

Original
Article

Medical Thoracoscopy-Assisted Argon Plasma Coagulation Combined with Electrosurgical Unit for the Treatment of Refractory Pneumothorax in Elderly Patients

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Purpose: This study aims to compare the effects and prognosis of medical thoracoscopy-assisted argon plasma coagulation (APC) combined with electrosurgical unit (ESU) surgery, video-assisted thoracic surgery (VATS), and pleurodesis surgery, in providing appropriate treatment for elderly refractory pneumothorax patients.

Methods: Patients with refractory pneumothorax aged over 65 years were divided into three groups: APC combined with ESU (N = 20), VATS (N = 26), and pleurodesis (N = 24). Data on demographic characteristics, lung function evaluation, and short- and long-term prognoses were collected.

Results: Following surgery, compared with the APC-ESU and pleurodesis groups, patients in the VATS group demonstrated poor short-term prognoses, with high pleural effusion drainage levels and high visual analog scores (VAS; $P < 0.05$). After the surgery, St. George's Respiratory Questionnaire (SGRQ) scores in the pleurodesis group were slightly elevated, whereas SGRQ scores in both the APC-ESU and VATS groups demonstrated a continual decrease. Finally, medical resource consumption analysis demonstrated a significant difference in hospitalization costs among the three groups; the VATS group being the most expensive.

Conclusion: Medical thoracoscopy-assisted APC combined with ESU is a safe, effective, and affordable treatment for elderly patients with refractory pneumothorax.

Keywords: elderly, refractory pneumothorax, medical thoracoscopy, argon plasma coagulation, electrosurgery unit

Introduction

Refractory pneumothorax is a life-threatening disease in elderly patients and appears as a result of a persistent air leak following closed thoracic drainage.^{1,2)} A clinical

course of primary spontaneous pneumothorax (PSP) lasting for longer than 1 week or secondary spontaneous pneumothorax (SSP) lasting longer than 2 weeks can be referred to as *refractory pneumothorax*. A Japanese study found that the incidence of pneumothorax peaked

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at the age of 80 years in females and 79 years in males.³⁾ Besides severe lung disease, elderly patients with refractory pneumothorax often present with coexisting diseases.²⁾ Non-union subpleural bullae rupture is the main pathogenic mechanism and therefore surgical intervention is recommended.⁴⁾ However, the poor state of health associated with diffuse lung injury and comorbid illness places elderly patients in a dangerous situation. Rehospitalization in both male and female patients is common (above 50%).⁵⁾ Thus, a safe and effective treatment is urgently required.

Various minimally invasive procedures have been used for the treatment of pneumothorax, and video-assisted thoracic surgery (VATS), a micro-invasive television (TV)-assisted thoracoscopic surgery, has been the first choice of treatment for the past decade.^{6,7)} However, whether VATS therapy is appropriate for elderly patients with refractory pneumothorax remains controversial. Although elderly patients can often be cured via this procedure, postoperative complications and death are also frequently observed.⁸⁾ In VATS, not only does the indispensable anesthetic during surgery bring distinct risk to this population, but high costs also prevent patients from receiving this therapy.⁹⁾

Pleurodesis is considered a safe, effective, and easy procedure for managing SSP, which functions by limiting the progression of the persistent air leak. However, old age and underlying interstitial disorders are confirmed risk factors and lead to a poor prognosis for elderly patients with refractory pneumothorax, complications include acute respiratory disease syndrome (ARDS) or even death.¹⁰⁾ In addition, inflammatory reactions induced by the pleurodesis procedure confer a potential risk for elderly patients with possible imbalanced inflammation homeostasis.¹¹⁾

Thoracoscopy-assisted argon plasma coagulation (APC) has proved to be an effective treatment (mainly in type II and partial type III pulmonary bullae, based on Reid classification) for the general Chinese population, most notably in PSP patients.¹²⁾ However, whether it is an appropriate choice for elderly patients with various types of subpleural bullae and complex complications requires further analysis. This study aims to investigate the feasibility and efficacy of APC combined with electro-surgical unit (ESU) surgery in the treatment of elderly patients with refractory pneumothorax; the expectation being that this economical and minimally invasive therapy could ultimately be used as an optimized, standard treatment.

Materials and Methods

Participants and recruitment

This non-randomized concurrent control trial recruited a total of 70 patients with refractory pneumothorax from Nanhai Hospital, affiliated to Southern Medical University from July 2013 to June 2016. Patients were divided into three groups according to the types of surgery they received: 20 patients who underwent APC combined with ESU surgery were considered the experimental group, 26 patients who underwent VATS and 24 patients who underwent pleurodesis in the same period were considered as controls. This study was approved by the ethics committee of our hospital and adhered to the tenets of the Declaration of Helsinki. All patients were informed of the purpose, method, and precautions of the study and informed consent was obtained from all patients. Demographic information and medical history were collected. The inclusion criterion was ≥ 65 years old and the exclusion criteria were extensive pleural adhesions, coagulopathy, international normalization rate (INR) >1.2 , renal insufficiency (creatinine >3 mg/dL), severe hypoxemia ($\text{PaO}_2 < 50$ mmHg), persistent cough or fever, severe arrhythmia, cardiac insufficiency, myocardial infarction, and aortic dissection.¹³⁾

Surgery assessment

Clinical situations, including the durations of operations and hospitalizations, were collected. The preoperative lung condition was estimated by forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), and FEV1 as a percentage of predicted value (FEV1%Pred). Short- and long-term postoperative evaluations were also carried out. The short-term postoperative evaluation comprised four sections: complications (including fever, subcutaneous emphysema, wound infection, lung infection, tube dissociation, chest pain, atelectasis, and abnormal vital signs); volume of pleural effusion drainage, duration of pleural drainage; and visual analog scale (VAS) 3 days after operation, whereas long-term postoperative evaluation comprised a combination of lung function assessment, St. George's Respiratory Questionnaire (SGRQ) score, recurrence of pneumothorax, and survival analysis with a follow-up of patients for 1–2 years. Medical resource consumption was also determined from the costs associated with hospitalization.

Primary outcome measures

VAS assessment: 0: no pain; ≤ 3 : mild, tolerable pain; 4–6: tolerable pain which affects sleep; and 7–10: severe pain.¹⁴⁾

SGRQ score divided into three domains: symptom, activity, and impact. Scores ranging from 0 to 100 represented a deterioration in quality-of-life, with higher scores representing a poorer quality-of-life.¹⁵⁾

Surgery procedure

(a) *Preoperative preparation*: blood gas analysis, routine blood test, coagulation function evaluation, electrocardiographic examination, and four relevant etiological examinations, including hepatitis B antigen test (HBsAg), hepatitis C antibody test (anti-HCV), human immunodeficiency virus detection, and *Treponema pallidum* antibody (TPAb) analysis, were performed. Chest computed tomography examination was used for the identification of pneumothorax and giant lung bullae; the function of which was to ensure that there was adequate chest space for surgery and to record the location and size of the bullae. Ultrasound detection was used for the localization of the surgery; a thin chest wall site against the lesion and away from the pleural hypertrophy or adhesion was preferred. For potent sedation and analgesia, 2–5 mg midazolam was intravenously administered and 50–75 mg pethidine hydrochloride (according to gender, age, weight, and drug sensitivity of the patient) was administered via intramuscular injection 15 min prior to surgery. A low flow rate of oxygen inhalation was maintained throughout surgery and oxygen saturation and heart rate were also monitored.

(b) Surgery was performed in a lateral position on the uninjured side; the arm was lifted up and fixed on the head frame and the entire pleural cavity of the affected side was exposed. One of three intersections, including the intersection of the anterior axillary line and fourth rib, intersection of the midaxillary line and fifth rib, and intersection of the posterior axillary line and sixth rib, were selected as a thoracoscopic approach. A 1-cm incision was made and a flexible Trocar sleeve was placed within this incision; the cannula ferrule was then withdrawn and the thoracoscope was inserted. When the thoracoscope was ready, the location, number, and size of pulmonary bullae could be observed and the presence of pleural adhesions and locations of air leaks were determined.

(c) Argon ion (power 30–50 W) was used to burn and coagulate bullae; for Reid grade III bullae (2 cm \leq diameter < 5 cm), a puncture was performed before burning. If no large blood vessels were found nearby, a high-frequency electro-tome (power 30–50 W) was used to separate the adhesive tape. The position of the thoracoscope was adjusted and the coagulation step repeated. Coagulation treatment was performed by introducing the argon ion coagulation catheter along the thoracoscope, 5 mm into the lesion. Bullae coagulation lasted for 3–5 s in each instance, until the bullae gradually shrank and solidified into eschar. There were five cases with bullae of <2 cm and 15 cases with bullae 2–5 cm among the 20 patients in the APC-ESU group. Bullae all shrank after the coagulation (**Fig. 1**).

Statistical analysis

Comparison among the APC-ESU, VATS, and pleurodesis groups was performed using one-way analysis of variance (ANOVA) and post hoc multiple comparisons were performed using Bonferroni adjusted analysis. For non-normal quantitative data, the Kruskal–Wallis H test was used for comparison among groups and the Nemenyi test was used for further pairwise comparison. A chi-squared test was used for categorical comparison. A paired t-test and Wilcoxon rank sum test were, respectively, used for comparison of clinical parameters for both normal and non-normal data before and after surgery within each group. Correlation analysis was performed using Pearson's correlation analysis. IBM SPSS Statistics for Windows v22.0 (IBM, Armonk, NY, USA) was used and a P value of <0.05 was defined as significant.

Results

Clinical characteristics

Clinical characteristics, including age, gender, body mass index (BMI), smoking rate, and secondary pneumothorax ratio showed no significant differences among the APC-ESU, VATS, and pleurodesis groups. The proportion of the underlying extrapulmonary disease in the VATS group was higher than in the pleurodesis group (84.6% vs 45.8%, $P < 0.05$). No significant differences were found in size and location of bullae between the three groups ($P = 0.079$, $P = 0.361$). As the accurate number of pulmonary bullae was uncountable in patients who had pleurodesis treatment, total pulmonary bullae number between the VATS group and the APC-ESU

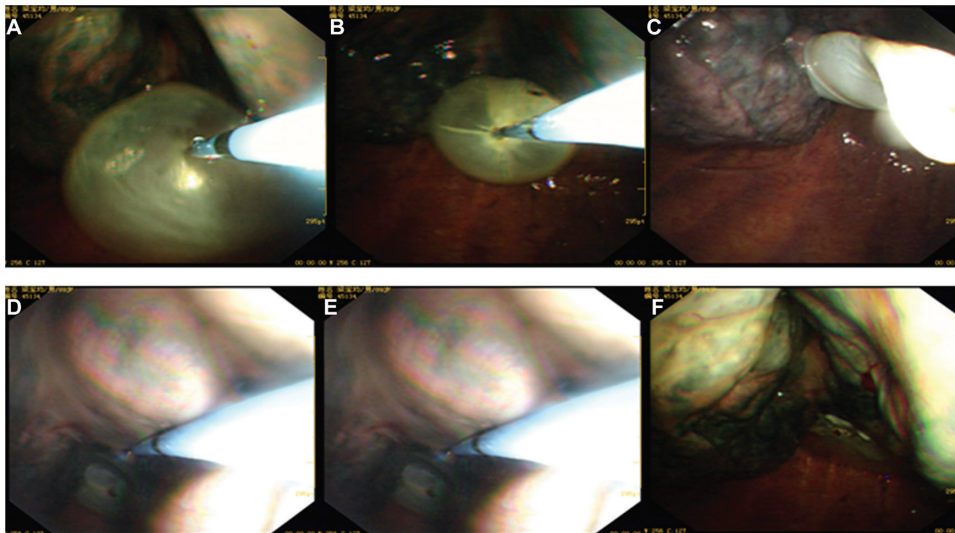


Fig. 1 Pulmonary bullae all shrank after the coagulation. Bullae with diameter of <2 cm (A–C). Bullae with diameter 2–5cm (D–F).

group were compared and showed no significant difference ($P = 0.419$) (**Table 1**).

Surgical features and overall complications

Both the APC-ESU and VATS groups had operation durations of 1.5 ± 0.6 h, which was significantly longer than the pleurodesis group (0.9 ± 0.4 h, $P < 0.01$). Short-term postoperative evaluation indicated that $\sqrt{26.6 \pm 5.7}$ mL pleural effusion drainage in the VATS group was much higher than both the APC-ESU and pleurodesis groups, with $\sqrt{22.3 \pm 6.8}$ mL and $\sqrt{21.9 \pm 8.7}$ mL, respectively ($P < 0.05$). In addition, patients in the VATS group had an average 3-day postoperative VAS of 5.62 ± 1.4 , which was also higher than the other two groups ($P < 0.01$). Medical consumption analysis demonstrated a significant difference among the three groups, in which the VATS group had the highest spend of 38831.11 ± 18016.1 yuan ($P < 0.001$). No significant difference in postoperative complications, duration of drainage, hospitalization, recurrence of pneumothorax, or death was observed among the three groups ($P > 0.05$; **Table 1**).

Short- and long-term prognoses assessment

No significant differences were observed in FVC and FEV1%Pred among the three groups, whereas FEV1 was significantly higher in the VATS group than in the APC-ESG group prior to surgery (1.03 ± 0.4 L vs 0.76 ± 0.3 L, $P < 0.05$). Following surgery, levels of FVC, FEV1, and FEV1%Pred in the VATS group were higher than those in the pleurodesis group (2.34 ± 0.6 L vs 1.66 ± 0.7 L, 1.32 ± 0.4 L vs 0.78 ± 0.4 L, 44.5 ± 10.9 L vs 35.7 ± 11.2 L,

$P < 0.05$) and the level of FEV1 was higher in the VATS group than in the APC-ESG group (1.32 ± 0.4 L vs 1.00 ± 0.4 L, $P < 0.001$). In intra-group comparison, levels of FVC, FEV1, and FEV1%Pred were significantly higher following surgery in the VATS and APC-ESG groups ($P < 0.001$), whereas FEV1%Pred was significantly decreased following surgery in the pleurodesis group ($P < 0.001$). In lung function analysis, significant correlations were seen across all parameters, including FVC, FEV1, and FEV1%Pred before and after surgery ($P < 0.05$). In addition, FEV1%Pred had a strong correlation among the three groups (each with an r of 0.914, 0.896, and 0.919), whereas FEV1 had a comparatively weak correlation with an r of 0.446 in the VATS group, 0.757 in the APC-ESG group, and 0.66 in the pleurodesis group before and after surgery (**Table 2**). Only SGRQ symptom score in the VATS group was observed to be significantly lower than that of the other two groups prior to surgery, with 72.4 ± 8.1 points vs 78.6 ± 6.7 and 77.0 ± 9.7 points ($P < 0.05$). Following the operation, SGRQ scores in the pleurodesis group rose slightly, whereas SGRQ scores in both the APC-ESU and VATS groups demonstrated a continual decrease. The scores in the pleurodesis group were significantly higher than those in the other two groups ($P < 0.05$) (**Table 2**).

Discussion

This study found that, for elderly patients with refractory pneumothorax, medical thoracoscopy-assisted APC

Table 1 Clinical characteristics and surgical features of patients

	APC-ESU group (N = 20)	VATS group (N = 26)	Pleurodesis group (N = 24)	F/ χ^2 value	P value
Age	75.1 ± 6.3	74.8 ± 8.6	76.1 ± 6.3	0.21	0.812
Male (%)	19 (95.0)	24 (92.3)	23 (95.8)	0.525	1.000
BMI (kg/cm ²)	21.2 ± 1.6	21.9 ± 2.0	22.7 ± 2.5	2.634	0.079
Smoking (%)	16 (80.0)	19 (73.1)	19 (79.2)	109.572	0.378
Combined extrapulmonary disease (%)	15 (75.0)	22 (84.6)	11 (45.8)	9.247*	0.010
Secondary spontaneous pneumothorax (%)	20 (100)	23 (88.5)	24 (100)	3.622	0.105
	<2	4 (15.4)	3 (12.5)	5.08	0.079
Size (cm)	2-5	16 (61.5)	15 (62.5)		
	5-10	0 (0.0)	5 (19.2)		
	>10	0 (0.0)	1 (3.8)		
Location	Upper lobe	13 (65.0)	12 (50.0)	2.04	0.361
	Middle lobe	0 (0.0)	1 (3.8)		
	Lower lobe	6 (30.0)	4 (16.7)		
	Multiple	1 (5.0)	2 (8.3)		
Bullae number	3.65 ± 3.33	4.54 ± 3.89	-	0.67	0.419
Operation duration (h)	1.5 ± 0.6	1.5 ± 0.6	0.9 ± 0.4	8.059**	0.001
Postoperative complications (%)	19 (95.0)	23 (88.5)	23 (95.8)	1.111	0.617
\sqrt Volume of postoperative drainage (\sqrt mL)	22.3 ± 6.8	26.6 ± 5.7	21.9 ± 8.7	3.327**	0.042
VAS in 3d after operation	4.45 ± 1.3	5.62 ± 1.4	4.17 ± 1.9	5.979**	0.004
Length of duration of drainage (Lgd)	0.96 ± 0.2	0.92 ± 0.3	0.82 ± 0.3	1.583	0.213
Hospitalized duration (d)	19.0 ± 7.4	21.0 ± 10.2	19.3 ± 8.1	2.885	0.216
Hospitalization expense (yuan)	19060.08 ± 8175.2	38831.11 ± 18016.1	21559.04 ± 8823.4	16.805**	<0.001
Recurrence of pneumothorax/death (%)	1 (5.0)	4 (15.4)	1 (4.1)	2.044	0.363

Annotation: Logarithmic and square root transformation were performed with volume of postoperative drainage and duration of drainage in order to meet the normal distribution and equal variance.

APC: argon plasma coagulation; BMI: body mass index; ESU: electro-surgical unit; VATS: video-assisted thoracic surgery

*APC-ESU group vs VATS group, P <0.05; #APC-ESU group vs pleurodesis group, P <0.05; *VATS group vs pleurodesis group, P <0.05.

Table 2 Pulmonary function and SGRQ score comparisons

	APC and ESG group (N = 20)				VATS group (N = 26)				Pleurodesis group (N = 24)			
	Detective value and estimated score	T/F/ χ^2 /Z value	P value	Detective value and estimated score	T/F/ χ^2 /Z value	P value	Detective value and estimated score	T/F/ χ^2 /Z value	P value	F value	P value	
FVC (L)	Pre-	1.68 ± 0.5	<0.001	1.89 ± 0.6	3.786	0.001	1.79 ± 0.5	1.686	0.105	0.821	0.445	
	Post-	2.13 ± 0.6		2.34 ± 0.6			1.66 ± 0.7			7.516*	0.001	
FEV1 (L)	Pre-	0.76 ± 0.3	<0.001	1.03 ± 0.4	0.493	0.01	0.85 ± 0.3	0.813	<0.001	3.812&	0.027	
	Post-	1.00 ± 0.4		1.32 ± 0.4	-3.846	0.001	0.78 ± 0.4	1.163	0.257	13.078&*	<0.001	
FEV1pred (%)	Pre-	37.5 ± 11.7	<0.001	40.2 ± 10.5	0.446	0.022	39.7 ± 12.4	0.66	<0.001	0.337	0.715	
	Post-	41.5 ± 12.9	0.003	44.5 ± 10.9	-4.471	<0.001	35.7 ± 11.2	4.088	<0.001	3.720*	0.029	
SGRQ symptom score	Pre-	78.6 ± 6.7	<0.001	72.4 ± 8.1	0.896	<0.001	77.0 ± 9.7	0.919	<0.001	3.486&	0.036	
	Post-	72.3 ± 7.5	<0.001	68.5 ± 10.3	-2.809	0.005	83.0 ± 7.8	-4.01	<0.001	19.957**	<0.001	
SGRQ activity score	Pre-	68.2 ± 7.8	0.001	67.7 ± 6.9	-3.544	<0.001	67.5 ± 9.1	-2.503	0.004	2.586	0.274	
	Post-	56.5 ± 10.8		61.4 ± 10.8			73.4 ± 10.6			16.114**	<0.001	
SGRQ impact score	Pre-	71.7 ± 5.7	0.001	67.9 ± 8.8		<0.001	71.5 ± 7.7		0.113	1.540	0.463	
	Post-	62.6 ± 9.4		58.3 ± 12.5			74.5 ± 8.9			15.419**	<0.001	
SGRQ score	Pre-	72.4 ± 5.1	<0.001	70.8 ± 7.7		<0.001	71.8 ± 7.2		0.002	0.340	0.713	
	Post-	61.1 ± 8.2		57.6 ± 7.0			74.1 ± 7.2			31.295**	<0.001	

APC: argon plasma coagulation; ESU: electrosurgical unit; SGRQ: St. George's Respiratory Questionnaire; VATS: video-assisted thoracic surgery
 *APC & ESU group comparison vs VATS group, P <0.05; #APC & ESU group vs pleurodesis group, P <0.05; **VATS group vs pleurodesis group, P <0.05.

combined with ESU surgery was an affordable treatment and was effective in improving prognosis with a reduced incidence of complications.

VATS-assisted APC surgery to treat pleural mesothelioma has proved no better than pleurodesis; however, this remains controversial given that the study did not apply APC on bullae coagulation.¹⁶⁾ This study is the first report on the positive effects of medical thoracoscopy-assisted APC combined with ESU surgery in elderly patients for the treatment of SSP, serving to reduce pneumothorax recurrence. One explanation for this can be that the non-contact, high-frequency current between the APC probe and the tissue contract and coagulate tissues, thus leading to repair of pulmonary bullae. Additionally, the argon ion beam can conduct linear flow and produce lateral, radial irradiations, surround discharge and subsequently locate the air leaks and automatically coagulate them. This basal granulation coagulation of bullae may represent an advantage of APC treatment and explain the reduction in pneumothorax recurrence.¹⁷⁾ Recently, a minimally invasive procedure, based on VATS radio frequency energy and continuous saline solution perfusion, was introduced for bullae treatment. This procedure has the ability to lower wound temperature and reduce oxidation and carbonization of damaged tissues; however, the indispensable epidural anesthesia required, together with the long operation time and high cost, may limit its promotion in elderly patients.^{18,19)}

The patients in our study presented with low BMIs, decreased muscle mass, thin chest walls, and severe symptoms, thus leading to a high incidence of subcutaneous emphysema. A high incidence of subcutaneous emphysema may further increase the duration of hospitalization and postoperative drainage.^{20,21)} Interestingly, improved prognosis has been described in our patients, even when enlarged bullae filled more than half of the chest cavity, residual adhesive band was present, and localized pneumothorax were observed after surgery. The possible reasons for this improved prognosis are as follows. First, the patient's compensation for underlying diseases can tolerate hypoxia in turn. Second, the locations of the leakiest pulmonary bullae are distributed in the upper lung, which has less effect on lung function and life quality. The results of this study show that the probable advantage of pulmonary bullae coagulation with APC and thermal ablation of pleural adhesion for interruption of the open of visceral pleural in medical thoracoscopy-assisted APC-ESU treatment. A high-frequency electrotome can quickly stop bleeding

and prevent energy from being absorbed by colored tissues, thus preventing necrosis of both pleural and lung tissues,²²⁾ whereas medical thoracoscopy can cause artificial pneumothorax, mediates the exudation of bullae, and eliminates bullae.

The European Respiratory Society (2015) points out that the generation of diffused visceral pleural pores and pulmonary bullae are two main mechanisms of pneumothorax.²³⁾ Multiple pathomorphisms of pulmonary bullae were found in the entire lung of our patients and were accompanied by pleural adhesion. Therefore, the disease was categorized into type II-IV according to Vanderscheren's classification criteria of spontaneous pneumothorax. Bullae in elderly patients always locate in the lung parenchyma rather than the visceral pleura; therefore, pneumothorax development is rare in this population and is the reason for the limited sample size in this study. The target of pleurodesis is eliminating diffused pleural pores, whereas APC or VATS targets bullae removal.²⁰⁾ Only one recurrence of pneumothorax (3.85%) was found in the VATS group, which was consistent with a frequency of 2%–14% in previous studies.²⁴⁾ Lung collapse during the operation and expansion following the operation caused by VATS, combined with tension of sutures, may explain the postoperative recurrence of pneumothorax.²⁵⁾ The VATS group underwent pulmonary bullae resection combined with pleural abrasion. The increased volume of thoracic drainage found in this group further indicated that VATS combined with pleural abrasion was not recommended.²⁶⁾ Compared with the APC-ESU group, a poorer short-term prognosis with a higher VAS and long-term prognosis with a higher SGRQ score were found in the VATS and pleurodesis groups. The SGRQ score was originally developed for chronic obstructive pulmonary disease (COPD), which easily develops into SSP in elderly patients. Most patients in our study demonstrated disease secondary to COPD, with only two patients with tuberculosis in the VATS group and one COPD combined with organizing pneumonia; thus, the SGRQ score was used for life quality assessment in this study. On the one hand, the fact that most of the patients enrolled in the study were smokers may partly account for this result. Nevertheless, for elderly patients, the anesthesia required for VATS and the overly conservative pleurodesis surgery prevent them from considering priority treatments compared with APC.

In lung condition estimations, FEV1 in the VATS group was higher than the APC-ESU group prior to surgery.

Following surgery, FVC, FEV1, and FEV1%Pred levels in both the VATS and APC-ESU groups were increased, whereas these levels in the pleurodesis group were decreased. Compared with the other two groups, the increase in the APC-ESU group was barely noticeable due to the significantly low level recorded prior to surgery. On the other hand, our results further revealed that patients with poor lung conditions are unable to tolerate VATS. In addition, the level of FEV1%Pred was considered a stable observation index for postoperative long-term evaluation due to its significant correlation before and after surgery, with a coefficient above 0.8 among the three groups. This may be effective in improving small airway obstruction in COPD patients with pneumothorax; however, this requires further research. As a small sample size is a limitation of our study, further studies with an expanded sample size are required to promote multi-center research in this respiratory field. In addition, studies focused on the correlations between gene mutations and spontaneous pneumothorax, which indicate refractory pneumothorax based on genetic polymorphism, would be worth noting.²⁷⁾

Conclusion

In conclusion, our study suggests that medical thoracoscopy-assisted APC-ESU surgery in elderly patients with refractory pneumothorax is a minimally invasive and effective treatment, with fewer complications than VATS and with improved prognosis compared to pleurodesis surgery.

Acknowledgments

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Disclosure Statement

The authors declare that they have no conflict of interests.

References

- 1) Ono M, Komiya K, Oka H, et al. Prognosis of pneumothorax in elderly patients treated with thoracic drainage. *J Palliat Med* 2014; **17**: 1197-8.
- 2) Odaka M, Akiba T, Mori S, et al. Thoracoscopic surgery for refractory cases of secondary spontaneous pneumothorax. *Asian J Endosc Surg* 2013; **6**: 104-9.
- 3) Barros PP. Economics meets healthcare: how can it be useful? *Eur J Cardiothorac Surg* 2018; **54**: 1-3.
- 4) Schoenenberger RA, Haefeli WE, Weiss P, et al. Timing of invasive procedures in therapy for primary and secondary spontaneous pneumothorax. *Arch Surg* 1991; **126**: 764-6.
- 5) Bobbio A, Dechartres A, Bouam S, et al. Epidemiology of spontaneous pneumothorax: gender-related differences. *Thorax* 2015; **70**: 653-8.
- 6) Case JB, Mayhew PD, Singh A. Evaluation of video-assisted thoracic surgery for treatment of spontaneous pneumothorax and pulmonary bullae in dogs. *Vet Surg* 2015; **44 Suppl 1**: 31-8.
- 7) Sihoe ADL, Hsin MKY, Yu PSY. Needleoscopic video-assisted thoracic surgery pleurodesis for primary pneumothorax. *Multimed Man Cardiothorac Surg* 2014; **2014**: 1-5.
- 8) Matsuoka K, Kuroda A, Kang A, et al. Surgical results of video-assisted thoracic surgery and risk factors for prolonged hospitalization for secondary pneumothorax in elderly patients. *Ann Thorac Cardiovasc Surg* 2013; **19**: 18-23.
- 9) Ota H, Kawai H, Matsuo T. Treatment outcomes of pneumothorax with chronic obstructive pulmonary disease. *Asian Cardiovasc Thorac Ann* 2014; **22**: 448-54.
- 10) Shinno Y, Kage H, Chino H, et al. Old age and underlying interstitial abnormalities are risk factors for development of ARDS after pleurodesis using limited amount of large particle size talc. *Respirology* 2018; **23**: 55-9.
- 11) Chen JS, Hsu HH, Huang PM, et al. Thoracoscopic pleurodesis for primary spontaneous pneumothorax with high recurrence risk: a prospective randomized trial. *Ann Surg* 2012; **255**: 440-5.
- 12) Zhang H, Ge CS, Sun ZM, et al. Effectiveness and safety of argon plasma coagulation via thoracoscopy on the treatment of spontaneous pneumothorax with subpleural bullae. *Zhonghua Yi Xue Za Zhi* 2017; **97**: 3171-3.
- 13) Jin FG. Internal medicine thoracoscopy diagnosis and treatment norms. *Chin J Lung Dis (Electron Ed)* 2018; **11**: 6-13.
- 14) Reips UD, Funke F. Interval-level measurement with visual analogue scales in internet-based research: VAS generator. *Behav Res Methods* 2008; **40**: 699-704.
- 15) Jones PW, Quirk FH, Baveystock CM, et al. A self-complete measure of health status for chronic airflow limitation. The St. George's Respiratory Questionnaire. *Am Rev Respir Dis* 1992; **145**: 1321-7.
- 16) Bobbio A, Ampollini L, Internullo E, et al. Thoracoscopic parietal pleural argon beam coagulation versus pleural abrasion in the treatment of primary spontaneous pneumothorax. *Eur J Cardiothorac Surg* 2006; **29**: 6-8.
- 17) Kuwata T, Shinohara S, Takenaka M, et al. The impact of covering the bulla with an absorbable polyglycolic

- acid (PGA) sheet during pneumothorax surgery. *Gen Thorac Cardiovasc Surg* 2016; **64**: 1-3.
- 18) Ambrogi MC, Zirafa CC, Davini F, et al. Transcollation® technique in the thoracoscopic treatment of primary spontaneous pneumothorax. *Interact Cardiovasc Thorac Surg* 2015; **20**: 445-8.
 - 19) Sagawa M, Maeda T, Yoshimitsu Y, et al. Saline-cooled radiofrequency coagulation during thoracoscopic surgery for giant bulla. *Eur J Cardiothorac Surg* 2014; **46**: 737-9.
 - 20) Noppen M. Spontaneous pneumothorax: epidemiology, pathophysiology and cause. *Eur Respir Rev* 2010; **19**: 217-9.
 - 21) Zou W, Ding YB, Liu ZC, et al. Clinical characters and age distribution of pulmonary bulla. *Chin J Lung Dis (Electron Ed)* 2016; **9**: 267-70.
 - 22) Menzies R, Charbonneau M. Thoracoscopy for the diagnosis of pleural disease. *Ann Intern Med* 1991; **114**: 271-6.
 - 23) Tschopp JM, Bintcliffe O, Astoul P, et al. ERS task force statement: diagnosis and treatment of primary spontaneous pneumothorax. *Eur Respir J* 2015; **46**: 321-35.
 - 24) Zeybek A, Kalemci S, Gürünlü Alma O, et al. The effect of additional pleural procedures onto recurrence rates on the spontaneous pneumothorax surgery. *Iran Red Crescent Med J* 2013; **15**: 136-41.
 - 25) Lyra RM. Etiology of primary spontaneous pneumothorax. *J Bras Pneumol* 2016; **42**: 222-6.
 - 26) Ling ZG, Wu YB, Ming MY, et al. The effect of pleural abrasion on the treatment of primary spontaneous pneumothorax: a systematic review of randomized controlled trials. *PLoS ONE* 2015; **10**: e0127857.
 - 27) Fröhlich BA, Zeitz C, Mátyás G, et al. Novel mutations in the folliculin gene associated with spontaneous pneumothorax. *Eur Respir J* 2008; **32**: 1316-20.