Original Article

The analgesic efficacy of ultrasound-guided thoracic paravertebral block in pulmonary tumor ablation surgery: a prospective single-arm study

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Background: Local thermal ablation is a rapidly developing minimally invasive treatment for lung tumors. This technique has the advantages of less trauma, ease and convenience of the operation, fast recovery, and fewer complications. Thoracic paravertebral block (TPVB) has been demonstrated can provide sufficient pain relief with high safety. This study aimed to evaluate the efficacy of TPVB for anesthesia management during the ablation surgery of lung tumors.

Methods: In our study, a total of 30 patients undergoing Local thermal ablation surgery were enrolled. All patients received TPVB anesthesia before CT positioning starting. Analgesics and rescue drugs were used according to the patient's condition during operation. The main observation and assessment outcome were intraoperative and postoperative Visual Analog Scale (VAS) score. Other outcomes were total dose of analgesics and rescue drugs, incidences of adverse events, and the patients' and surgeons' satisfaction degrees.

Results: All patients successfully received ablation surgery under TPVB anesthesia. None of the patients were switched to general anesthesia. There were no statistically differences were found between the preoperative VAS score (0.54±1.12) and the intraoperative VAS score (0.58±1.15) (P>0.05). No adverse events occurred and no rescue drugs were used during operation. The satisfaction scale of both patients and surgeons was 3 points or above, and all patients were discharged from the hospital.

Conclusions: TPVB is an effective and safe anesthesia management technique which can provided adequate pain relief in local thermal ablation therapy for lung tumors. This discovery could provide a better anesthesia protocol for anesthetists in lung tumors ablation surgery, especially when patients have a poor cardiopulmonary function and combined with serious underlying diseases.

Keywords: Lung tumor; percutaneous thermal ablation; nerve block; paravertebral

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Introduction

Lung cancer is a grievous threat to human health and life. Statistics indicate that the diagnostic rate of lung cancer in 2020 was ranked second after breast cancer, and the mortality rate was ranked first (1,2). Local thermal ablation therapy for lung tumors has been the focus of domestic and overseas research in the past decade. This technique has the advantages of less trauma, ease and convenience of the operation, fast recovery, and fewer complications; it is especially suitable for patients with lung cancer who have poor cardiopulmonary function and intolerance to thoracotomy (3). The most commonly used thermal ablation technologies are radiofrequency ablation (RFA) and microwave ablation (MWA). However, this operation still lacks safe and effective anesthesia management.

Thoracic paravertebral block (TPVB) involves the injection of local anesthetics (LA) into the paravertebral space to anesthetize the spinal nerve roots and sympathetic chain, which produces ipsilateral, segmental, somatic, and sympathetic nerve block. It has long been used to provide unilateral chest and abdominal wall analgesia (4), especially for chest or breast surgery, which has been proved that has good analgesic effect and safety (5,6). TPVB has been successfully used as anesthesia for liver and kidney tumor ablation surgery (7-9). However, whether it can be used similarly in the anesthesia of lung tumor ablation surgery lacks sufficient clinical evidence.

This study was designed to explored the application of TPVB in lung tumor ablation surgery, aiming to improve surgical safety and patient comfort. The primary goal was to evaluate the analgesic effect and safety of TPVB in ablation surgery. Evaluation of patient and surgeon satisfaction was the secondary goal. We present the following article in accordance with the STROBE reporting checklist (available at https://apm.amegroups.com/article/view/10.21037/apm-22-1040/rc).

Methods

Patients

After obtaining approval from the Institutional Ethics Committee of Affiliated Hospital of Nantong University (Approval number: 2021-K145), we recruited 30 consecutively admitted adult patients aged from 56 to 84 years and scheduled for MWA or RFA of primary or secondary malignant lung tumors (*Table 1*). Patients with chest wall deformity, severe coagulation disorders, allergic to local anesthetics were excluded, and so did if they had a history of psychiatric illness or chronic pain. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Written informed consents were obtained from all patients or their legal representatives.

Table 1 Demographic and clinical data of pulmonary ablation surgery patients

Variable	Value
Age, years	71.3±7.7
Sex	Male: 18 (60.0%), female: 12 (40.0%)
BMI, kg/m^2	24.0±3.1
ASA	III: 21 (70.0%), IV: 9 (30.0%)
Tumor size (mm)	20.8±12.9
Distance to pleura (mm)	8.0±9.4
Operative position	Supine position: 15 (44.1%), lateral position: 5 (14.7%), prone position: 14 (41.1%)

Values are expressed as mean ± SD or number (percentage). One patient underwent two positions during surgery. BMI, body mass index; ASA, American Society of Anesthesiologists.

During the preoperative visit, all patients received an explanation of the overall research approach and accepted the instruction of the Visual Analog Scale (VAS), which was used to assess the pain degree (where 0= "no pain" and 10= "the worst pain"). None of the patients received premedication. Upon admitting to the CT fluoroscopy room, standard monitoring was conducted, including heart rate (HR), pulse oximetry and noninvasive arterial blood pressure. Oxygen therapy was performed at a rate of 3 L/min with nasal cannula.

Anesthesia methods

Patients were firstly positioned in the prone position. Then, TPVB was performed 20 minutes before the MWA or RFA began, with the ultrasonic probe positioned in the transverse plane and located the appropriate thoracic spinous. After locating pleura and thoracic paravertebral space, the probe was manipulated slightly to avoid the ribs, and the needle was inserted using an in-plane approach. After negative aspiration of blood or cerebrospinal fluid, 15 mL of 0.375% ropivacaine was injected in a single injection, and downward displacement of the pleura confirmed the correct placement of the needle. A total of 30 mL of ropivacaine was given

Table 2 Comparison of VAS before and during ablation surgery

	Before surgery	During surgery	P
VAS, mean ± SD	0.54±1.12	0.58±1.15	0.915

Some pain that patients felt before surgery might be caused by other diseases. VAS, Visual Analog Scale; SD, standard deviation.

in the T3–4 and T5–6 levels (block level could be adjusted depending on the location of the tumor). After patients were placed in the position required for the surgery, sensory blocking was assessed by cold sensation to an alcohol-soaked sponge.

Outcome measures

The degree of pain was assessed using the VAS score: before, during, 6 and 24 hours after surgery. The pain was considered mild if the VAS range was 1–3, moderate if the VAS score was 4–6, and severe if the VAS score was ≥7. A score of 0 was considered painless. Intravenous dezocine 2–3 mg was given once if the VAS was ≥3 and repeated once if needed, and the total dose of dezocine was recorded. If the patient still experienced pain with a VAS score ≥4 after repeated use of dezocine, the surgery was suspended, and the patient was switched to general anesthesia (GA). In addition, the use of rescue drugs during the operation was recorded; atropine would be given if intraoperative bradycardia occurred (a heart rate below 50), and ephedrine would be given if hypotension occurred (a decrease in systolic arterial pressure >30% of the basal value). Low oxygen saturation, defined as SaO_2 <90%, were recorded.

Following surgery, monitoring the patients' vital signs for 30 min. Thereafter, paracetamol would be given as postoperative analgesia if the VAS score was ≥4. Before the patient's discharge from the hospital, a four-point satisfaction scale (1= very dissatisfied, 2= dissatisfied, 3= satisfied, and 4= very satisfied) was used to assess the degree of patient and surgeon satisfaction with the anesthesia management.

Statistical analysis

SPSS 24.0 software was used to statistically analyze the data, the Wilcoxon signed-rank test was used for non-normally distributed continuous variables. A value of $P<0.05$ was considered statistically significant. All values are shown as mean ± SD, unless indicated otherwise.

Results

TPVB surgery was performed successfully in all 30 patients, with a total of 33 ablations completed. None of the patients needed to be switched to GA. The VAS results showed that 93.9% of cases received significant pain relief (VAS ≤2) from the onset of surgery to 24 h post-surgery, and 78.8% of cases achieved complete pain relief (VAS ≤1). The VAS data are presented in *Table 2*, were not statistically different between preoperative and intraoperative groups ($P>0.05$), which proved that TPVB provided adequate pain relief during surgery. No adverse events occurred during the operation, and similarly there was no rescue drugs were used, all operations were performed smoothly. Which proved the safety of TPVB in ablation surgery. The satisfaction scale of both patients and surgeons was 3 points or above. Among them, two cases had VAS scores greater than 3 points and required a single administration of dezocine. We considered that the patients felt pain because of poor drug solution diffusion, which resulted in an insufficient sensory blockade. This phenomenon may be a potentially uncontrollable factor in the actual operation of TPVB.

Complications and side effects

After each TPVB, a CT scan demonstrated that no pneumothorax associated with the anesthetic operation had occurred. Pneumothorax developed after the ablation procedure in five patients: two cases were cured by chest-tube placement similarly under TPVB, and the other three cases resolved without additional treatment. Self-limiting pulmonary hemorrhage occurred in one case that also resolved without additional treatment. There were no major adverse cardiovascular events requiring the treatment of vasoactive agents during the procedure. No surgical pain events requiring human intervention occurred from the end of the procedure to discharge.

Follow-up

Postoperative nausea and vomiting occurred in some patients, but most did not require additional treatment. More than one factor may have contributed to this phenomenon; it may have reflected the presence of post-ablation syndrome (3) or may have been due to epidural spread of the LA. Contralateral segmental sensory blockade was reported in five cases (15.2%), which may have been due to epidural (10) or prevertebral (11) spread of the

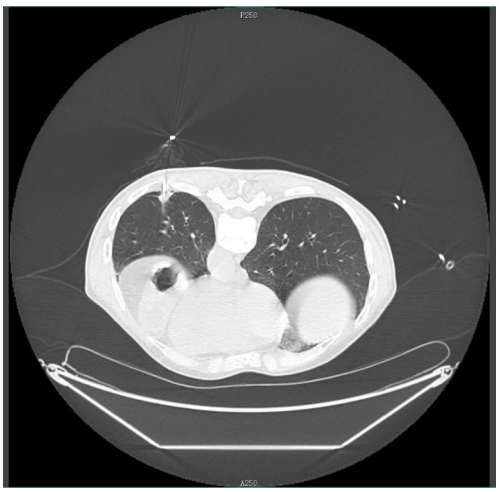

Figure 1 The tumor clings to the chest wall, where the heat generated by the ablation needle can cause unbearable pain to the patient. Intravenous conscious sedation anesthesia generally cannot provide sufficient analgesic effect for the ablation procedure unless under GA. However, this patient successfully received ablation surgery under TPVB and felt no pain. GA, general anesthesia; TPVB, thoracic paravertebral block.

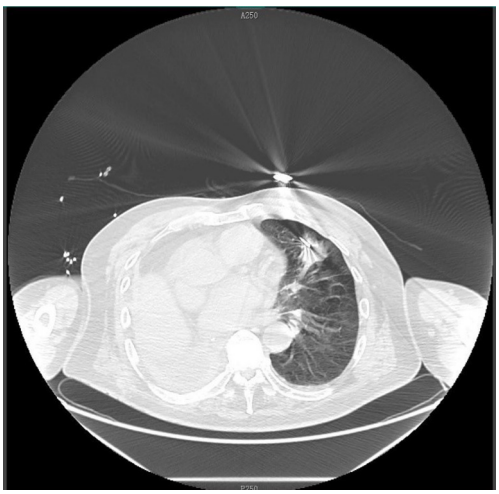

Figure 2 The patient had received a total resection of the right lung for squamous cell carcinoma two years previously, had a history of pulmonary embolism, and had particularly poor general health. The patient could not tolerate reoperation or GA, so ablation surgery was chosen. TPVB can significantly reduce the risk of surgery and anesthesia while meeting the anesthesia requirements of surgery. GA, general anesthesia; TPVB, thoracic paravertebral block.

LA. The previously reported data on the incidence of contralateral blockade has been inconsistent and may reflect the operational approach of each surgeon.

Discussion

The results of the present study showed that TPVB without other drugs effectively reduced intraoperative and postoperative pain, decreased the use of rescue analgesia during ablation surgery, caused little inhibition of circulation and respiration, and demonstrated good patient and surgeon satisfaction.

Pain is one of the most common side effects of ablation. Unendurable pain is reported in about 46% of treatment procedures, especially where the tumor is less than 1 cm away from the chest wall (*Figure 1*) (12). The occurrence of pain during ablation surgery may be due to stimulation of the parietal pleura. The parietal pleura and chest wall are sensitive to pain due to the large number of intercostal nerve branches running between them. Pain will occur when they suffer from stimulation and is often transmitted by the intercostal nerve (13). Intercostal nerves are inevitably damaged when a tumor is ablated adjacent to the pleura, which can cause persistent intraoperative or postoperative pain. In clinical practice, it has been demonstrated that most patients who experienced severe pain had tumors adjacent to the pleura.

Since the advent of ablation surgery for the treatment of lung tumors, the optimal anesthesia has been controversial, with some anesthetists preferring GA (14), others preferring LA combined with sedation, and still others choosing epidural analgesia (EPI) (15). For the majority of patients undergoing ablation surgery, LA with opioid sedation is preferred (16), or opioids combined with benzodiazepines and propofol (17). Nevertheless, intravenous anesthesia may negatively affect respiratory function in some patients. They may also suffer from post-ablation pain, which can limit their respiratory movement, ultimately leading to an increased risk of pulmonary infection and a slower postoperative recovery time. In addition, some commonly used intravenous anesthetics, such as opioids, have been found to suppress immunologic function in tumor patients (18). A previous study has concluded that ablation of pulmonary tumors under GA or conscious analgo-sedation anesthesia (AS) did not result in different tumor control or complication rates (14). There is no need to do these interventions under GA.

Most patients who require pulmonary ablation surgery are usually older with poor general health and have other significant comorbidities (*Figure 2*). They may not be ideal candidates for anesthesia due to the increased risk of

complications, which requires the anesthetist to carefully consider an anesthetic prescription that maintains an appropriate balance of benefits and risks. In most instances, RFA or MWA are performed under ultrasound or CT-fluoroscopic guidance, and operating theatres generally do not have these facilities. Therefore, surgery is commonly performed outside of the operating room. GA usually requires airway instrumentation, anesthetic assistance, and monitoring equipment, which is less readily available in the radiology suites. Conscious anesthesia is preferred for non-operating room anesthesia (NORA), where patient safety always takes precedence (19).

TPVB produces an anesthetic effect by injecting LA into the paravertebral space (4). The paravertebral space is longitudinally distributed along the vertebral body and can achieve a unilateral multilevel block by a single puncture injection without causing severe hemodynamic changes. TPVB is typically performed for intraoperative and postoperative analgesia in thoracic surgery or breast surgery and has been proven to positively affect perioperative lung injury, immune function, and postoperative recovery (20). TPVB has also been used successfully in anesthesia for liver and kidney tumor ablation surgery domestically and internationally. Successful cases of TPVB in lung tumor ablation have also been reported (21,22).

Commonly used LA with sedation is not effective enough to meet the anesthesia requirements of ablation surgery, and increasing the dose of intravenous anesthesia creates greater risk. Sometimes the surgeon needs to decrease the power and shorten the ablation time to help relieve pain, but this can lead to incomplete ablation and increased recurrence. In this circumstance, TPVB has an incomparable advantage, providing similar pain relief to traditional EPI while at the same time improving respiratory function and maintenance of hemodynamic stability with fewer complications, such as nausea, vomiting, and urinary retention (23,24). Additionally, TPVB has fewer contraindications when compared with GA and EPI. As such, we believe that TPVB is more suitable for complicated situations that arise in anesthesia for ablation surgery. Additionally, we chose to carry out the TPVB procedure under ultrasound guidance, which has potentially fewer complications and superior safety than the traditional blind puncture technique (25).

Reducing the consumption of opioids and sedative drugs and allowing patients to avoid GA during the ablation procedure are the primary advantages of TPVB, which can greatly improve safety. Another important benefit of TPVB is enabling the patient to maintain an adequate conscious level and preserve the respiratory drive, which ensures that they can take a deep breath or hold their breath for a brief apneic pause at the surgeon's request. Furthermore, the patient can change their position in response to the surgeon based on the surgical requirements. In this study, 33 ablations were performed on 30 patients, including 15 in the supine position, 13 in the prone position, and 5 in the lateral position. Intravenous anesthesia for patients in the lateral and prone positions increases the anesthesia risk and is not conducive to emergency treatment and rescue. Compared with intravenous anesthesia, TPVB is more suitable for operations with high requirements for specific surgical positioning (*Figure 3*).

Severe pleural reactions can occur during the ablation procedure, which primarily manifest as a decreased heart rate. Some factors may account for this phenomenon; for instance, ablation stimulates the vagus nerve that innervates the parietal pleura, and the excitatory vagus nerve can reduce the heart rate, even causing cardiac arrest. TPVB cannot block the vagus nerve, which is considered the main drawback of this technique. In addition, some patients do not cope well with illness, and their fear of treatment puts them in a highly anxious state. These factors can contribute to the occurrence of pleural reactions. In such cases, the anesthetist can consider giving 2 mg midazolam preoperatively to the patient to enhance the sedative effect of the anesthesia, which may relieve the patient's anxiety and enable them to achieve a more successful surgical experience. Our previous experience has demonstrated the safety and efficacy of this approach.

One problem we noticed in using TPVB for ablation surgery was the onset of cough during the ablation procedure. In some cases, the patient developed a cough, and a small minority of patients developed a severe, uncontrollable cough. Intraoperative cough may be caused by alveolar, endobronchial, or pleural irritation due to the elevated local temperature. Displacement of the ablation needle can happen when a patient's severe cough causes body movements, leading to serious consequences, whereas GA can completely avoid this problem. Although the probability of this occurrence is very low, it is indeed a disadvantage of TPVB, and we hope that more studies can be conducted to eliminate this adverse effect.

The TPVB was administrated with the dual-injection technique at two segments in this study. Previous studies have shown that the cranial and caudal distribution of the single-injection encompasses approximately 4.0 vertebral levels, mainly in the caudal direction (26), and there were

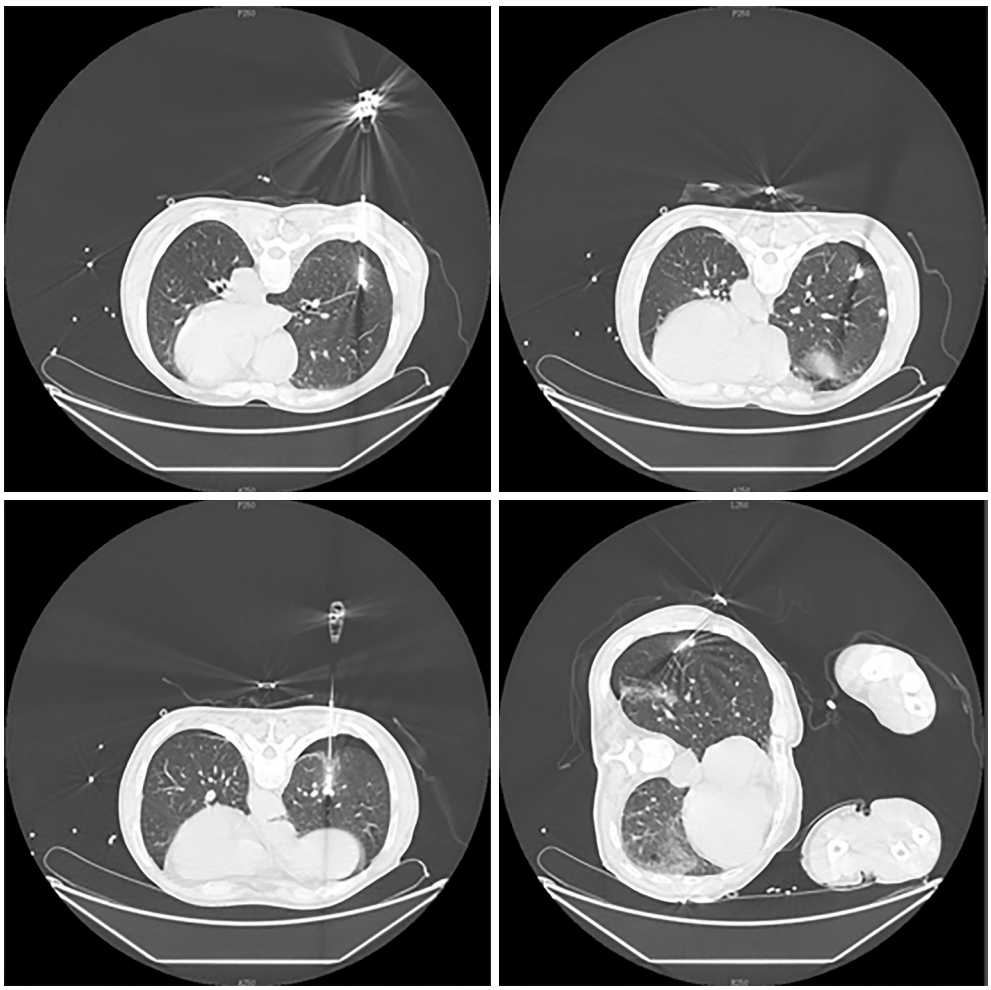

Figure 3 This case is a patient with lung metastases from colon cancer. A total of four tumors were ablated at different locations during the whole operation, which took a long time. In addition, the surgeon had to reposition after each ablation, and the patient was also required to change from the prone position to the lateral position. TPVB allows the patient to retain consciousness, so they can cooperate with the surgeon and meet the surgery requirements. TPVB, thoracic paravertebral block.

no significant differences in the extent of spread between the single- and dual-injection techniques (27). For most cases in this study, puncture points were chosen at T3–4 and T5–6, and 15 mL of 0.375% ropivacaine was injected at each segment. The puncture site can be modulated in other cases according to the actual situation. Currently, there are no published data describing the optimal LA concentration or dosage for TPVB. More studies are required to explore whether single-injection techniques can satisfy surgical requirements.

Patients who underwent MWA were mainly selected for this study for MWA's superior advantage to RFA in therapeutic effect and technology and because the quicker heating times and higher intralesional temperatures during the MWA procedure create more palpable pain (3,28). Therefore, we deemed that selecting cases undergoing MWA was more valid. This study did not simultaneously compare TPVB with other commonly used anesthesia methods under the actual control experiment, which may be a major limitation of the study.

Conclusions

Ultrasound-guided TPVB is an effective and safe anesthetic technique for patients with primary or secondary malignant lung tumors who undergo thermal ablation therapy. The

block was well tolerated by the patients and also acceptable to the surgeons. We believe that TPVB can be widely used as anesthetic management for tumor ablation surgery in various populations and is especially advantageous for patients who have poor general health and cardiopulmonary function.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://apm.amegroups.com/article/view/10.21037/apm-22-1040/rc

Data Sharing Statement: Available at https://apm.amegroups.com/article/view/10.21037/apm-22-1040/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://apm.amegroups.com/article/view/10.21037/apm-22-1040/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This prospective study was approved by the ethics committee of Affiliated Hospital of Nantong University (Approval number: 2021-K145). Written informed consents were obtained from all patients or their legal representatives.

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