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ORIGINAL ARTICLE

Usefulness of a suction ball coagulation probe for hemostasis in complete VATS lobectomy for patients with non-small cell lung cancer

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Abstract

Purpose In recent years, several reports have noted that the specific coagulation mode called "soft coagulation" with modern electrosurgical tools offers superior hemostasis. The "suction ball coagulation" (SBC) device, which can achieve hemostasis using a soft coagulation mode and simultaneous suction, has been developed as a next step. This study aimed to evaluate the hemostatic effects of SBC in comparison to a conventional soft coagulation device (non-SBC) in video-assisted thoracoscopic surgery (VATS) for patients with non-small cell lung cancer (NSCLC).

Methods This study retrospectively analyzed 351 patients who underwent complete VATS lobectomy for NSCLC. A propensity score analysis generated matched pairs from the patients in the SBC and non-SBC groups (119 patients each).

Results After propensity score matching, the bleeding volume during surgery in the SBC group (27.0 g) was significantly less than that in the non-SBC group (42.0 g, $p < 0.001$). No significant difference was seen in the frequency of postoperative complications. A logistic regression analysis identified the non-use of SBC as an independent risk factor for greater intraoperative blood loss during complete VATS lobectomy (odds ratio 3.14, $p < 0.001$).

Conclusions SBC was safe for complete VATS lobectomy in patients with NSCLC, and the use of this device was associated with significantly decreased intraoperative blood loss.

Keywords Soft coagulation · Video-assisted thoracic surgery · Hemostasis

Introduction

With the recent spread of video-assisted thoracoscopic surgery (VATS) for patients with non-small cell lung cancer (NSCLC), there has been marked progress in the development of associated medical devices related to thoracoscopic surgical systems. To further improve the quality of VATS enabling accurate surgery under a magnified view, securing a clear surgical field with less bleeding during surgery is one of the most important issues needing attention. Against a background of improved resolution on thoracoscopic images and more elaborate VATS, various hemostatic devices are also being developed.

Conventional electrosurgical units for hemostasis involve both Joule heating, generated by passing an electrical current through tissue with increased electrical resistance, resulting in tissue temperatures well above boiling point, and intensive heat generated by high-voltage components, forming carbonized eschar [1]. Modern electrosurgical generators, such as the VIO300D (ERBE Elektromedizin GmbH, Tubingen, Germany) include a special coagulation output mode called "soft coagulation", which automatically regulates the output voltage to keep it below 190 V, causing the generation of Joule heat alone without discharge [1, 2]. Protein within the target tissue is effectively coagulated at temperatures of between 70 and 80 °C due to the Joule heat causing dehydration and contraction of the tissue; thus, there is no incision of the tissue, allowing coagulation at low temperatures and without carbonization [1]. Soft coagulation has been

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reported to be useful for hemostasis in animal experiments and in surgery in general clinical practice [1–3].

When the tissue is in an excessively wet state, however, such as with pleural effusion, lymph fluid, or when washing water has not been appropriately removed from the surgical field, maximum hemostatic effects cannot be obtained; this also occurs with conventional electrocautery. The successful simultaneous use of suction is key to maximizing the hemostatic effects of soft coagulation. When the surgeon independently performs suction and coagulation hemostasis, the tissue will become wet again while switching from the conventional suction tube to electrocautery, thus hemostasis will not be optimally achieved. In such cases, the operator usually performs coagulation with an electrocautery device, while an assistant aspirates with a suction tube, but if the timing of the surgeon and assistant is not synchronized, hemostasis may be delayed.

In recent years, a revolutionary device called the "suction ball coagulator (SBC)" has been developed. This device provides a soft coagulation mode with suction function. Since the SBC can stop bleeding by soft coagulation while maintaining a dry surgical field by simultaneous suction, surgeons can perform hemostasis independently under their own timing. The utility of the SBC has been reported for laparoscopic surgery, especially in surgery for colorectal cancer [4]. However, the SBC has not been clearly evaluated in detail for thoracic surgery.

The aim of this retrospective study was to evaluate the hemostatic effect of SBC in comparison to a conventional soft coagulation device for complete VATS lobectomy in patients with NSCLC.

Methods

Patient selection

Data for this retrospective cohort study were obtained from the medical records of all patients who underwent complete VATS lobectomy for NSCLC between January 2014 and December 2017 at Iwate Medical University Department of Thoracic Surgery. This retrospective study was approved by the institutional review board at Iwate Medical University (permit number: H28-124). The need to obtain informed consent was waived for this retrospective medical record review. All patients underwent complete preoperative pulmonary evaluation. Any patients who smoked were instructed to refrain from smoking for at least 8 weeks before surgery. The surgical indication for complete VATS lobectomy was a thoracoscopically resectable lesion; this covered almost 95% of patients who underwent surgical treatment for NSCLC in our institute. Patients received preoperative chemotherapy or radiation, and cases of pneumonectomy or bilobectomy were excluded. Cases in which the bleeding volume during surgery could not be accurately measured were also excluded. Finally, 351 patients met the selection criteria.

Energy device for hemostasis

Around the first half of 2010, an electrosurgical device (VIO300D soft-coagulation system) containing a soft coagulation mode became commercially available as a hemostatic device for use during surgery. We began to use this conventional soft coagulation device as a ball electrode without suction (Fig. 1a, b) for complete VATS lobectomy in patients with NSCLC from January 2014 to June 2015 (non-SBC group). Following this, a novel suction ball coagulation device (Fig. 1c, d) was developed, and we replaced the conventional soft coagulation device with the SBC in July 2015 (SBC group). During surgery, the mode was usually set to effect 5 and 60 W.

Surgical procedures

Complete VATS lobectomy was performed under general anesthesia with a double-lumen endotracheal tube for single-lung ventilation. The affected lung was deflated as soon as the pleural space was opened, and deflation was maintained throughout most of the operative period. The patient was placed in the lateral decubitus position. The first 3 cm incision was made in the sixth intercostal space in the mid-axillary line, then 5 mm of a flexible thoracoscope (ENDOEYE FLEX, LTF-S190-5; Olympus, Tokyo, Japan) was inserted. General exploratory thoracoscopy was performed, and an additional intercostal incision was made on the anterior axillary line in the third intercostal space and posterior auscultation triangle in the sixth intercostal space. Complete VATS lobectomy was performed via a 3-port method under monitor vision alone, and systematic complete hilar and mediastinal lymph node dissection was performed in all cases. After completing the procedure, a sealing test was performed before the wound was closed. The sealing test was confirmed with reinflation of the lung on the affected side, and a chest tube (Blake®, 19 Fr; Ethicon, Somerville, NJ, USA) was placed from the fifth intercostal trocar to the apex.

Postoperative management

In general, patients were extubated at the end of the operation and transferred to the ward after a brief stay in the recovery area. In the case of chest tube insertion, the tube was placed under − 5 cm H_2O suction on the morning of postoperative day 1. Chest X-rays were obtained daily. The chest tube withdrawal criteria were: absence of air leakage through the chest tube at the time of evaluation;

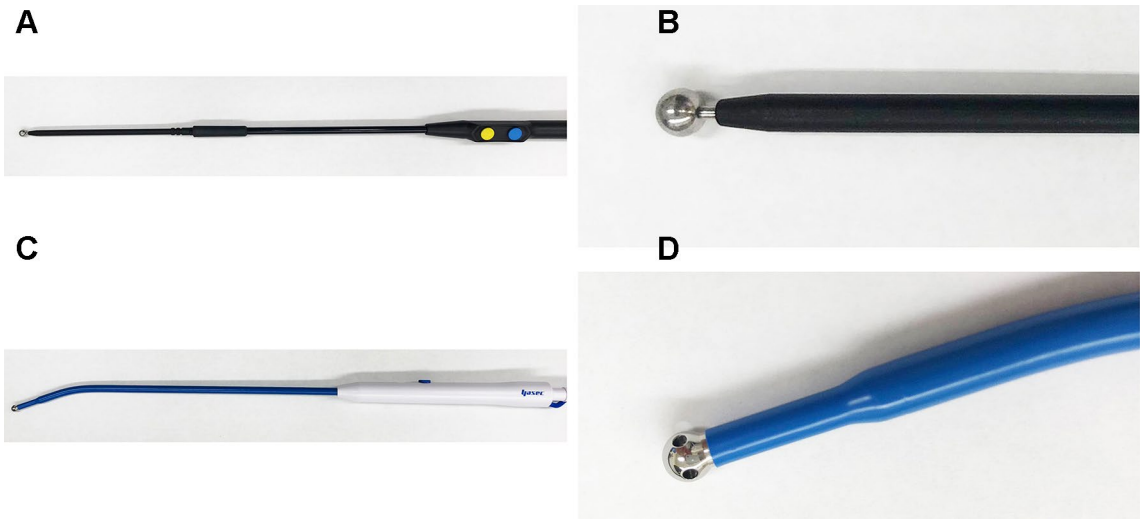

Fig. 1 **a** A soft coagulation device, consisting of a ball electrode without suction, and **b** the ball part at the tip of the device. **c** The novel suction ball coagulation device (SBC), and **d** the ball part at the tip of the device

pleural fluid drainage < 200 mL/24 h; and postoperative chest X-ray showing no pneumothorax. The morning after chest tube withdrawal, a chest X-ray was obtained to rule out pneumothorax. Routine postoperative pain management was performed in all patients from both groups. Briefly, oral analgesia was started 6 h after surgery; this typically included loxoprofen (60 mg, three times per day), sometimes with a diclofenac suppository (25 mg, 1–2 times per day, as needed). Patients were discharged when convenient, if no complications occurred during this perioperative period. Our institutional standard protocol is to follow all patients every 3–6 months after surgery for 5 years.

Statistical analysis

The JMP software program (version 12.2.0, SAS Institute, Cary, NC, USA) was used for all of the statistical analyses, which were performed by the authors with the support of a statistician. The groups were compared using Pearson's Chi-squared test or Wilcoxon's rank sum test. A propensity score matching method was used to control for potential differences in the preoperative characteristics of the patients in the two groups. Propensity scores were generated using logistic regression based on clinically relevant preoperative variables, such as age, gender, body mass index (BMI), pack-years smoked, presence of chronic obstructive pulmonary disease (COPD) (forced expiratory volume percent in 1 s; $FEV_1\% < 70\%$), presence of usual interstitial pneumonia (UIP) findings on preoperative chest computed tomography (CT), history of anti-thrombotic therapy, and tumor size, which were considered as possible confounders due to potential associations with the outcome of interest based on clinical knowledge. Patients were matched 1:1 by nearest neighbor-matching (caliper width: 0.2) without replacement. Comparisons between matched groups were performed using McNemar's test for categorical variables and the paired *t* test or Wilcoxon's signed rank test for continuous variables, as appropriate. The standardized difference was used to measure covariate balance, with an absolute standardized difference above 0.1 representing a meaningful imbalance.

Multivariate predictors were evaluated in a logistic regression analysis, and odds ratios (ORs) and 95% confidence intervals (CIs) were estimated. In the logistic regression analysis, the conventional receiver operating characteristic (ROC) curve was used to determine the cutoff values for each variable that yielded maximal sensitivity and specificity with respect to predicting prolonged postoperative air leakage in this study population. *p* values of < 0.05 were considered to indicate a statistically significant difference. Normally distributed continuous data are expressed as the mean ± standard deviation. If the data did not follow a normal distribution (tested with the Shapiro–Wilk test), the values were presented as the median and interquartile range. Categorical data were expressed as the number and proportion.

Results

All 381 patients who underwent complete VATS lobectomy for NSCLC were retrospectively reviewed. The reasons for exclusion from this study are shown in Fig. 2. A total of 351 patients (120 patients from the non-SBC group, 231 patients from the SBC group) were enrolled in this study. The clinical characteristics of the study population are summarized

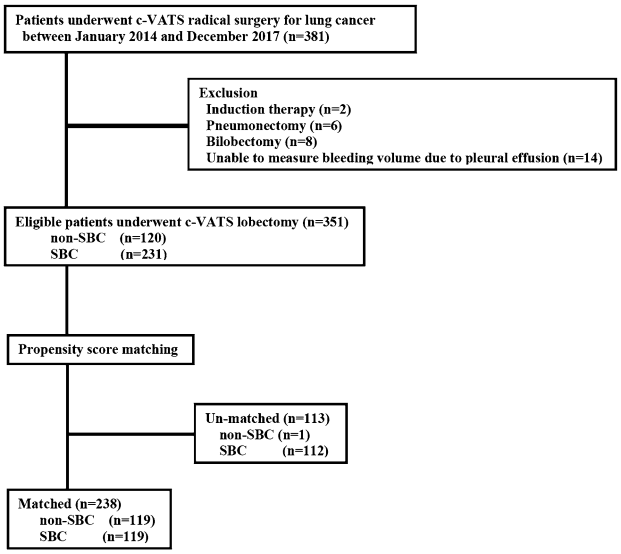

Fig. 2 A flow chart of patient selection

in Table 1. Among the eligible patients, the SBC group showed significantly lower BMI values (median 22.8 kg/m^2 vs. 23.5 kg/m^2, $p = 0.038$), and reduced blood loss during surgery (median 25.0 g vs. 42.0 g, $p < 0.001$) in comparison to the non-SBC group. There were no significant differences in the history of anti-thrombotic therapy, tumor size, lymph node metastasis, operation time, postoperative hospital stay, or postoperative complications between the groups.

The propensity score analysis generated two well-matched pairs of 119 patients (Table 2); briefly, 99.2% (119/120) of the patients in the non-SBC group and 51.5% (119/231) of the patients in the SBC group were matched. After matching, no significant differences between the two groups were identified among any of the observed preoperative variables, including age, gender, BMI, Brinkman index, COPD population, and history of anti-thrombotic therapy, or perioperative variables, including tumor size, lymph node metastasis, operation time, postoperative stay, and postoperative complications. The balance of each sample size was assessed by standardized differences, and the values of most preoperative and perioperative variables were under 0.1. The SBC group still showed significantly reduced blood loss during surgery in comparison to the non-SBC group (median 27.0 g vs. 42.0 g, respectively, $p < 0.001$).

The results of the multivariate analysis to identify predictors of blood loss during surgery are shown in Table 3. The cutoff value for blood loss was determined to be 40 g from the ROC curve. A statistical analysis was performed using this value. The intraoperative use or non-use of SBC was independently associated with blood loss during surgery in all patients and matched patients (OR 2.93, $p < 0.001$; OR 3.14, $p < 0.001$, respectively).

Discussion

This study evaluated the hemostatic effects of SBC in comparison to a conventional soft coagulation device in VATS for NSCLC patients. The propensity score analysis generated matched pairs from the SBC and non-SBC groups (119 patients each), and intraoperative blood loss in the SBC group was found to be significantly reduced in comparison to the non-SBC group. The logistic regression analysis demonstrated that the non-use of SBC was an independent risk factor for intraoperative blood loss during complete VATS lobectomy. This result indicated that the SBC was safe for complete VATS lobectomy in patients with NSCLC, and that the use of this device was associated with a significant decrease in intraoperative blood loss.

Conventional electrosurgical coagulation systems produce sparks and can cause carbonization and adhesion to the electrode during coagulation, resulting in incomplete hemostasis. However, this soft coagulation system coagulates by protein denaturation while automatically suppressing the voltage to ≤ 190 V, thereby preventing the development of sparks and carbonization of tissue, reducing adhesion of the electrode to tissue, and resulting in greater coagulation intensities in comparison to conventional electrosurgical coagulation systems.

In the field of thoracic surgery, some reports have noted the usefulness of soft coagulation in comparison to conventional electrocautery [1, 5]. In recent years, the usefulness of soft coagulation has spread and its use is increasing in lobectomy for NSCLC. However, the utility of SBC has not been verified in thoracic surgery to date. The advantages of SBC include: (1) in complete VATS lobectomy, where the number of access ports is limited, hemostasis can be achieved using a single device that provides soft coagulation and suction functions simultaneously; (2) the shaft is curved and the tip is ball-shaped, so blunt dissection during coagulation procedures is possible, such as when performing interlobular separation or lymph node dissection; and (3) both suction and hemostasis operations can be controlled with the fingertips, which eliminates the bothersome search for and operation of the foot pedal.

During mediastinal lymph node dissection in complete VATS lobectomy, the surgeon must often perform suction to keep the surgical field dry, since oozing blood or lymph fluid may leak from resected lymph vessels. In such situations, if suction and soft coagulation can be performed at the same time without changing the device, the stress of the surgeon is reduced. Another option is for an assistant to perform suctioning and hemostasis at the appropriate time on behalf of the surgeon using the SBC. Thus, SBCs are effective for micro-bleeding or oozing. The use of an

Table 1 The clinical background of all patients who underwent complete VATS lobectomy for NSCLC

	All patients		*p* value
	Non-SBC ($n=120$)	SBC ($n=231$)	
Age (years)			
Median, interquartile range	71.0, 65.3–76.8	71.0, 66.0–76.0	0.824
Gender			
Male	76 (63.3)	138 (59.7)	0.513
Female	44 (36.7)	93 (40.3)	
BMI (kg/m^2)			
Median, interquartile range	23.5, 22.0–25.8	22.8, 20.6–25.1	0.038*
Brinkman index			
Median, interquartile range	400.0, 0–927.0	430.0, 0–940.0	0.433
Population of never smokers	48 (40.0)	84 (36.4)	0.505
Population of COPD	18 (15)	45 (19.5)	0.300
UIP pattern on chest CT	9 (7.5)	32 (13.9)	0.079
History of anti-thrombotic therapy	27 (22.5)	44 (19.0)	0.446
Procedure			
RUL	35 (29.2)	57 (24.7)	0.459
RML	9 (7.5)	16 (6.9)	
RLL	28 (23.3)	76 (32.9)	
LUL	25 (20.8)	46 (19.9)	
LLL	23 (19.2)	36 (15.6)	
Histology			
Adenocarcinoma	90 (75.0)	171 (74.0)	0.843
Squamous cell carcinoma	16 (13.3)	43 (18.6)	
Others	14 (11.7)	17 (7.4)	
Tumor size (mm)			
Median, interquartile range	25.0, 18.0–37.3	25.0, 18.0–35.0	0.698
Lymph node metastasis			
N0	89 (74.2)	173 (74.9)	0.882
N1	12 (10.0)	20 (8.7)	
N2	19 (15.8)	38 (16.4)	
Operation time (min)			
Median, interquartile range	243.5, 209.8–276.5	251.0, 216.0–295.0	0.132
Blood loss (g)			
Median, interquartile range	42.0, 22.0–72.8	25.0, 14.0–43.0	< 0.001*
Period of chest tube placement (days)			
Median, interquartile range	4.0, 4.0–5.0	4.0, 4.0–6.0	0.318
Postoperative stay (days)			
Median, interquartile range	9.0, 8.0–10.8	8.0, 8.0–11.0	0.735
Postoperative pulmonary complication	26 (21.7)	49 (21.2)	0.922

*$p < 0.05$ vs. non-SBC group

SBC is inappropriate in cases of massive fatal bleeding from a thick pulmonary artery or vein. In such cases, the surgeon should immediately switch to open thoracotomy for hemostasis.

In this study, the reason why the use of an SBC did not shorten the operation time is not clear. One possibility is that the total intraoperative blood loss was less than 100 ml in most cases, even the non-SBC group. This low frequency of hemostasis may have been why we there was no statistically significant difference in the operation time. It is possible that the use of an SBC would reduce the operation time in cases with a greater bleeding volume. In addition, regarding the learning curve in the early and late periods, even if the operation was performed by an experienced surgeon, there is a possibility that the clinical background may have influenced the results in this study period. However, in the present study, there were no significant differences in several of the clinical background factors of the early (non-SBC)

Table 2 Clinical characteristics of patients who underwent complete VATS lobectomy for NSCLC after propensity score matching

	After propensity score matching		Standardized difference	*p* value
	Non-SBC ($n=119$)	SBC ($n=119$)		
Age (years)				
Median, interquartile range	71.0, 65.0–76.0	71.0, 65.0–76.0	0.086	0.534
Gender				
Male	75 (63.0)	76 (63.9)	0.019	0.893
Female	44 (37.0)	43 (36.1)		
BMI (kg/m^2)	23.5 ± 2.9	23.6 ± 3.1	0.033	0.881
Brinkman index				
Median, interquartile range	400.0, 0–940.0	330.0, 0–900.0	0.030	0.812
Population of never smoker	48 (40.3)	43 (36.1)	0.087	0.506
Population of COPD	18 (15.1)	19 (16.0)	0.023	0.858
UIP pattern on chest CT	9 (7.6)	9 (7.6)	0.000	1.000
History of anti-thrombotic therapy	26 (21.8)	21 (17.6)	0.106	0.417
Procedure				
RUL	35 (29.4)	25 (21.0)	0.194	0.178
RML	9 (7.6)	8 (6.7)		
RLL	27 (22.7)	40 (33.6)		
LUL	25 (21.0)	24 (20.2)		
LLL	23 (19.3)	22 (18.5)		
Histology				
Adenocarcinoma	89 (74.8)	88(74.0)	0.019	0.882
Squamous cell carcinoma	16 (13.4)	23 (19.3)		
Others	14 (11.8)	8 (6.7)		
Tumor size (mm)				
Median, interquartile range	25.0, 18.0–38.0	25.0, 18.0–35.0	0.000	0.678
Lymph node metastasis				
N0	88 (73.9)	84 (70.6)	0.075	0.563
N1	12 (10.1)	13 (10.9)		
N2	19 (16.0)	22 (18.5)		
Operation time (min)				
Median, interquartile range	243.0, 209.0–275.0	253.0, 215.0–294.0	0.165	0.334
Blood loss (g)				
Median, interquartile range	42.0, 22.0–69.0	27.0, 15.0–42.0	0.356	< 0.001*
Period of chest tube placement (days)				
Median, interquartile range	4.0, 4.0–5.0	4.0, 4.0–6.0	0.000	0.499
Postoperative stay (days)				
Median, interquartile range	9.0, 8.0–10.0	8.0, 8.0–10.3	0.130	0.771
Postoperative pulmonary complication	25 (21.0)	23 (19.3)	0.042	0.747

*$p < 0.05$ vs. non-SBC group

and late (SBC) periods, with the exception of intraoperative blood loss (Table 1).

Few reports have examined the harmful effects of soft coagulation. Intraluminal damage to the bronchial wall caused by a soft coagulation system during endoscopic procedures was reported in an animal model [6]. That study demonstrated that bronchial damage appeared as whitish coagulation at 48 h. Evaluation at 6 weeks showed a persistent inflammatory lesion that extended deeply into the submucosa and perichondral spaces. In addition, Shibano et al. reported a case of intraoperative bronchial injuries caused by soft coagulation, and a case of bronchopleural fistula (BPF) developing in actual clinical practice [7]. They discussed the mechanisms underlying the harmful effects of soft coagulation in their report, suggesting that bronchial cautery induced by the soft coagulation system damages the deep tissue layer, leading to a potential risk of BPF. Other than the bronchus, the chest wall and lung parenchyma have a high moisture content that prevents tissue damage from heat causing coagulation. In contrast, the cartilage portion of

Table 3 Logistic regression analysis of predictors of the amount of blood loss during complete VATS lobectomy in patients with NSCLC

Variables	All patients			After propensity score matching		
	OR	95% CI	*p* value	OR	95% CI	*p* value
Age (≥ 70 years)	1.46	0.89–2.47	0.133	1.34	0.73–2.48	0.346
Gender (male)	2.20	1.16–4.26	0.015*	2.08	0.98–4.52	0.058
BMI (≥ 25)	1.31	0.78–2.19	0.310	1.34	0.73–2.48	0.342
Brinkman index (≥ 400)	0.59	0.28–1.05	0.070	0.57	0.26–1.23	0.157
COPD (presence)	0.93	0.48–1.81	0.840	0.80	0.34–1.86	0.604
UIP pattern on chest CT (presence)	1.66	0.78–3.57	0.094	1.53	0.50–4.90	0.459
History of anti-thrombotic therapy	1.25	0.69–2.26	0.464	1.20	0.56–2.53	0.640
Histology (adenocarcinoma)	0.57	0.32–1.00	0.052	0.51	0.25–1.02	0.057
Tumor size (> 30 mm)	1.51	0.91–2.50	0.112	1.47	0.80–2.71	0.215
Lymph node metastasis (positive)	1.51	0.87–2.63	0.142	2.04	1.05–3.98	0.035*
Non-use of SBC	2.93	1.81–4.78	< 0.001*	3.14	1.79–5.61	< 0.001*

*$p < 0.05$

the bronchial wall contains less moisture and is easily damaged by coagulation heat, even under low temperature output [7]. As a result, careful evaluation of the bleeding point is necessary during surgery. From this perspective, SBC may offer some advantages over conventional soft coagulation systems.

Our study was associated with several limitations, including the retrospective nature and the small number of patients from a single institute. A randomized study is essential for drawing stronger conclusions. Propensity score matching is a useful method that is effective when some degree of prediction of the results is already possible, but random comparisons are ethically difficult. However, not all preoperative differences between groups were compensated for by propensity score matching, despite efforts to control for possible biases. Nevertheless, we believe that our findings could contribute to improving the quality of complete VATS lobectomy for patients with NSCLC. A multicenter, prospective study is required to validate our results.

In conclusion, the SBC was safe, its application in complete VATS lobectomy for the treatment of NSCLC was reasonable, and the use of this device was associated with a significant decrease in intraoperative blood loss.

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Compliance with ethical standards

Conflict of interest The authors declare no conflicts of interest in association with the present study.

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