 in each group (Fig 1). No differences in patients' characteristics or other factors were noted between the groups (Table 1).

The TP group required significantly less intraoperative and postoperative sufentanil consumption than the CO groups (Table 2). The CO group had higher NRS pain scores than the TP group at 1, 2, 6, 24 h after extubation both at rest and during movement; time points both at rest and during movement (Fig 2, Fig 3). Patients in the CO group received significantly more flurbiprofen axetil in the first 48 hours than patients in the TP group (Table 2). The time to extubation, time to the first flatus, length of stay in the ICU and length of hospital stay were significantly decreased in

the TP group compared with the CO groups (Table 2). The quality of the two nights' of sleep after extubation was rated as better in the TP group than in the CO group (Table 2). There were no significant differences between the groups in terms of the time to first feces or the time to drain removal (Table 2). No complications due to the TTMP blocks occurred in our study.

Discussion

The present study demonstrated that the use of ultrasound-guided TTMP blocks could reduce the perioperative sufentanil consumption, dosage of postoperative flurbiprofen axetil, time to extubation, time to the first flatus, length of stay in the ICU and length of hospital stay in patients undergoing open cardiac surgery. Furthermore, the TTMP block also provide effective analgesia and good sleep quality for patients who underwent open cardiac surgery.

The use of TTMP blocks has been reported in recent years ^{11,12}; this type consists of a shallow block, and there were no adverse events in our study, such as hematoma, arterial puncture, ropivacaine allergy, pneumothorax or infection. A previous study that included 299 patients who underwent TTMP blocks showed that there were only 2 incidences of 'slight infections' around the injection site¹⁷. Therefore, TTMP blocks represent a safe technique that can be widely used in patients who undergo open cardiac surgery¹⁸. Ueshima et al ¹⁵found that the spread of ropivacaine in the TTMP between the fourth and fifth ribs was larger than that between the third and fourth ribs. Therefore, the fourth and fifth ribs next to the sternum were used in all patients in our

study for the TTMP block.

High-dose sufentanil was able to maintain hemodynamic stability; it is still widely used in many countries for bolus dosing or infusion regimes during cardiac anesthesia¹⁹. However, high-dose opioid techniques cause PONV, respiratory depression, pruritus, delayed recovery, prolonged ventilation, increased ICU stays, increased costs²⁰, and limited postoperative recovery after open cardiac surgery²¹. Our study revealed that the use of bilateral TTMP blocks decreased the consumption of perioperative sufentanil without adverse events and that they may work via the following two aspects. On the one hand, the TTMP block was found to cover the T2-T6 intercostal nerves¹¹, and it had the potential to provide analgesia for surgery of the anterior chest wall. Therefore, it could greatly reduce the amount of intraoperative sufentanil used during open cardiac surgery before opening the sternum. On the other hand, this block reduced the dose of postoperative sufentanil needed by providing effective postoperative analgesia²². Therefore, reducing the perioperative dose of sufentanil was an important part of the enhanced recovery of cardiac surgery.

Open cardiac surgery results in severe and prolonged postoperative pain, especially at the median sternotomy site, and peaking during the first two days after the operation²³. Poorly controlled postoperative pain in open cardiac patients results in hemodynamic instability, hypercoagulability, pulmonary complications, sympathetic activation, and increased rates of delirium²⁴. In the current study, we demonstrated that bilateral TTMP blocks provided effective analgesia during open cardiac surgery both at rest and during mobilization. Moreover, sufentanil and flurbiprofen axetil

consumption was still significantly lower in the TP group than in the CO group during the 48 h after surgery, and it could reduce the adverse effects of these two drugs. Neuraxial techniques and paravertebral nerve blocks can also provide effective postoperative analgesia for patients undergoing open cardiac surgery²⁵. However, they are not routinely performed in cardiac surgery due to concerns of hemorrhage and hematoma after coagulopathy and heparinization²⁴. Therefore, ultrasound-guided TTMP blocks represent a novel, effective, promising, and safe regional analgesic technique in cardiac surgery and should be widely used.

Sleep quality is critical for patients' postoperative comfort and fatigue after cardiac surgery. Our results showed that the TP group had better sleep quality than the CO group, which may be associated with the enhanced recovery after cardiac surgery. Better pain relief and pain reduction after sufentanil consumption contributed to better sleep quality in the TP group because sufentanil is known to disrupt sleep quality²⁶. Our study demonstrated that bilateral TTMP blocks led to early extubation and early time to the first bowel movement. Finally, decreased sufentanil consumption, improved pain control, early extubation and early time of the first flatus were responsible for the reduction in the length of stay in the ICU and the length of hospital stay.

This study has some limitations. The volume and concentration of the TTMP block used in our study was based on previous research. In further trials, the optimum capacity and concentration of the TTMP block in open cardiac surgery should be evaluated. Continuous TTMP block may provide optimal and long postoperative

analgesia during median sternotomy²⁷, but our study did not use this technique. Therefore, randomized controlled studies are necessary to explore the utility of continuous TTMP block in different surgical patients. In addition, effective postoperative pain relief may prevent the development of chronic pain²⁸, but we did not observe the effect of this block on postoperative chronic pain.

In conclusion, this study showed that the use of ultrasound-guided TTMP block in open cardiac surgery reduced the length of hospital stay by providing effective postoperative pain, reducing sufentanil and flurbiprofen axetil consumption, decreasing the mechanical ventilation time and the time to the first flatus, improving sleep quality and reducing the length of stay in the ICU.

Declarations

Ethics approval and consent to participate

This study was approved by the First Affiliated Hospital of Nanchang University (Ethical Committee number 201926; Chairperson Ge Gao) and registered in the Chinese Clinical Trial Registry (ChiCTR2000032318) on 04/08/2019. Written informed consent was obtained from each patient.

Consent for publication

Not applicable.

Availability of data and materials

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

Competing interests

The authors declare that they have no competing interests or disclosures.

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The authors received no external funding.

Authors' contributions

YZ and SBC were responsible for conceived, designed this study and collected the data. YZ and BMZ were responsible for study execution and manuscript writing. HXG was responsible for data analysis. All authors have read and approved the final version of the manuscript.

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Figures

Figure 1

Patient flow diagram

Figure 2

Pain intensity at rest after extubation which was measured using the verbal numerical scale (NRS) score.

* $P < 0.05$ considered statistically significant. Results are mean $\pm$ SD.

Figure 3

Pain intensity at movement after extubation which was measured using the verbal numerical scale (NRS) score. * $P < 0.05$ considered statistically significant. Results are mean $\pm$ SD.

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