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ORIGINAL ARTICLE

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Spontaneous ventilation anaesthesia: total intravenous anaesthesia with local anaesthesia or thoracic epidural anaesthesia for thoracoscopic bullectomy

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Abstract

OBJECTIVES: At present, few data exist regarding the comparisons of perioperative outcomes and recurrence of spontaneous ventilation (SV) video-assisted thoracic surgery (VATS) bullectomy using total intravenous anaesthesia (TIVA) with local anaesthesia (LA) or thoracic epidural anaesthesia (TEA). We evaluated the feasibility and safety of TIVA with LA in the management of primary spontaneous pneumothorax (PSP).

METHODS: We conducted a single-institution retrospective analysis of patients undergoing VATS bullectomy between July 2011 and May 2015; 240 patients were included for analysis. Preoperative, intraoperative and postoperative variables of patients undergoing VATS bullectomy using TIVA-TEA ($n = 140$) were compared with those using TIVA-LA ($n = 100$).

RESULTS: Baseline demographics were similar between groups. No patients in either group required conversion to thoracotomy. Three patients (TIVA-TEA: 2; TIVA-LA: 1) required conversion to intubated general anaesthesia. Both groups had comparable surgical duration, estimated blood loss, peak $EtCO_2$ and lowest intraoperative SpO_2 level. Postoperatively, thoracic drainage volume, duration of chest tube drainage and hospitalization cost did not differ between groups. The incidence of postoperative complications between groups was not significant (2% for TIVA-TEA vs 2% for TIVA-LA, $P = 1.00$). Pneumothorax recurrence rate was 3% in TIVA-TEA cases ($n = 4$) and 2% in TIVA-LA cases ($n = 2$).

CONCLUSIONS: SV-VATS bullectomy using TIVA with LA or TEA is technically feasible and safe. Both groups have comparable short-term outcomes and recurrence rates; TIVA-LA seems a valid alternative to TIVA-TEA for the surgical management of PSP under SV.

Keywords: Thoracoscopy • Spontaneous ventilation • Lung bullectomy • Total intravenous anaesthesia • Thoracic epidural anaesthesia • Local anaesthesia

INTRODUCTION

Primary spontaneous pneumothorax (PSP) is a relatively common clinical problem typically occurring in young patients without clinically apparent lung disease [1]. The main characteristic of PSP is its tendency to recur. The recurrence rate after conservative treatment ranges from 16 to 52%, with a mean of 30% [2]. With surgical treatment, the recurrence rate is <5% [3].

Video-assisted thoracic surgery (VATS), a standard therapy for spontaneous pneumothorax, is usually performed under general anaesthesia with single-lung ventilation. However, there are some adverse effects of this traditional anaesthetic method, including intubation-related airway trauma, residual neuromuscular blockade, impaired cardiac performance, and postoperative nausea and vomiting [4–6]. To avoid the above complications, some scholars have investigated the role of spontaneous ventilation (SV) VATS under thoracic epidural anaesthesia (TEA) for PSP [7, 8].

However, TEA is potentially associated with the risk for epidural haematoma or spinal cord injury; though rare, associated risks are life altering if they occur [9]. To explore alternative options for SV-VATS, we began to employ total intravenous anaesthesia (TIVA) with local anaesthesia (LA) in selected VATS cases. The objective of this study is to assess the feasibility and efficacy of thoracoscopic bullectomy performed under TIVA-LA compared with that of TIVA-TEA and report our initial experience of its use.

[†]The first two authors contributed equally to this work.

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MATERIALS AND METHODS

This study was approved by the First Affiliated Hospital of Guangzhou Medical University Research Ethics Committee. Written informed consent was obtained from all enrolled patients.

Patients

We identified and retrospectively reviewed all patients who underwent 2-port SV-VATS bullectomy for the treatment of PSP between July 2011 and May 2015. A total of 240 patients were identified of which 100 were treated under TIVA-LA and 140 were treated under TIVA-TEA. CT scans of all patients were performed before the procedure. Indications for SV-VATS bullectomy include patients with persistent air leakage following chest tube drainage (longer than 5 days), recurrent PSP, abnormal findings (bleb/bulla or residual space) on radiological examinations or patient request. Eligibility criteria were: (i) American Society of Anaesthesiologist's class I–II, (ii) body mass index (BMI) <25, (iii) Mallampati grade I–II, (iv) little airway secretion, (v) absence of epidural puncture contra-indication (such as coagulopathies and sepsis) and (vi) reported pneumothorax on chest X-ray or CT scan. Exclusion criteria were: (i) history of previous thoracic surgery, (ii) chest traumas or (iii) existence of infection such as pneumonia or tuberculosis.

Prior to operation, surgeons and anaesthesiologists presented eligible patients with the pros and cons of TIVA-TEA and TIVA-LA. Patients made a decision whether or not to be included in the study only after being informed. If patients did not meet the criteria or patients and their families were unable to make a decision after our detailed explanation, they would receive intubated general anaesthesia. Patients in both groups had the same pre-operative preparation, and all surgeries were completed by the same surgical team.

Anaesthesia technique

SV anaesthesia was administered as follows: midazolam (0.06 mg/kg) and atropine (0.01 mg/kg) were injected intramuscularly 30 min before anaesthesia. After entering the operation room, the patients' electrocardiogram, heart rate, blood pressure, pulse oxygen saturation (SpO_2), end-tidal carbon dioxide ($EtCO_2$), respiratory rate and bispectral index (BIS) were continuously monitored.

Anaesthesia was induced with the target-controlled infusion (TCI) of propofol (target plasma concentration of 2–3 μg/ml) and sufentanil 0.1–0.2 μg/kg. Muscle relaxants were not used. BIS monitoring was maintained at 40–60 during the operation. The spontaneous respiration rate was 12–20/min. During SV procedures, a gradual and natural collapse of the operative lung occurred allowing maximal visualization of the lungs after making the incisions. To reduce the cough induced by thoracoscopic manipulation, 6 ml of 2% lidocaine was sprayed on the lung surface under thoracoscopic guidance in the chest cavity.

Anaesthesia in total intravenous anaesthesia with thoracic epidural anaesthesia patients

After establishing intravenous rehydration, the thoracic epidural catheter was inserted into the T7-8 or T8-9 space. In the supine position, a test dose (2 ml) of 2% lidocaine was given through the epidural catheter. If signs of spinal anaesthesia were not present in 5 min, fractionated injection of 10–15 ml 0.375% ropivacaine was administered. Before surgery, the anaesthesia level should reach between T2 and T10. During the procedure, a ventilation mask was used for oxygen inhalation, with an oxygen flow of 4–5 l/min, keeping oxygen saturation above 95%. Anaesthesia was maintained with TCI of propofol (target plasma concentration of 1–2 μg/ml) and dexmedetomidine 0.5–1 μg/kg/h. A single dose of anaesthetic was administered at the beginning of the operation. The epidural catheter was removed after the surgery in the operating room.

Anaesthesia in total intravenous anaesthesia with local anaesthesia patients

All patients were provided supplementary oxygen (2–5 l/min) via laryngeal mask (LM; Royal Fornia Medical Equipment Co., Ltd, China). Anaesthesia was maintained with TCI of propofol (target plasma concentration of 1–2 μg/ml), dexmedetomidine 0.5–1 μg/kg/h and remifentanil 0.05 μg/kg/min. Two incisions were performed after local anaesthetic of 1% lidocaine. Optimally, intercostal muscle and pleura were infiltrated under direct vision or palpation through the skin incision.

Surgical management

All patients were treated by VATS bullectomy alone. Patients were placed in full lateral position with the upper arms extended and fixed on the hand support. A 2-port thoracoscopic technique was used. The first port was a 1 cm incision, generally made in the seventh intercostal space at the anterior axillary line. A soft incision protector (Lap Protector; Hakko Co., Ltd, Japan) was placed into this space and a 30° video thoracoscope (Stryker, USA) was introduced. Following visualization of the thoracic cavity, a 1.5 cm operative port was made in the fourth or fifth intercostal space at the linea preaxillaris. In all cases, wedge resection was performed using a linear endoscopic stapler (Echelon 45 Endopath stapler; Ethicon Endosurgery Corp., Cincinnati, OH, USA) and included not only targeted bullae but also surrounding degenerated areas. When no blebs were visible, a small portion of the apex of the lung was resected. At the end of the procedure, sterile warm physiological saline was instilled and the operated lung was manually expanded via temporary positive-pressure ventilation to check for air leaks. Afterwards, an 18 Fr chest tube was introduced through the camera port incision guided to the apex under direct camera visualization. After the pleural cavity was closed and the wound was sutured, the collapsed lung was re-expanded with a mild negative-pressure auxiliary suction device through the chest tube. Postoperatively, the patient was sent to the recovery room and returned to the ward after full anaesthetic recovery. All patients were monitored for an average of 4 h postoperatively in the general ward. Subsequently, they were allowed to drink and eat.

Postoperative anaesthesia consisted of non-steroidal anti-inflammatory drugs and/or opioids. Criteria for chest tube removal were standardized and included thoracic fluid volume of <200 ml for 24 h, no observed air leak and chest X-ray confirmed well-expanded lung.

Statistical analyses

Statistical analysis was performed using SPSS 19.0 software (SPSS Inc., Chicago, IL, USA). Differences between the two groups were assessed by Student's t-test. Categorical variables such as sex and smoking status are presented as frequencies (%). Differences between groups with continuous variables were assessed by the χ^2 test or the Fisher's exact test. Statistical significance was presented as a P-value of <0.05 throughout the study.

Table 1: Demographic and clinical patient characteristics

Variable[a]	TIVA-TEA (n = 140)	TIVA-LA (n = 100)	P-value
Age (years)	29.4 ± 11.9	26.7 ± 12.6	0.095
Weight (kg)	56 ± 9	56 ± 8	0.76
Height (cm)	172 ± 7	171 ± 8	0.30
BMI	18.9 ± 2.4	19.1 ± 2.4	0.69
Gender			0.005
Male	127 (91%)	77 (77%)	
Female	13 (9%)	23 (23%)	
Smoking status			0.60
Smoking	21 (15%)	17 (17%)	
No smoking	119 (85%)	83 (83%)	

BMI: body mass index; TIVA: total intravenous anaesthesia; LA: local anaesthesia; TEA: thoracic epidural anaesthesia.
[a]Continuous data are shown as mean ± standard deviation and categorical variables as number (%).

Table 2: Surgical and anaesthetic results

Variable[a]	TIVA-TEA (n = 140)	TIVA-LA (n = 100)	P-value
Surgical duration (min)	71 ± 39	74 ± 64	0.66
Peak $EtCO_2$ during operation (mmHg)	42 ± 5	43 ± 7	0.090
Lowest SpO_2 during operation (%)	99 ± 1	99 ± 1	0.29
Total blood loss (ml)	13 ± 25	12 ± 15	0.51
Conversion to intubation (%)	2 (1%)	1 (1%)	
Conversion to thoracotomy (%)	0 (0%)	0 (0%)	

TIVA: total intravenous anaesthesia; LA: local anaesthesia; TEA: thoracic epidural anaesthesia; $EtCO_2$: end-tidal carbon dioxide; SpO_2: oxyhaemoglobin saturation by pulse oximetry.
[a]Continuous variables are presented as mean ± standard deviation and categorical variables as number (%).

RESULTS

Baseline characteristics

Demographic details are presented in Table 1. There was no difference between the age, gender, height, weight, BMI and smoking status of the two groups.

Surgical and anaesthetic results

Between-group comparison of operative findings is detailed in Table 2. During the operation, collapse of the operative lung was satisfactory in both groups. Cough reflex was effectively inhibited using the lidocaine sprayed onto the lung surface. Intraoperative details were assessed for each group. Surgical duration and estimated blood loss were similar between groups. The mean detectable lowest SpO_2 and peak $EtCO_2$ in the TIVA-LA group during the operation was not significantly different compared with that in the TIVA-TEA group. No conversions to open thoracotomy were performed. Conversion to tracheal intubation was required in 3 patients: 2 patients (1%) in TIVA-TEA group because of extensive pleural adhesions with persistent cough and 1 patient (1%) in the TIVA-LA group due to profound lung movement.

Postoperative results

Postoperatively, there was no difference in thoracic drainage volume, chest tube duration and cost of the hospitalization between groups (Table 3). A statistically significant reduction in the length of hospital stay (P = 0.001) of the TIVA-LA group was seen compared with the TIVA-TEA group (Table 3). The two groups had comparable postoperative complication rates: 2% in TIVA-TEA group and 2% in TIVA-LA group (P = 1.00). Complications are detailed in Table 4. There was 1 case of air leakage (>3 days), 1 case of atelectasis and 1 case of bleeding in the TIVA-TEA group. In the TIVA-LA group, there was 1 case of atelectasis and 1 case of bleeding. Postoperative bleeding was controlled with haemostatic medicine without the need for reoperation.

Follow-up

Patients were followed up through either a clinic visit or a telephone interview in 100% of included patients. As the TIVA-LA

Table 3: Postoperative results

Variable[a]	TIVA-TEA (n = 140)	TIVA-LA (n = 100)	P-value
Chest drainage (days)	1.6 ± 1.1	1.4 ± 1.0	0.25
Postoperative hospital stay (days)	3.4 ± 1.5	2.7 ± 1.5	0.001
Total thoracic drainage (ml)	176 ± 205	145 ± 170	0.22
Hospitalization cost (Yuan[b])	28 702 ± 7939	30 213 ± 5692	0.11
Pneumothorax recurrence	4 (3%)	2 (2%)	1.00
Reoperation	3 (2%)	1 (1%)	
Absorption by O_2 therapy	1 (1%)	1 (1%)	

TIVA: total intravenous anaesthesia; LA: local anaesthesia; TEA: thoracic epidural anaesthesia.
[a]Continuous variables are presented as mean ± standard deviation and categorical variables as number (%).
[b]The basic unit of money in China.

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Table 4: Postoperative complications

Variable[a]	TIVA-TEA (*n* = 140)	TIVA-LA (*n* = 100)	*P*-value
Air leak >3 days	1 (1%)	0 (0%)	1.00
Atelectasis	1 (1%)	1 (1%)	1.00
Bleeding	1 (1%)	1 (1%)	1.00
Perioperative death	0 (0%)	0 (0%)	–
Total	3 (2%)	2 (2%)	1.00

TIVA: total intravenous anaesthesia; LA: local anaesthesia; TEA: thoracic epidural anaesthesia.
[a]Categorical variables are presented as number (%).

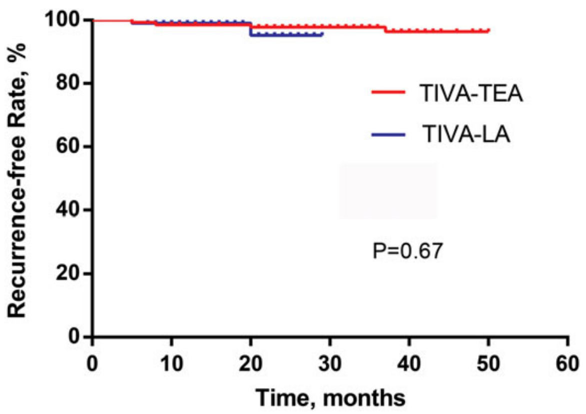

Figure 1: Kaplan–Meier curve of recurrence-free primary spontaneous pneumothorax after video-assisted thoracic surgical procedure. TIVA: total intravenous anaesthesia; LA: local anaesthesia; TEA: thoracic epidural anaesthesia.

approach is a relatively recent development, the mean follow-up time from surgery for the group was only 17 months (range, 5–29 months), while the mean follow-up for the TIVA-TEA technique was 35 months (range, 5–50 months). There was no difference in recurrence-free PSP after video-assisted thoracic surgical procedure between TIVA-LA group and TIVA-TEA group (Fig. 1). Pneumothorax recurred in 2 patients in the TIVA-LA group (2%) and 4 patients in the TIVA-TEA group (3%). Among these cases of recurrence, 1 patient in the TIVA-LA group and 3 patients in the TIVA-TEA group required a reoperation (Table 3).

DISCUSSION

Presently, bullectomy procedures are usually performed under VATS. As thoracoscopic techniques have advanced, an interest in reducing invasiveness of anaesthesia has increased. This is the first report showing that SV-VATS bullectomy performed under TIVA with LA is a feasible and safe option with comparable short-term results to TIVA with TEA for PSP.

VATS can be performed under local, regional or general anaesthesia depending on the surgical type and duration, the patient's tolerance and coordination, and the cardiopulmonary status of the patient [10–12]. At present, our centre has performed over 1200 SV-VATS procedures [13]. On the basis of previous results of published literature and our own experience, we consider VATS bullectomy to be a relatively simple procedure with patients in a generally favourable overall condition; we therefore consider these patients as a good candidate for an SV procedure [8, 13].

Compared with general anaesthesia, the TEA technique may offer some advantages including quicker recovery times, reduction of pulmonary complications and pains, and a decrease in systemic stress response to surgery [7, 11, 13]. However, there are still some potential disadvantages [14, 15]. TEA is a technically demanding technique, inevitably associated with certain adverse effects, including epidural haematoma, spinal cord injury and phrenic nerve palsy. In addition, some other anaesthesia-related phenomena, such as hypotension and bradycardia, may arise. Although these complications and adverse effects are rare, their life-altering negative impact must still be considered, and the potential risks of TEA may reduce acceptance and enthusiasm for this technique.

To avoid these potential complications, some studies have reported the use of a modified SV technique using TIVA with LA that does not require TEA. Studies have also reported the successful use of a nasal cannula or facial mask in different types of SV thoracic surgery, and indeed, in our experience, an LM might not be necessary for many simple SV operations. However, patient safety is always the priority. The use of TIVA with LA in SV-VATS may require a deeper level of sedation, which may sometimes result in airway obstruction and respiratory depression. Using an LM to secure the patients' airway during the procedure allows us to provide deep sedation without compromising patient safety. In our study, the LM was mainly used for airway management and inhalation of oxygen. It also has the added use of providing assisted ventilation in the event that significant hypoventilation or respiratory depression occurs. Ambrogi *et al.* [16] reported that 8 patients underwent thoracoscopic apicectomy under TIVA using an LM with excellent postoperative results. Gonzalez-Rivas *et al.* described the performance of a successful single-port thoracoscopic lobectomy in a non-intubated patient under a similar anaesthetic method [17]. Nonetheless, no one technique is better than another. The use of an LM also has potential complications, including leak, gastric insufflation and reflux, though none of these complications were observed in our patients. According to our results, SV-VATS bullectomy under TIVA-LA is a valid alternative to the TIVA with TEA technique. Difference of postoperative complication rate, incidence of conversion to tracheal intubation, short-term outcomes, mean operative times, estimated blood loss, thoracic drainage volume and chest tube duration were comparable between groups (Tables 2–4). No patients in either group required conversion from VATS to thoracotomy. Both anaesthetic methods were considered safe from our clinician's standpoint.

We reviewed all available literature on SV anaesthesia in the treatment of PSP as a method to assess the feasibility of TIVA-LA in SV-VATS bullectomy. In addition to our current study, we found three clinically meaningful reports with available data that conclude that VATS bullectomy using either TIVA with LA or TEA with TIVA is acceptable (Table 5). In addition to these existing data, TIVA-LA group was associated with a non-negligible reduction in hospital length of stay compared with TIVA-TEA group. However, the TIVA-TEA group contained the initial cases of SV-VATS anaesthesia at the beginning of the learning curve which may attribute to the better results for TIVA-LA cases.

In previous investigations on the SV-VATS approach, a concern regarding the cough reflex that often occurs during the operation was noted. Cough reflex may cause challenges when performing SV pulmonary resection. Chen *et al.* reported that the epidural anaesthesia-associated sympathetic blockade could lead to

Table 5: Various studies on the use of spontaneous ventilation anaesthesia to treat spontaneous pneumothorax

First author (Year) [citation]	Anaesthesia	Case numbers	Surgical management	Chest tube duration (days)	Postoperative hospital stay (days)	Complications (%)	Follow-up (months)	Recurrences
Pompeo *et al*. (2007) [5]	TEA	21	3-Port VATS	–	2.0 ± 1.0	–	12	1 (4.8%)
Present study	TEA + TIVA	140	2-Port VATS	1.6 ± 1.1	3.4 ± 1.5	3 (2%)	35 (5–50)	4 (3%)
Li *et al*. (2015) [8]	TEA + TIVA	32	Single-port	0.8 (0.6–1.08)	1.7 ± 0.3	–	–	–
Ambrogi *et al*. (2012) [14]	TIVA	8	3-Port VATS	2.4	3.3	0	17.7	0
Present study	TIVA + LA	100	2-Port VATS	1.4 ± 1.0	2.7 ± 1.5	2 (2%)	17 (5–29)	2 (2%)

TIVA: total intravenous anaesthesia; LA: local anaesthesia; TEA: thoracic epidural anaesthesia.

increased bronchial tone and airway hyper-reactivity [18]. Excessive stretch of the lung parenchyma and the tracheobronchial tree can also trigger persistent cough that can interfere with the procedure itself. We initially began to apply TIVA-LA in SV-VATS for the treatment of PSP to avoid the cough related to TEA. Another method described by Chen *et al.* [18] to effectively inhibit this cough reflex is the application of vagus blockade. However, Yang *et al.* [19] reported that residual vagal blockade may occur in some patients undergoing short operations, who would then experience hoarseness in the recovery room. Residual vagal blockade can endure for >3 h [18], thus negating the positive benefits of the cough reflex, an important defence mechanism that can help clear excessive secretions from airways, postoperatively. Furthermore, vagal blockade raises the risk of damage to adjacent vessels. To avoid these potential problems, in our own institution, we have found that a gentle spray of 1–2% lidocaine on the lung surface in lieu of vagal blockade will also effectively abolish the cough reflex during simple procedures [20].

Regarding the view inside the thorax, a naturally occurring collapse of the lung, comparable with that produced during intubated procedures, is seen during SV procedures once the incision is performed. As a result, the ability to recognize blebs or bullae was not impaired in our experience. Consequently, the recurrence rate was not increased in either group [TIVA-LA (2%) and TIVA-TEA (3%)] when compared with the surgical results for PSP under general anaesthesia (<5%) reported in previous studies [3]. These results suggest that the SV technique allows for good exposure and adequate resection of the affected areas of the lung with PSP.

Theoretically, nearly complete ipsilateral lung collapse could result in functional compromise under SV, which may result in the development of hypoxia and hypercapnia. However, Ambrogi *et al.* [16] reported that when SV-VATS was performed with the addition of an LM, the values of arterial oxygen saturation and maximum end-tidal carbon dioxide tension results remained excellent throughout the procedure for all patients. In our present study, the mean detectable lowest SpO_2 in the TIVA-LA group was not significantly different compared with that in the TIVA-TEA group; therefore, both groups were able to maintain a satisfactory oxygenation index. Furthermore, the peak $EtCO_2$ measured during single-lung SV in the TIVA-LA group was comparable with that measured in the TIVA-TEA group. However, hypercapnia was outstanding in a proportion of both groups. We have reported on this SV-related phenomenon in a previous publication: in our previous SV experience, this phenomenon may occur as a result of the hypoventilation and rebreathing effect. However, the transitory hypercapnia observed was permissive and did not affect the haemodynamics and surgical manoeuvres, and is generally resolved without medical intervention after surgery [21].

Of particular concern to SV anaesthesia sceptics are the lung movements that can sometimes interfere with surgical manipulation. In our study, only one patient in the TIVA-LA group required conversion to intubation and general anaesthesia as a result of profound lung movement; however, it should be noted that this conversion occurred in the early period of SV anaesthesia experience of our centre. As our team became more experienced with this technique, normal lung movements were no longer a problem in minor operations such as wedge resections.

Single-lumen endotracheal intubation should be prepared as backup in all SV procedures. In the event that conversion is required, surgeons should place a chest tube to the apex through the camera port incision immediately and seal the wounds with transparent waterproof dressings. At the same time, without changing the lateral position of the patient, anaesthetists should intubate the patient using a single-lumen endotracheal tube under the guidance of fibre bronchoscopy or visual laryngoscopy, followed by the insertion of a bronchial blocker. In our experience, an expert and skilled anaesthesiologist can perform this conversion safely and quickly. Patient safety is always the priority. There should be no hesitation to convert to intubated general anaesthesia [21].

Mechanical pleurodesis by pleural abrasion is one of the most widely used techniques for PSP to control recurrence; however, this technique is also correlated with the extent of abrasions and development of complications, including postoperative bleeding or haemothorax, Horner syndrome, impairment of pulmonary function and postoperative chest discomfort. Moreover, the effectiveness of pleural abrasion remains unclear in the management of PSP [22–24]. Park *et al.* [22] reported that additional pleural abrasion did not decrease the recurrence of pneumothorax after bullectomy for PSP. In a recent randomized controlled trial, Min *et al.* [24] concluded that wedge resection alone was sufficient to prevent recurrence, especially in patients with isolated or limited bullae. In our centre, we also do not recommend routine application of this technique due to the observed greater incidence of adverse effects and the similar recurrence rate when compared with bullectomy alone.

The limitation of this study was the retrospective nature and the non-randomized patient selection, which has the potential for introducing bias in patient selection and perioperative management. In addition, this report was derived from the extensive experience of a single institution in SV-VATS anaesthesia techniques, thus limiting the general applicability of the reported findings to thoracic surgical practice. Consequently, the inherent differences

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in the follow-up period between TIVA-LA and TIVA-TEA are difficult to address objectively, and may therefore reduce the ability to detect differences, if any, between the outcomes of the two procedures. We plan to continue close follow-up of these patients. Conversion from intubated general anaesthesia to SV anaesthesia using TIVA-LA should be done cautiously, under proper instruction from surgeons experienced in the SV technique. Most PSP patients are in relatively good health, and therefore more likely to tolerate this sort of anaesthetic technique. Extended works in the form of randomized controlled trials in both sicker patients and more complex operative procedures are needed to evaluate the potential benefits of this new technique before its use can be widely recommended in thoracic surgery.

In summary, for patients with PSP resected by SV-VATS bullectomy, short-term outcomes and recurrence rates were not significantly different under TIVA-LA or TIVA-TEA. SV-VATS bullectomy using either TIVA-LA or TIVA-TEA is safe, technically feasible and well tolerated in selected patients. TIVA-LA may be a valid alternative to TIVA-TEA in SV surgical management of PSP.

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