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Thoracic Paravertebral Block versus Epidural Anesthesia Combined with Moderate Sedation for Percutaneous Nephrolithotomy

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Key Words
Percutaneous nephrolithotomy · Paravertebral block · Epidural anesthesia · Conscious sedation · Postoperative analgesia

Abstract
Objective: To investigate the feasibility of thoracic paravertebral block (TPVB) for percutaneous nephrolithotomy (PCNL) in comparison with epidural anesthesia (EA) combined with moderate sedation. ***Subjects and Methods:*** One hundred American Society of Anesthesiologists (ASA) I–II adult patients scheduled for first-stage unilateral PCNL were randomly assigned to receive either TPVB or EA. All patients were given standard sedation and analgesia with propofol and sufentanil. Patient characteristics, surgical outcomes, anesthetic outcomes, and time to first use of a patient-controlled intravenous analgesic (PCIA) device and postoperative consumption of sufentanil in the first 24 h were recorded. Intergroup differences of the parameters were analyzed using an independent t test, Mann-Whitney test, and χ^2 test as appropriate. ***Results:*** Patients who received TPVB consumed more propofol during ureteroscopy (56.2 ± 28.4 vs. 42.9 ± 27.5 mg, $p < 0.05$) and more sufentanil during ureteroscopy (9.7 ± 4.8 vs. 3.9 ± 2.7 μg, $p < 0.05$) and during PCNL (7.0 ± 4.3 vs. 1.9 ± 1.8 μg, $p < 0.05$) than those who received EA. The volume fluids infused in patients who received TPVB was less than in those who received EA (854 ± 362 vs. 1,320 ± 468 ml, $p < 0.05$). Time to first PCIA use, postoperative 24-hour consumption of sufentanil, and other parameters were comparable between groups. ***Conclusions:*** In this study, TPVB was as effective and safe as EA in providing intraoperative anesthesia and postoperative analgesia for PCNL, although more sedatives and analgesics were used during PCNL in patients who received TPVB.

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Introduction

Percutaneous nephrolithotomy (PCNL) is a very common minimally invasive method for the management of large and complex renal calculi [1, 2]. General anesthesia (GA) and regional anesthesia (RA; including epidural, spinal, or combined anesthesia) are commonly used for PCNL [3, 4]. Two recent systematic reviews showed that both GA and RA were safe and effective for PCNL; RA offered several potential advantages over GA in terms of surgical duration, hospitalization period, postoperative pain, analgesic requirements, and blood transfusion [3,

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4], which indicated that RA may be a good alternative technique to GA for PCNL. Another advantage of RA for PCNL is that patients can position themselves without much assistance, and thus less operative theater staff is required for positioning from the supine to prone position [5].

Thoracic paravertebral block (TPVB) is the technique of injecting a local anesthetic agent adjacent to the thoracic vertebra close to where the spinal nerves exit the intervertebral foramina, resulting in ipsilateral, segmental, somatic, and sympathetic nerve blockade [6]. This helps to preserve lower limb motor power and promotes early mobilization [6]. TPVB is effective for pain management following lithotripsy [7], PCNL [8–10], and nephrectomy [11], and provides anesthesia in percutaneous radiologic procedures involving the renal pelvis and ureter [12]. Nonetheless, there is no study on the usefulness of TPVB as a main anesthetic technique in PCNL. Therefore, our aim was to assess the feasibility of TPVB for PCNL in comparison with epidural anesthesia (EA) when combined with moderate sedation. The hypothesis was that TPVB could require more sedation, but surgical and anesthetic complications might be less than with EA.

Subjects and Methods

The study was conducted from May 2012 to August 2014. The Institutional Ethics Committee approved the study and written informed consent was obtained from all the patients. Inclusion criteria were patients (aged 18–60 years) scheduled for first-stage unilateral PCNL who had stones in the upper ureter and the pelvicalyceal system which were larger than 1.5 cm, multiple, or resistant to extracorporeal shock wave lithotripsy with American Society of Anesthesiologists (ASA) I–II. Exclusion criteria were a history of psychiatric illness, allergy to local anesthetic drugs, severe obstructive or restrictive pulmonary diseases, morbid hepatic or cardiac dysfunction, unregulated diabetes mellitus, coagulation disorders, pathological obesity (BMI ≥35), local or systemic infection, vertebral deformity, patient refusal or noncompliance, and postoperative admission to the intensive care unit. The kidney stones were diagnosed by plain radiography of the kidney-ureter-bladder region and abdominopelvic CT. Stone size was defined as the sum of the maximal length of renal stones on CT images.

A day prior to the surgery, the patients were blinded and randomly assigned to receive TPVB combined with moderate sedation, or EA combined with moderate sedation for PCNL using the closed envelope method, and instructed on the use of a 0–10 numeric rating scale (NRS) and the patient-controlled intravenous analgesic (PCIA) device.

On arrival in the operating room, intravenous access was established and standard monitors were applied, including electrocardiography, pulse oximetry, and noninvasive blood pressure. Oxygen was delivered using a face mask at 5 liters · min^{-1}. A single anesthesiologist (C.L.) performed TPVB and EA. In patients who received TPVB, prior to the procedure, 10 ml of 2% lidocaine jelly was slowly instilled into the urethra over 30 s, then the patients were positioned in the lateral decubitus position with the side to be operated upwards. Subsequently, the spinous process of the 11th thoracic vertebra was located. A point was then marked with a skin-marking pen on the skin of the side to be operated, 2.5 cm lateral to the cephalic edge of the tip of the spinous process of the 11th thoracic vertebra. Under aseptic precautions, a 20-gauge 80-mm Tuohy needle was inserted perpendicular to the skin and advanced until it made contact with the transverse process. The needle was then withdrawn and redirected in the cephalic direction to walk off the transverse process to about a depth of 1 cm until a subtle loss of resistance to the injection of saline was felt. After negative aspiration of blood or cerebrospinal fluid, 3 ml of 2% lidocaine, used as a test dose, and 15 ml of 0.75% ropivacaine were slowly injected into the paravertebral space. Fifteen minutes after injection, the adequacy of blockade was assessed using a pinprick test over the lower thorax and abdomen. Analgesia including no less than two contiguous dermatomes from the T10 to the T12 segment was defined as a successful TPVB. Four cases from those who received TPVB were excluded due to failed block. In patients who received EA, epidural puncture was performed with a 16-gauge Tuohy needle at the L1–L2 interspace using a paramedian approach, and the epidural space was identified by the loss of resistance. An 18-gauge epidural catheter was inserted into the epidural space and then 3 ml of 2% lidocaine, used as a test dose, and 15 ml of 0.75% ropivacaine were intermittently injected via the catheter. The upper limit of sensory block was bilaterally identified by a pinprick test 15 min after injection. When bilateral sensory block to the T8 level was achieved, the block was accepted as a successful EA. One case from those who received EA was excluded due to admission to the intensive care unit because of postoperative septic shock. A total of 100 patients completed the study.

After confirming effective block, midazolam 0.02 mg/kg was administrated and propofol was titrated at a rate of 1–3 mg · $kg^{-1} \cdot h^{-1}$ to maintain a Ramsay Sedation Scale (RSS) score between 2 and 3, at which the patients could respond during ureteroscopy and PCNL. The RSS scores are as follows: anxious and agitated or restless: 1; cooperative, orientated, and tranquil: 2; responds to commands: 3; asleep and brisk response to light glabellar tap loud auditory stimulus: 4; asleep and sluggish response to light glabellar tap loud auditory stimulus: 5, and asleep and no response to light glabellar tap loud auditory stimulus: 6 [13].

One endourologist (W.W.) performed the ureteroscopy and PCNL. If excessive bleeding or hemodynamic instability occurred during PCNL, the procedure was terminated, an 18-Fr nephrostomy tube was placed, and the patient was transferred for a second-stage operation. Two 5-Fr ureteric catheters were placed into the upper ureter or renal pelvis of the side to be operated via a 9.8-Fr rigid ureteroscope in the lithotomy position in order to block leakage of large fragmented stones from entering into the ureter. After ureteroscopy, all patients attempted self-positioning to the lateral decubitus position with the operated side upward. If self-positioning was difficult, the position change was gently performed together with the urologists and anesthesiologists. Renal access was established in the lateral decubitus position under ultrasound guidance. The access tract was dilated with fascia dilators to 22 Fr at which point the Amplatz sheath was placed. A 20-Fr nephroscope was introduced to the collecting system, and the stone was disintegrated with a pneumatic lithotripter and removed by forceps. After complete clearance as judged by ultrasonography, the ureteric catheters were removed, a 5-Fr double-pigtail ureteral stent was inserted, and an 18-Fr nephrostomy tube was placed as routine in all the patients. The time taken for the ureteroscopy and PCNL in each patient was recorded. At the end of the PCNL procedure, the endourologist's satisfaction with anesthesia was assessed using the 11-point NRS as very bad (0) to very good (10). The nephrostomy tube was removed after 48–72 h, depending upon the clearance of gross hematuria. The double-pigtail stent was removed after 2 weeks.

The severity of pain experienced by patients during ureteroscopy and PCNL was self-assessed according to the NRS as mild pain (1–3), moderate pain (4–6), and severe pain (7–10); then if the patient reported an NRS score ≥4, sufentanil (0.05 μg/kg) was intravenously administered as rescue analgesia and repeated at 3-min intervals if necessary. The anesthesiologist (C.S.) in the operating room decided whether or not a blood transfusion was necessary. Hypotension was defined as SBP <80 mm Hg, DBP <50 mm Hg, or SBP decreasing to ≥30% below baseline, and was then treated with intravenous fluid and ephedrine (10-mg bolus). Hypertension was defined as SBP >180 mm Hg, DBP >100 mm Hg, or SBP increasing to ≥30% above baseline, and was then treated with nitroglycerin (0.2-mg bolus or titration). Hypoxia was defined as SpO_2 <94% or a decrease of 10% below baseline saturation, and was treated with deep breathing or intravenous naloxone 0.05 mg. The infusion volume of fluids was noted.

After completion of PCNL, propofol sedation was discontinued. The amount of sufentanil and propofol consumed during the operation was recorded. Surgical complications that included blood transfusion, pneumothorax, and water intoxication were recorded. Postoperative analgesia was provided using a PCIA device, which was set for a 2.5-μg bolus dose of sufentanil with a 5-min lockout interval and a 1-hour limit of 20 μg. Side effects such as nausea, vomiting, sedation, and itching were recorded. Tropisetron 2 mg was intravenously used to treat postoperative nausea and vomiting. Time to first PCIA use and postoperative sufentanil consumption over 24 h were recorded. Patient satisfaction with anesthesia was evaluated using the 11-point NRS as very bad (0) to very good (10). Stone-free status was defined as the absence of any fragment >4 mm using abdominopelvic CT 2 days after the operation.

A power analysis was performed based on a pilot study in which 9 out of 10 patients who received TPVB got a successful block and the postoperative 24-hour consumption of sufentanil was 33.1 ± 6.5 μg, which revealed that 49 patients in each group would be required to detect a 10% difference in the postoperative requirement of sufentanil over 24 h with a power of 80% and α = 0.05.

Statistical Analysis

Data were processed using the Statistical Package for Social Sciences (version 17.0, 2009; SPSS Inc., Chicago, Ill., USA). The values are expressed as means ± SD for quantitative variables and as number (%) for categorical variables and ordinal variables. Quantitative variables were compared using an independent t test. Ordinal variables were compared using a Mann-Whitney test, and categorical variables were compared using a χ^2 test. $p < 0.05$ was considered significant.

Table 1. Patients' characteristics

	TPVB	EA	p
Gender, males/females	34/16	31/19	0.529
Age, years	48.3±11.8	47.7±12.2	0.803
Weight, kg	70.8±12.4	68.3±10.9	0.287
Height, cm	164.1±9.7	166.2±10.1	0.292
BMI	26.3±4.1	24.7±4.2	0.059
Comorbidity			
Hypertension	18 (36.0)	13 (26.0)	0.280
Diabetes	3 (6.0)	5 (10.0)	0.712
COPD	0 (0)	1 (2.0)	1.000
Stone			
Laterality, right/left	21/29	23/27	0.687
Size, mm	30.2±10.1	27.8±11.8	0.277
Number	2.2±2.2	2.8±3.1	0.267
Location			
Staghorn: complete/partial	6/5	8/4	0.922
Ureteropelvic, upper ureter, or lower calyx	19 (38.0)	18 (36.0)	
Renal pelvis and upper calyx	7 (14.0)	9 (18.0)	
Upper calyx	0 (0)	1 (2.0)	
Pelvic	13 (26.0)	10 (20.0)	
Hydronephrosis, no/mild-moderate/severe	8/34/8	10/31/9	0.811

Values are given as n (%) or means ± SD. COPD = Chronic obstructive pulmonary disease.

Results

The demographic data and stone characteristics are outlined in table 1. There were no significant differences between the two groups regarding age, gender, body weight, height, and comorbidity (p > 0.05). Stone laterality, size, number, and location were also similar in the two groups (p > 0.05).

Surgical and anesthetic data are summarized in table 2. No significant intergroup differences were found regarding duration of ureteroscopy and PCNL, transfer for second-stage PCNL, selection of renal access tract, surgical complications, or endourologist's satisfaction with anesthesia (p > 0.05). Out of 50 patients who received TPVB, 2 male cases received deep sedation and mask ventilation during ureteroscopy due to intolerance to the procedure; these patients did not change position by themselves to the lateral decubitus position for PCNL. The 50 patients who received EA required the assistance from operation theater assistants for position change.

Table 2. Surgical and anesthetic data

	TPVB	EA	p
Surgical outcomes			
Duration of ureteroscopy, min	18.4±7.6	19.1±8.1	0.657
Duration of PCNL, min	64.5±19.4	68.5±22.3	0.341
Transfer for second-stage PCNL	4 (8.0)	3 (6.0)	1.000
Renal access tract			
Intercostal access	38 (76.0)	41 (82.0)	0.461
Second access tract	4 (8.0)	3 (6.0)	1.000
Surgical complications			
Pneumothorax	0 (0)	1 (2.0)	1.000
Blood transfusion	1 (2.0)	0 (0)	1.000
Hydrothorax	0 (0)	0 (0)	1.000
Anesthetic outcomes			
RSS score, 2/3/>4			
During ureteroscopy	21/27/2	14/36/0	0.254
During PCNL	21/29/0	16/34/0	0.303
Duration of anesthesia, min	84.4±24.7	89.7±24.0	0.279
Propofol consumption, mg	157.7±83.2	126.4±63.1	0.037
During ureteroscopy	56.2±28.4	42.9±27.5	0.019
During PCNL	101.5±59.3	83.5±48.6	0.100
Sufentanil consumption, µg	16.7±5.2	5.8±4.8	0.000
During ureteroscopy	9.7±4.8	3.9±2.7	0.000
During PCNL	7.0±4.3	1.9±1.8	0.000
Intraoperative adverse events			
Hypertension	6 (12.0)	0 (0)	0.035
Hypotension	0 (0)	4 (8.0)	0.126
Hypoxia	3 (6.0)	0 (0)	0.241
Volume of fluid infused, ml	854±362	1,320±468	0.000
Self-positioning without assistance	48 (96.0)	0 (0)	0.000
Endourologist's satisfaction with anesthesia	9.2±2.0	9.3±1.5	0.778

Values are given as n (%) or means ± SD.

Table 3. Postoperative data

	TPVB	EA	p
Time to first PCIA use, h	8.1±5.1	9.4±4.3	0.171
Postoperative consumption of sufentanil over 24 h, µg	32.4±6.8	30.3±7.1	0.134
PONV	5 (10.0)	6 (12.0)	0.749
Itching	0 (0)	0 (0)	1.000
Patient's satisfaction with anesthesia	8.8±2.2	8.4±3.2	0.468
Blood transfusion	0 (0)	0 (0)	1.000
Stone-free rate	44 (88.0)	46 (92.0)	0.739
Hospitalization, days	11.2±3.4	12.4±3.7	0.094

Values are given as n (%) or means ± SD. PONV = Postoperative nausea and vomiting.

Propofol consumption during ureteroscopy was higher in patients who received TPVB than in those who received EA (56.2 ± 28.4 vs. 42.9 ± 27.5 mg, $p < 0.05$). Compared with patients who received EA, more sufentanil was used in those who received TPVB during ureteroscopy (3.9 ± 2.7 vs. 9.7 ± 4.8 µg, $p < 0.05$) and during PCNL (1.9 ± 1.8 vs. 7.0 ± 4.3 µg, $p < 0.05$). The infusion volume of fluids was less in patients who received TPVB than in those who received EA (854 ± 362 vs. 1,320 ± 468 ml, $p < 0.05$). Intraoperative adverse events such as hypertension, hypotension, and hypoxia were similar in the two groups ($p > 0.05$).

The data from the postoperative interviews are shown in table 3. Time to first PCIA use and postoperative 24-hour consumption of sufentanil were comparable between groups: 8.1 ± 5.1 vs. 9.4 ± 4.3 h and 32.4 ± 6.8 vs. 30.3 ± 7.1 µg, respectively ($p > 0.05$). No significant difference was seen in the stone-free rate, patient's satisfaction with anesthesia, and postoperative complications such as itching and postoperative nausea and vomiting ($p > 0.05$).

Discussion

In this study, TPVB was feasible for providing intraoperative anesthesia for PCNL, although more sedatives and analgesics were required with a slightly higher failure rate in comparison with EA when combined with moderate sedation. Furthermore, an equivalent efficacy was demonstrated in postoperative analgesia for PCNL between TPVB and EA as evidenced by postoperative 24-hour consumption of sufentanil and time to first PCIA use.

The single-injection technique was used in patients who received TPVB in the present study, according to the belief that the multilevel-injection technique of TPVB might be associated with a slightly higher successful rate, but would expose the patients unnecessarily to additional risks related to punctures [14, 15]. Fortunately, pneumothorax associated with punctures did not occur in any patient who received TPVB in the present study. The failure rate of TPVB for PCNL was 6.1–20%, as reported by Kaur et al. [10] and Naja and Lönnqvist [16], which was not indifferent from our result of 7.4%.

In this study, we arbitrarily defined a successful TPVB as loss of pinprick sensation no less than two contiguous dermatomes from the T10 to the T12 segment, according to the study by Kaur et al. [10], but the defined success of TPVB could not meet the need for elimination of renal pain, which needs a block over T10–L2 segments according to the classic textbook definition [17]. This was also partially confirmed by the result that more sufentanil was used during PCNL in patients who received TPVB. In addition, more propofol and sufentanil were used during ureteroscopy in patients who received TPVB and 2 cases of them received deep sedation during ureteroscopy, which indicated that TPVB could not provide effective anesthesia for ureteroscopy. Hence, topical urethra anesthesia would be necessary for ureteroscopy. However, the use of sedatives and analgesics is not always safe [18]. The occurrence of hypoxia indicated that cautious respiratory monitoring was essential when moderate sedation was given.

In the present study, although no significant difference was found in adverse hemodynamic events between groups, patients who received EA required more fluids, and hypotension controlled by ephedrine occurred only in them. This indicates that TPVB is superior to EA in maintenance of hemodynamics and prevention of hypotension, which was also demonstrated by Okajima et al. [19].

As our results showed, TPVB had an equivalent efficacy in postoperative analgesia for PCNL as EA, which was also demonstrated for thoracic surgery [20] and breast surgery [21]; however, Elbealy et al. [22] reported that lumbar paravertebral block was superior to EA for PCNL as demonstrated by lower pain scores and less systemic morphine. The 8.1 h to first demand of analgesia in patients receiving TPVB in our study was similar to the results of Hill et al. [23] and Zhang et al. [24], who reported a 6- to 8-hour analgesic effect after thoracoscopic procedures, and longer than the results of Ak et al. [8] and Borle et al. [9], who described 1.5–2 h of pain relief following PCNL.

As Nandanwar et al. [5] described, positioning a patient with less assistance was an additional advantage of EA, but the advantage was more prominent with TPVB because of ipsilateral somatic blockade. At our institute, unilateral PCNL was preferably performed in lateral decubitus position by endourologists on the belief of ease for establishing renal access and manipulating the nephroscope and lithotripters. Minimal disturbance on hemodynamics and easy airway control could be another advantage in the position, as described by El-Husseiny et al. [25].

Conclusion

In this study, TPVB was as effective and safe as EA in providing intraoperative anesthesia and postoperative analgesia for PCNL, although more sedatives and analgesics were used during PCNL in patients who received TPVB. Therefore, TPVB could serve as a safe alternative to the conventional method of EA for PCNL.

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