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APPLICATION AND PROSPECT OF ULTRASOUND-GUIDED TRANSVERSE THORACIC MUSCLE PLANE BLOCK IN ERACS

Can Deng, Hao Wang*

Department of Anesthesia, the First Affiliated Hospital of Jinan University, Guangzhou, 510630, China

** Corresponding E-mail: Hao Wang, MD, drwanghao@yeah.net*

Abstract: Transverse thoracic muscle plane block (TTPB) is a novel fascial plane block (FPB) intended to provide efficient analgesia in patients undergoing median thoracotomy. This review aims to describe the anatomy, procedural approach, and clinical implementation of TTPB, thereby providing a new perspective on enhancing recovery after cardiac surgery (ERACS).

Keywords: Ultrasound-guided, Transverse thoracic plane block, Postoperative analgesia, Enhanced recovery after cardiac surgery

1. INTRODUCTION

Large doses of opioids are often used in traditional cardiac surgery anesthesia programs, which can lead to delayed respiratory depression and extubation, postoperative nausea and vomiting, pruritus, and other adverse reactions after surgery[1]. However, traditional regional analgesia (RA), such as spinal anesthesia, paravertebral block, and erector spinal block, are associated with potential complications, such as hematoma, general spinal anesthesia, spinal nerve injury, and pneumothorax[2]. Due to poor cardiac function and difficulty in cooperating with the required positions, most cardiac surgery patients are at high risk of perioperative management. Hence, there is a pressing need for safer and more effective techniques that can reduce the dosage of opioids and related complications and promote rapid patient recovery.

Recently, advances in ultrasound visualization technology have led to the emergence of new RA, including various types of fascial plane block (FPB)[3]. In 2015, Ueshima et al. [4] first proposed transverse thoracic plane block (TTPB), which is injecting local anesthetics into the potential fascial space of the internal intercostal muscle (IIM) and the transverse thoracic plane (TTP) under ultrasound guidance. This technique can safely and effectively block the anterior cutaneous branch of the intercostal nerve Th2-Th6 in the medial region of the breast. Despite its potential benefits, comprehensive reports of TTPB in enhancing recovery after cardiac surgery (ERACS) are limited.

Therefore, this article aims to review the application of ultrasound-guided TTPB in ERACS.

2. OVERVIEW OF TTPB

2.1 Plane anatomy of transversal thoracic muscle

The TTP is commonly described in classic textbooks as a continuation of the transverse abdominal muscle. It begins at the inner lower part of the anterior chest wall and fans obliquely outward, terminating at the 2nd-6th ribs. The muscle is innervated by the intercostal nerve and plays a role of in lowering the ribs to assist breathing. A study of 120 recently deceased individuals thoroughly examined the location and variability of the transverse thoracic muscle[5]. The study found that the transverse thoracic muscles were absent in 5.8% of instances but were symmetrically distributed in 55.8%. The most common attachment point is the 2nd-6th ribs. The internal thoracic artery (ITA) and thoracic veins (ITV) located on the surface of the transversal thoracic muscle are important anatomical markers for identifying the transverse thoracic muscle. Near the lateral border of the sternum, the intercostal nerve emits anterior cutaneous branches across the IIM and epi costal membrane to innervate the parasternal and medial mammary regions[6] (Fig. 1).

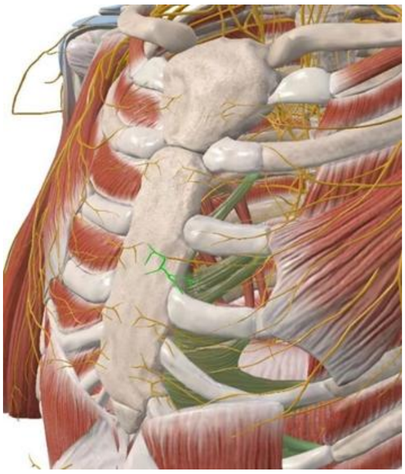

Fig. 1 Diagram of the anterior cutaneous branch of the intercostal nerve and the transverse thoracic muscle plan in the chest wall (The anterior cortical branch of the intercostal nerve

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and the transverse pectoralis muscle are shown in green, and the anatomical drawings are from 3Dbody software)

In a study by FUJI et al.[7], bilateral TTPB was performed on a fresh cadaver with a left ITA coronary artery bypass grafting history. Under ultrasound guidance, they injected 20 ml of methylene blue mixed dye into the fourth and fifth intercostal spaces at the sternal border. After dissection, the blue dye diffused to the Th1-Th6 level in the right Chest wall, while in the left chest wall, it was confined to the fourth intercostal space. This may have been due to postoperative scar tissue in the left chest wall, which limited dye diffusion, consistent with the clinical findings of Zhang Y et al[8].

2.2 Procedure for ultrasound-guided TTPB

The method for performing TTPB varies among different literature reports[9-11]. The procedure typically as follows: positioning the patient supine with the anterior thoracic region fully exposed, placing a high-frequency line array probe longitudinally 1-2 cm from the sternum of the second rib, and sliding the probe downward to count the ribs to the 4th-5th rib space (Fig. 2).

Fig. 2 The positioning diagram of transverse thoracic plane

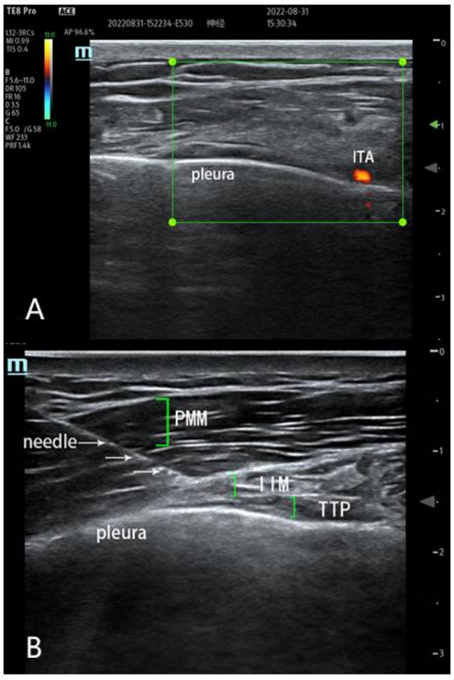

Fig. 3 The structure of each layer of the chest wall. A. The anatomical marker of TTPB. B. The needle reaches between the IIM and TTP. (ITA: internal thoracic artery; PMM: pectoralis major muscle; IIM: internal intercostal muscle; TTP: transverse thoracic plane)

Then operator clearly identify the layers of the chest wall, including pectoralis major muscle (PMM), IIM, TTP, internal thoracic artery/vein (ITA/ITV), and pleura. The plane of the transverse thoracic muscle is located based on the ITA/ITV. Next, routine disinfection and towel spreading are performed, followed by parasternal transverse axis plane puncture. Once the needle tip reaches between the IIM and TTP, the retraction is bloodless and airless, after confirming that the needle is in the correct plane, a test dose (< 2 ml) of local anesthetics is injected. which can observe the local anesthetic spread along the fascial space. Then, the target dose of the local anesthetic is injected to complete the TTPB procedure. In addition, successful blockade can be confirmed by the downward depression of the pleura (Fig. 3).

2.3 The choice of local anesthetics

There is currently no standardized protocol for the type, dose, and concentration of local anesthetics and adjuvants used in TTPB. Commonly used local anesthetics for TTPB include lidocaine, ropivacaine, bupivacaine, and levobupivacaine. However, bupivacaine has potential cardiotoxicity, while lidocaine has a shorter block time, limiting their applications. Ropivacaine, on the one hand, has a lower risk of cardiotoxicity and central nervous system toxicity compared to bupivacaine, on the other hand, provides better nerve block efficiency than lidocaine. It is currently one of the most commonly used local anesthetics in clinical nerve blocks[12].

Previous studies have shown that the selection of local anesthetics type, dose, and concentration should be based on the surgical procedure and site[8, 13-16]. For example, 20-40 ml of 0.25%-0.75% ropivacaine can produce an excellent blocking effect. In addition, the combined use of adjuvants such as dexmedetomidine, dexamethasone, and epinephrine can prolong nerve block duration and optimize the therapeutic effect. However, it is essential to monitor for potential side effects associated with these adjuvants, such as excessive sedation, bradycardia, hypotension, and neurotoxicity associated with adjuvants[17].

To establish a standardized dosing regimen for TTPB, multicenter, large-scale clinical studies are needed. These studies will help further refine the optimal dosing protocols for local anesthetics and adjuvants, ensuring safer and more effective TTPB procedures.

3. THE CLINICAL APPLICATION OF TTPB

TTPB is a viable option for perioperative analgesia. In a study by Wu et al.[18] involving 60 patients undergoing trans mammary cavernous thyroidectomy under general

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anesthesia. The experimental group receiving bilateral TTPB with 10 ml of 0.33% ropivacaine on the transverse thoracic muscle surface had significantly lower heart rate (65.35 ± 5.66 vs. 80.04 ± 11.44), mean arterial pressure (80.04 ± 11.44 vs. 92.73 ± 4.86), and reduced postoperative nausea and vomiting rate (p = 0.012) compared to the control group. Intraoperative and postoperative opioid analgesics were also decreased, with VAS being reduced at 2 h and 6 h postoperatively. In another study, FUJI [9] and Jaya[19] et al. explored the stress response and analgesic effect of TTPB on patients undergoing cardiopulmonary bypass (CPB) valve surgery via median sternotomy. They found that bilateral TTPB under general anesthesia can reduce the use of general anesthetics during surgery, the perioperative stress response of patients and the time of mechanical ventilation while providing better postoperative analgesia and accelerating postoperative recovery.

TTPB can also be used as a form of anesthesia for some surgical procedures, such as subcutaneous implantable cardioverter defibrillator (S-ICD) implantation. Foreign electrophysiology centers mainly use general anesthesia for S-ICD[20], but this method poses a higher risk of cardiac decompensation and systemic hypotension. Omri et al.[21] proposed using thoracic paravertebral blockade for S-ICD implantation. However, the technique was difficult to operate and prone to complications such as pneumothorax and paravertebral hematoma, its clinical application was limited. TTPB, combined with serratus anterior plane block (SAPB), can provide effectively anesthesia and postoperative analgesia for S-ICD implantation[22] .

4. THE PROMOTION OF TTPB IN ERACS

Patients undergoing Cardiac surgery with median sternotomy often experience severe postoperative pain due to sternal destruction, tissue retraction, chest wall nerve injury, and chest drainage tube placement. A multi-center study of 1247 cardiac surgery cases revealed that 30%-40% of patients experienced moderate to severe pain after surgery, and 3.6% still had residual pain even two years after cardiac surgery[23]. Poorly controlled postoperative pain can have short-term and long-term adverse effects on patients, including increased myocardial oxygen consumption, delayed recovery of gastrointestinal function, inflammatory stress response, and even the gradual development of chronic pain. It can seriously impact the quality of postoperative recovery, increase the burden of family and society[24], and conflict with the concept of ERACS advocated in the field of cardiac surgery today.

ERACS is based on fast-track cardiac anesthesia (FTCA) or ultra-fast-track cardiac anesthesia (UFTCA)[25]. In 2019, the European Association of Accelerated Recovery Surgical Cardiology recommended the use of multimodal analgesia (MMA) and oligo-opioid strategies to optimize patient outcomes[26], shorten hospital stays, reduce medical costs, and promote postoperative recovery in cardiac surgery patients in multiple stages and aspects MMA involves combining different mechanisms of action to achieve the best analgesic effect. The emerging technique of FPB has unique advantages such as visualization, safety, and effectiveness, and is favored by anesthesiologists and surgeons. By adopting MMA, including the use of FPB, patients undergoing cardiac surgery can experience better pain control, shorter hospital stays, lower medical costs, and improved postoperative recovery in multiple stages and aspects[27-29].

Several studies have demonstrated that TTPB is a safe technique for patients undergoing cardiac surgery, as it reduces perioperative opioid consumption, postoperative nausea and vomiting, respiratory depression, skin itching, and other complications, while lowering hospitalization costs and promoting postoperative recovery. FUJI et al.[9] conducted a study on 20 patients scheduled for median thoracotomy for bilateral TTPB (20 ml 0.3% or 0.5% ropivacaine) was performed. The results showed that the numeric rating scale (NRS) of the intervention group within 12 h after the operation was 3.3 (3.2), compared to 5.6 (3.2) for the control group. Another prospective study also reached a similar conclusion[30]. The VAS at 8 h, 12 h, and 24 h after surgery, the duration of intense care unit (ICU) monitoring, and the amount of postoperative morphine in the T group were significantly lower than those in the control group (p < 0.001). Meltem et al.[14] evaluated the effectiveness of TTPB as postoperative analgesia after cardiac surgery in children. The perioperative fentanyl dosage, postoperative 24 h facial expression pain score, and extubation time in the block group were significantly lower than those in the control group (p < 0.001). However, high-quality, multicenter clinical studies are still needed to further clarify the role of TTPB in ERACS.

5. SUMMARY AND OUTLOOK

In summary, different types of fascial plane block provide various options for the rapid recovery of patients undergoing cardiac surgery, but there is still a significant room for improvement, including : a) establishing a standardized TTPB pathway and protocols that are more suitable for cardiac surgery patients, such as the choice of local anesthetics, dose, and concentration; b) expanding the observation and evaluation indicators of ERACS and increasing comparability between different research institutions; c) improving the postoperative follow-up system; d) combining TTPB with basic research to further explore the molecular basis of its function. These measures will provide new ideas for the rapid recovery of patients undergoing cardiac surgery in the future.

COMPETING INTERESTS

The authors declare that they have no conflicts of interest.

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