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RESEARCH ARTICLE

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Ultrasound-guided planar block of the transverse abdominis and the erector spine for analgesia after liver transplantation: A single-center study

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Abstract

Objective: *To observe the analgesic effects of ultrasound-guided transverse abdominis plane block (TAPB) or erector spinae plane block (ESPB) for postoperative liver transplantation.*

Methods: *Forty-five patients were selected for liver transplantations (American society of anesthesiology [ASA] class III or IV, males and females, ages 33-60-years-old). By using a random number table, the patients were divided into 3 groups (n=15): the transverse abdominal muscle plane block group (group T), the erector spinae plane block group (group E) and the control group (group C). With ultrasound guidance, preoperative TAPB was administered in group T, which consisted of an injection of 25 mL of 0.4% ropivacaine+5 mg dexamethasone, and the other side of the body was operated on by the same method. Group E received preoperative ESPB, which consisted of an injection of 25 mL of 0.4% ropivacaine+5 mg dexamethasone, and the other side was operated on by the same method. No nerve block was administered in group C. The three groups were all given intravenous anesthesia, which consisted of a targeted and controlled infusion of 3-5 μg/ml propofol and 3-5 ng/ml remifentanil, as well as intermittent intravenous injections of cisatracurium. Vasoactive agents were used to maintain stable circulation. Patient-controlled intravenous analgesia (PCIA) consisted of the following: 3.5 μg/kg sufentanil, no background infusion, a PCA dose of 2 ml and a locking time of 15 min. The Bruggemann Comfort Scale (BCS) was used to postoperatively measure comfort levels at 6, 12, 24, 48 and 72 h (T1-5, respectively). Tramadol was used to remedy the postoperative analgesia. The number of effective compressions of the patient-controlled analgesia pump, the use of tramadol, the occurrence of adverse reactions and the postoperative analgesia satisfaction levels of the patients were recorded. Additionally, complications related to TAPB and ESPB, as well as postoperative recovery times, first times out of bed, anal exhaust/defecation times and hospitalization times were recorded.*

Results: *The BCS levels of group T and group E increased at T4 and T5. Additionally, in groups T and E, the remifentanil doses were decreased, the postoperative recovery times were shortened, the tramadol utilization rates and incidences of nausea and vomiting were decreased, the postoperative analgesia satisfaction rates were increased and the first times out of bed, anal exhaust/defecation times and hospitalization times were shortened, compared to those of group C ($P<0.05$).*

Conclusions: *Ultrasound-guided TAPB or ESPB can safely and effectively be used for liver transplantations, which can reduce the dose of opioids and improve the prognoses of patients.*

keywords: *analgesia; liver transplantation; transverse abdominis plane block; erector spinae plane block*

Introduction

In 1963, the first liver transplantation (LT) was performed by Starzl et al [1,2]. Since then, the improvement of liver transplantation techniques in surgery, anesthesia and immunity has greatly increased the long-term survival rate of liver transplantation patients. Additionally, these types of transplantations have become a recognized treatment for many end-stage liver diseases [3-5].

The main perioperative analgesic method for LT has been intravenous analgesia, and the use of opioids represented the main analgesic method, although some patients have been treated with epidural analgesia when blood coagulation function was normal. Due to the many side effects of opioids, their clinical application effect is not optimal. However, liver transplantation recipients are mostly patients with liver failure who have abnormal blood coagulation functions that lead to a limited use of epidural analgesia.

Currently, the Enhanced Recovery After Surgery (ERAS) concept is gradually gaining popularity, and various measures to promote the rapid recovery of patients have been continuously applied. Patients who receive liver transplantations can remove their tracheal catheters after surgery, their sedative times in the intense care unit (ICU) are shortened and their postoperative pain levels present certain challenges [6]. Several studies have shown that rapid extubation and fast track anesthesia can reduce the length of stay and total hospital costs of patients by shortening the length of intensive care stays or can result in patients not requiring ICU care [7-9].

Along with the clinical application of ultrasound, new nerve block techniques, such as TAPB and ESPB, have been applied to abdominal surgery [10,11], living donor liver transplantations [9] and thoracic surgery [13,14], with optimal results. According to our knowledge, there have been no reports on the application of these

two techniques in LT recipients. Therefore, this study explored the safety and efficacy of these two techniques in liver transplantation, thus providing a reference for their use in clinical practice.

Patients and methods

The study was approved by the ethics committee of the Affiliated Foshan Hospital of Sun Yat-sen University, and informed consent was provided by the patients. The LT recipients included 45 patients with American society of anesthesiology[ASA]class III or IV, males and females, who were aged 31-60-years. By using a random number table, patients were divided into 3 groups (n=15): the transverse abdominal muscle plane block group (T group), the erector spinae plane block group (group E) and the control group (group C). With the use of ultrasound guidance, preoperative TAPB was administered in group T, which consisted of injections of 25 mL of 0.4% ropivacaine+5 mg dexamethasone, and the other side was operated on by the same method. Group E received preoperative ESPB, which consisted of injections of 25 mL of 0.4% ropivacaine+5 mg dexamethasone, and the other side received the same method. No nerve block was utilized in group C.

All of the patients were administered with the same preoperative routine, which consisted of water fasting and a lack of preoperative medication. The ECG, continuous arterial blood pressure and pulse oximeter values of the patients were monitored, as well as the central venous pressure, end-expiratory carbon dioxide ($PETCO_2$), body temperature, blood loss and urine volume of the patients. Additionally, internal jugular vein catheterizations and intravenous infusions of 500 ml succinyl gelatin were performed.

TAPB protocol

Each patient was placed into the supine position, and the skin was disinfected with a 70% alcohol solution containing 2% chlorhexidine. Then, via the use of a low frequency 2-5 MHz portable color two-dimensional ultrasound instrument (SonoSite company, USA), and after the positioning of the iliac crest, costal margin and axillary midline, the ultrasonic probe was placed in the middle route of the tibialis anterior and the axillary abdominal wall. Subsequently, with measurements taken from superficial to deep aspects, the subcutaneous fat, the external oblique muscle, the internal oblique muscle and the transverse abdominal muscle tissue were identified. For the abdominal transverse plane, ultrasonography by plane technology was utilized with an injection of 1 ml saline as a water separation experiment. After the muscle layers were observed and the needle position was determined, and after a withdrawal without the presence of blood and gas, a total of 25 ml of 0.4% ropivacaine (AstraZeneca company) mixed with 5 mg dexamethasone was injected, and TAPB on the opposite side was performed in the same manner. After 30 min, blunt plastic needles were used to detect the pain block plane.

ESPB protocol

Each patient was placed into the right lateral position and was disinfected with a 70% alcohol solution containing 2% chlorhexidine. Then, using a low frequency 2-5 MHz a portable color two-dimensional ultrasound instrument (SonoSite company, USA) to scan the median sagittal T8 spines, an offshoring probe for the T9 transverse process, the plane into the needle, light touch T9 transverse process bone sma in vertical plane, 1 ml saline was injected as a water separation experiment first. Then, after observing the muscle layers and determining the needle position, 25 mL of 0.4% ropivacaine that was mixed with 5 mg dexamethasone was injected. The same method was applied for the contralateral ESPB, and a blunt plastic needle was used to detect the pain block plane after 30 min.

After the completion of the block, the patients were placed into the supine position, and general anesthesia was induced with intravenous injections of 0.3 μg/kg sufentanil, 0.04 mg/kg midazolam and 0.15 mg/kg cisatacurium, as well as a target-controlled infusion of 4 μg/ml propofol and 2 ng/ml remifentanil. Mechanical ventilation was performed after tracheal intubations, and the following respiratory parameters were measured: tidal volume (8 ml/kg), respiratory frequency (12-14 breaths/min) and respiratory ratio (1:2). Anesthesia maintenance consisted of the following: a target controlled infusion of 3-5 ng/ml remifentanil and 3-5 μg/ml propofol, as well as an intermittent intravenous injection of cis-atracurium, a maintenance of propofol at 5 min before the surgery and a maintenance of remifentanil for the surgery. The procedure was performed by using standard techniques, and no venous bypass was performed. Intraoperative maintenance consisted of a $PETCO_2$ of 35-45 mmHg (1 mmHg=0.133 kpa). A compound electrolyte injection was used to supplement the physiological demands, succinyl gelatin and blood products were used to supplement blood loss and improve coagulation function, correct acidosis and electrolyte disorders and vasoactive drugs (norepinephrine, dopamine, adrenaline, etc.) were used to maintain stable circulation levels.

After the LT operation, each patient was transferred to the ICU for monitoring. No sedative drugs were used. After waking up, the tracheal catheter was removed when it was time for the extubation. Intravenous analgesic pumps were used for 3 days after surgery. The following drug combination was used: 3.5 μg/kg sufentanil and 15 mg/kg ondansetron diluted to 150 ml, with a background dose of 2 ml/h, a single dose of self-control of 0.5 ml and a locking time of 15 min. At rest, the VAS score was >4, after which analgesia was intravenously provided in the form of 50 mg tramadol. The block was performed by the same anesthesiologist, and the operation was performed by the same group of surgeons. The induction and maintenance of anesthesia were performed by the same anesthesia team, and the postoperative follow-up was performed by another anesthesiologist (who was blinded to the grouping of the patients). Patients who were allergic to ropivacaine, sufentanil and other anesthetics, as well as patients who died either during the operation or within 48 h after surgery, were excluded from this study.

The VAS and BCS scores were recorded at 6, 12, 24, 48 and 72 h (T1-5, respectively) after surgery. The BCS scores were defined as follows: 0 points, persistent pain; 1 point, no pain when quiet and severe pain during deep breathing or coughing; 2 points, slight pain when breathing deeply or coughing; 3 points, no pain during deep breathing; and 4 points, no pain during deep breathing and coughing.

Within 72 h after surgery, and if the VAS score >4, the patient was classified as having analgesia insufficiency, after which an intravenous injection of 50 mg tramadol was provided. When the patient was re-evaluated 1 h later, and if the VAS score >4, the patient was then provided with 25 mg tramadol. The use of tramadol, the occurrence of adverse reactions (such as hypotension, pruritus, local anesthetic poisoning, chest tightness, etc.) and the postoperative analgesia satisfaction of the patients were recorded. Complications related to the TAPB and ESPB blocks (local anesthetic poisoning, internal organ injury and total spinal anesthesia) were recorded. The postoperative recovery time (response times according to the instructions from the end of the surgery to the opening of the eyes) was recorded, and the rehabilitation indexes, including the first postoperative movement out of bed, anal exhaust, anal defecation and hospitalization time, were recorded.

Statistical analysis

TSPSS 17.0 software was used for the statistical analyses. The normally distributed data of were expressed as the mean±SD ($\bar{x}$ ±s). The data of the random block design were compared via a t test of two independent samples, and the data of the repeated measures design were compared via repeated measures analysis of variance (ANOVA). The skewed distribution data were expressed as the median (quartile spacing) [M (Q)], and a rank sum test was used for a comparison between the groups. The counting data were compared using $\chi 2$ test. The differences of the data were statistically significant if P<0.05.

Results

There were no deaths reported in the study. There were no significant differences in gender, age, weight and surgical conditions among the three groups (P>0.05), as shown in (Table 1)

Compared with group C, the amount of remifentanil that was used in group T and group E decreased, and the utilization rate of tramadol decreased (P<0.05), as shown in Table 2.

Compared with group C, the BCS scores of group T and group E were increased (P<0.05), as shown in Table 3.

No TAPB- and ESPB-related complications were observed in any of the patients. Compared with group C, the incidences of nausea and vomiting were decreased in group T and group E, and the postoperative analgesia satisfaction rate was increased (P<0.05), as shown in Table 4.

Compared with group C, the recovery time, first time out of bed, anal exhaust/defecation time and hospitalization time in group T and group E were shortened (P<0.05), as shown in Table 5.

Conclusion

Due to the long operation time (10-12 h) and the slow metabolism of the anesthetic drugs that were used in patients undergoing traditional liver transplantations, and for safety considerations, the patients were observed in the ICU for several days after the

Table 1: *Comparison of each index of general condition and surgical condition between the three groups (n=15)*

Groups	Male/ female	Age (y, $\bar{x}$ ±s)	Weight (kg, $\bar{x}$ ±s)	Operation Time (min, $\bar{x}$±s)	Blood loss (ml/kg, $\bar{x}$±s)	Urine volume (ml, $\bar{x}$±s)
Group C	10/5	45±14	57±9	530±30	62.2±320	1550±430
Group T	9/6	43±13	54±8	513±28	60.2±308	1520±320
Group E	11/4	43±12	55±7	520±38	61.0±306	1530±380

Table 2: *Comparison of the dosages of remifentanil and sufentanil, and the utilization rate of tramadol among the three groups (n=15)*

Groups	Tramadol utilization rate (%)	Dosage of remifentanil (ng, $\bar{x}$ ±s)	Dosage of sufentanil (μg, $\bar{x}$ ±s)
Group C	80	4590±1602	144±15
Group T	20[a]	3010±580[a]	112±12[a]
Group E	25[a]	3112±513[a]	109±11[a]

Note: compared with group C, [a]P<0.05

Table 3: *Comparison of BCS scores at each time point between the two groups (n=15)*

Groups	T1	T2	T3	T4	T5
Group C	1.5±0.3	1.7±0.3	2.0±0.4	2.3±0.3	2.5±0.3
Group T	3.3±0.4[a]	3.2±0.4[a]	3.1±0.4[a]	3.2±0.5[a]	3.3±0.4[a]
Group E	3.4±0.5[a]	3.2±0.4[a]	3.2±0.5[a]	3.1±0.4[a]	3.2±0.4[a]

Note: compared with group C, [a]P<0.05

Table 4: *Comparison of the tramadol utilization rate, adverse reaction rate and postoperative analgesia satisfaction rate among the three groups (%, n=15)*

Groups	Incidence of skin itching	Incidence of nausea and vomiting	Incidence of chest tightness	Incidence of local anesthetic intoxication	Postoperative analgesia satisfaction rate
Group C	30	50	40	2	60
Group T	0	10[a]	10[a]	2	90[a]
Group E	0	10[a]	10[a]	1	90[a]

Note: compared with group C, [a]P<0.05

Table 5: Comparison of recovery time and prognosis among the three groups (n=15)

Groups	Postoperative recovery time (min,±s)	First time out of bed (h, x̄±s)	Anal exhaust Time (h, x̄±s)	Anal defecation time (h, x̄±s)	Hospital stays [d, M (Q)]
Group C	81±17	75.3±22.9	48.4±17.0	112.4±23.0	24.4 (15.2)
Group T	42±10[a]	44.5±18.0[a]	30.6±11.8[a]	82.4±20.3[a]	18.6 (12.6)[a]
Group E	40±10[a]	46.2±19.2[a]	30.4±10.4[a]	82.4±20.3[a]	17.8 (12.4)[a]

operation. During this time period, the patients continued to receive mechanical ventilation, and both sedatives and opioids were provided for analgesia. When the patient was transferred back to the ward after his condition had stabilized, the patient experienced less pain because the time of the most severe pain had passed. At present, both surgical techniques and anesthesia techniques are rapidly developing, and the operation can be completed within 5-8 h. After the operation, the endotracheal catheter can be removed, and the patient will be awake. The EARS method advocates a reduction in the use of opioids, being removed out of bed as soon as possible and the restoration of gastrointestinal function as soon as possible, which are beneficial to the recovery of the patients.

In the past, the opinion of liver transplantation experts was that the postoperative pain was not serious and that the analgesia requirement was lower than for other abdominal surgeries. However, Milan [6] believed that there are seven reasons that account for high analgesia requirements in liver transplantation surgery. First, the "mercedes-benz incision" in liver transplantation is one of the longest and most painful types of incisions and can lead to deep breathing, coughing and specific pain during exercise [7]. Second, the operation time is relatively long, and the use of the retractor and the long-term compression of the lower ribs by the retractor can lead to the aggravation of postoperative pain [8]. Third, the circulation of end-stage liver diseases is characterized by high dynamics, which will lead to a faster clearance of analgesics [9]. Fourth, as large intraoperative bleeding and large blood transfusion volumes during the operation occur, some analgesics will be lost in combination with the loss of blood, which then results in the need for more compensatory analgesic measures. Fifth, when the new liver is functioning, the metabolism of the analgesics will be higher than in the pretransplantation state; therefore, the need for analgesics will increase. Sixth, some liver transplant patients experience chronic pain before surgery, and the management of postoperative pain is more complex than that of general surgery. Seventh, a small proportion of patients receiving liver transplantation have been maintained on methadone, which can significantly increase intraoperative and postoperative analgesia [10].

Traditional intravenous analgesia cannot satisfactorily solve this problem. Epidural analgesia has been associated with coagulation concerns. Therefore, peripheral nerve blocks, especially trunk nerve blocks such as TAPB and ESPB, are very valuable. Nerve blocks are important components of current multimodal analgesia, and they are also inevitable requirements of the acceleration of rehabilitation surgery. In recent years, ultrasound technology has been widely promoted in the department of anesthesiology, and TAPB and ESPB types of analgesia have been increasingly used in recent years [6,14,15].

Spinal nerves T7-L1 supply most of the sensory nerves in the skin, muscles and parietal peritoneum of the abdomen. The fascia layer running between the internal oblique muscle and the transverse abdominal muscle travels to the front of the abdominal wall. TAPB is used to block and innervate the anterior abdominal nerve by injecting local anesthetics into the plane of the internal oblique and transverse fascia, in order to alleviate postoperative pain. However, there is a risk of accidental injury to the intra-abdominal organs. Under the guidance of ultrasound, TAP blocks can be accurately positioned, and the direction and depth of the guided puncture needle can also be monitored in real time, to avoid damage to the nerve tissue and abdominal organs, which can then significantly improve the safety and success rate of the procedure [19]. The study found that different paths of the TAP block exhibited different effects under ultrasound guidance: the TAP block covered the spinal nerve T7-T12 innervation area under the costal margin; the lateral TAP block covered the spinal nerve T10-Tl1 innervation area; the TAP block in the lower ilioabdominal and groin area covered the spinal nerve T12-Tl1 innervation area; and the TAP block in the posterior gluteal area covered the spinal nerve T5-Tl1 innervation area [21]. We mainly used the TAP block under the costal margin, and its blocking range was essentially the same as in the "Benz" incision.

The ESP block is a new type of nerve block. Studies have shown that drugs can pass through the intercostal muscles, and local anesthetics may act on the starting points of the dorsal and ventral branches of the thoracic spinal nerves, thus playing an analgesic role. Several local anesthetics may even reach the paravertebral region and achieve the effect of inhibiting visceral pain [16].

According to the results of our study, and compared with group C, the dose of remifentanil and the use of tramadol were reduced, the BCS scores were increased, the incidences of nausea and vomiting were reduced, the postoperative analgesia satisfaction rates were increased and the awakening times, first times out of bed, anal exhaust/defecation times and hospitalization times in group T and group E were shortened. Moreover, TAPB or ESPB blocks can produce better analgesic effects, can reduce the doses of opioid drugs and can help to improve the prognoses of patients.

Previous studies have suggested that the action time of the ropivacaine nerve block is generally less than 24 h, whereas the postoperative action time of the trunk block group can be up to 24~48 h [21]. In this study, the analgesic effects of group T and group E were close to 2 d, which was similar to the previously mentioned conclusion. The reason for this effect may be related to the injection of the local anesthetics into the transverse fascia or the muscle plane of the erector spine, where the blood vessels are less distributed and the drug absorption is slow; thus, the analgesic time is prolonged. In addition, ropivacaine mixed with dexamethasone may also extend its action time.

The safety and efficacy of ESP are supported by the following facts. First, the ESP block is supported by a mature anatomical basis [22-28]. During the operation, at the level of the T9 transverse process, it is selected to be as close as possible to the central axis of the needle, which allows the local anesthetic to be as close as

possible to the transverse costal foramen, i.e., as close to the origin of each spinal nerve from the intervertebral foramen, thus ensuring the accuracy and effectiveness of the nerve block. Secondly, ultrasound-guided, in-plane needle insertion can monitor the needle movement and the diffusion of local anesthetics in real time. Third, compared with an ultrasound-guided, paravertebral nerve block or a high epidural puncture, the erector spine muscle is easy to recognize and relatively superficial in position, and the ESP operation is easier to grasp and promote. Fourth, ESP is punctured in the intermuscular space, is protected by the transverse process of the spine, and does not possess serious complications, such as spinal anesthesia caused by a dura penetration, pneumothorax caused by a pleural penetration and bleeding caused by the puncturing of the epidural vessels.

In this study, we only used a single concentration of ropivacaine (0.4%) for TAPB and ESPB, and it is unknown whether the application of different concentrations of ropivacaine could obtain better postoperative analgesic effects. It is also unknown as to whether the adjuvant dexamethasone prolongs the duration of action. We will further explore these possibilities in future studies. In addition, the number of cases included in this study was relatively small, but this small study is expected to be supported by the data of a large, multicenter sample.

In summary, ultrasound-guided TAPB or ESPB can safely and effectively be used for liver transplantation, which can then reduce the dose of opioids and improve the prognoses of patients.

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Authors contributions

QLZ drafted the manuscript. QLZ, HPW, HBW, MJL, HZL and WMO were responsible for the design of the study. SYF, QFD, FX and ZHZ were mainly responsible for data collection. The manuscript has been revised by SYF, FWD, HWC and HL. All of the authors read and approved the final manuscript.

Ethics approval and consent to participate

The study was approved by the Ethics Committee of the Affiliated Foshan Hospital of Sun Yat-sen University (Foshan, China). Signed informed consents were obtained from the patients or the guardians.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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