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ORIGINAL ARTICLE

Better intraoperative cardiopulmonary stability and similar postoperative results of spontaneous ventilation combined with intubation than non-intubated thoracic surgery

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Abstract

Objectives Non-intubated spontaneous ventilation video-assisted thoracic surgery lobectomy is a well-known procedure, but there are doubts regarding its safety. To solve this problem, we developed a safe procedure for spontaneous ventilation thoracic surgery (spontaneous ventilation with intubation). This study analyzed the intraoperative parameters and postoperative results of spontaneous ventilation with intubation.

Methods Between March 11, 2020 and March 26, 2021, 38 spontaneous ventilation with intubation video-assisted thoracic surgery lobectomies were performed. We chose the first 38 non-intubated spontaneous ventilation video-assisted thoracic surgery lobectomy cases with a laryngeal mask performed in 2017 for comparison.

Results There were no significant differences between the non-intubated spontaneous ventilation and spontaneous ventilation with intubation groups in postoperative surgical results (surgical time: 98,7 vs. 88,1 min ($p=0.067$); drainage time: 3.5 vs. 2.7 days ($p=0.194$); prolonged air leak 15.7% vs. 10.5% ($p=0.5$); conversion rate to relaxation: 5.2% vs. 13.1% ($p=0.237$); failure of the spontaneous ventilation rate: 10.5% vs. 13.1% ($p=0.724$); and morbidity: 21% vs. 13.1% ($p=0.364$)) and oncological outcomes. Significantly lower lowest systolic and diastolic blood pressure (systolic, 83.1 vs 132.3 mmHg, $p=0.001$; diastolic 47.8 vs. 73.4 mmHg, $p=0.0001$), lowest oxygen saturation (90.3% vs 94.9%, $p=0.026$), and higher maximum pCO_2 level (62.5 vs 54.8 kPa, $p=0.009$) were found in the non-intubated spontaneous ventilation group than in the spontaneous ventilation with intubation group.

Conclusions Spontaneous ventilation with intubation is a more physiological procedure than non-intubated spontaneous ventilation in terms of intraoperative blood pressure stability and gas exchange. The surgical results were similar in the two groups.

Keywords Intubation · Non-intubated · Spontaneous ventilation · Video-assisted thoracic surgery

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Introduction

In the field of anesthesia, for thoracic surgery, the standard method is mechanical one-lung ventilation (mOLV) using a double-lumen intratracheal tube. This method has several disadvantages; thus, in the last few decades, thoracic surgeons have pursued new techniques for even great interventions of the thorax in local anesthesia and spontaneous ventilation. In the early 2000s, a group at Tor Vergata University published their first results regarding awake non-intubated patients [1]. In 2014, Gonzales-Rivas first performed non-intubated uniportal video-assisted lobectomy [2]. In the last few years, this technique has gained approval in several medical facilities. Studies have shown that this method yields better clinical and immunological results [3, 4].

Despite the reported advantages, the technique still causes disputes between anesthesiologists because of potential airway loss and the complicated manner of conversion to traditional one-lung mechanical ventilation [5, 6]. These concerns may prevent the widespread application of this method.

Our department reported excellent clinical and oncological results among our non-intubated thoracic surgery (NITS) spontaneously ventilated patients [7, 8]. Therefore, we created a new method of spontaneous ventilation with a safe airway, which unites the uniportal video-assisted thoracic surgery (VATS) technique with minimal duration of relaxation, intubation, and mechanical one-lung ventilation followed by spontaneous ventilation of the patient (spontaneous ventilation with intubation [SVI]).

In this study, we compared the intraoperative feasibility and postoperative results of NITS lobectomies to those of lobectomies performed using the SVI method.

Patients and methods

The Ethical Committee of the Human Investigation Review Board of the University of Szeged approved this study (approval no.: 4703/2020.01.20).

Spontaneous ventilation combined with double-lumen tube intubation

Between March 11, 2020 and March 26, 2021, 68 SVI thoracic surgeries were performed in our department (Table 1). We used the VATS method in 89.7% ($n=61$) of the cases, and 62.3% ($n=38$) of the SVI VATS cases were lobectomies. In this study, 38 SVI VATS lobectomies were analyzed.

The SVI VATS method was previously published [9]. At the beginning of the procedure, a short-acting relaxant drug (mivacurium) was administered, and the patients were intubated with a double-lumen intratracheal tube. After that, uniportal VATS incision was performed with local anesthesia. To avoid coughing triggered by the intratracheal tube, vagus and paravertebral nerve blockades were performed. Bupivacaine (4–5 mL) was administered near the intercostal nerve between the second and fifth intercostal spaces close to the spine (paravertebral blockade) and near the vagus nerve (left side in the aortopulmonary window, right side in the upper mediastinum). Later, the patients arose from the initial relaxation and could breathe spontaneously. The bispectral index (BIS; Medtronic Vista) was controlled with propofol to maintain a BIS of 40–60. Due to the vagal nerve blockade, the intratracheal tube did not trigger coughing, and the movements of the thoracic cavity and mediastinum do not disturb the course of surgery. Meanwhile, a safe airway was ensured due to the double-lumen intratracheal tube during the entire procedure, all possible complications were managed easily, and conversion to mechanical one-lung ventilation is fast and safe.

Table 1 SVI surgeries

SVI ($n=68$)	Intended open SVI ($n=7$)	VATS SVI ($n=61$)
Lobectomy	4	38
Segmentectomy	1	7
Atypical resection	0	11
Thymectomy	0	5
Lymph node block dissection	2	0

SVI spontaneous ventilation with intubation, *VATS* video-assisted thoracic surgery

The pCO_2 and oxygen saturation could be kept within or close to the normal range with a higher FIO_2 (40–100%) and a positive end expiratory pressure (PEEP; 3–5 H_2Ocm) in the dependent lung (if required), which was easily measured through the double-lumen tube. If necessary, pressure support ventilation (PSV) without relaxation or recruitment maneuvers can be performed to maintain normal oxygen and CO_2 levels. Anaesthesiologic indications for conversion to relaxation and mOLV are hypoxemia and hypercapnia.

For SVI VATS lobectomies, we used the same oncological inclusion criteria as in the NITS cases [10]. We considered a body mass index (BMI) of more than 30 as the only exclusion criterion for SVI cases, and the other exclusion criteria of the NITS were not contraindications for SVI procedures.

Non-intubated thoracic surgery

The first 38 NITS VATS lobectomies were performed in our department between February 2, 2017 and September 14, 2017 and compared to the 38 SVI VATS lobectomies mentioned above. The chosen NITS VATS lobectomy results were already presented at the 2018 European Society of Thoracic Surgery annual meeting in Ljubjana.

The NITS patient selection criteria were based on the currently recommended selections [11]. The oncological aspects of selection are similar to the criteria applied in the SVI group, and it is based on the current recommended guideline (the diameter of the tumor is less than 7 cm; the lymph node stage is cN0 or cN1) [10].

The surgical procedure is similar to that of SVI, but in NITS cases at the beginning of the surgery, the patient is not relaxed and intubated; therefore, manipulation of the vagus and intercostal blockade must be very careful.

Anesthesiology

In addition to general standard monitoring, the depth of anesthesia was controlled by the BIS (Medtronic Vista), and invasive blood pressure measurements were performed. Fentanyl and midazolam were administered prior to surgery. Anesthesia was induced and maintained with propofol to maintain a BIS of 40–60 [4]. After the adequate depth of anesthesia was achieved, a laryngeal mask was inserted to maintain a clear airway. The oxygen and air mixture was supplemented via a T-piece, and FiO_2 was titrated to keep the SpO_2 at above 92%.

In both groups, phenylephrine (50–100 mcg) in divided doses was administered if systolic blood pressure decreased to less than 100 mmHg, decreased by more than 25%, or the mean arterial pressure was less than 60 mmHg.

In this study, there were two different periods of time with NITS and later SVI procedures. There was no period where mixing of the two types of surgeries took place.

The preoperative check-up was the same as that in the case of standard lobectomy in both groups.

The comorbidities of the selected patients were characterized using the Carlson Comorbidity Index. The lobectomies were performed using the uniportal VATS technique in both groups. In all cases, digital suction was applied with a negative pressure of 15 W. The drain was removed when there was no air leak and the daily fluid volume was less than 400 mL.

During the surgery, pulse, blood pressure, oxygen saturation, pCO_2, and ventilation rate were analyzed in both groups. Patient data and the lobectomy types are presented in Tables 2 and 3.

Results

The intraoperative anesthesiology parameters of the NITS and SVI groups are presented in Table 4. Significantly lower lowest systolic and diastolic blood pressures were found in the NITS group versus the SVI group (systolic: 83.1 vs 132.3 mmHg) ($p=0.001$); diastolic: 47.8 vs. 73.4 mmHg) ($p=0.0001$). The lowest oxygen saturation was significantly lower in the NITS group than in the SVI group (90.3% vs 94.9%) ($p=0.026$). The highest pCO_2 level was significantly higher in the NITS group than in the SVI group (62.5 vs 54.8 kPa) ($p=0.009$). There were no significant differences in the other parameters measured by anesthesia.

Table 2 Data of the NITS and SVI lobectomy patients

	NITS VATS ($n=38$)	SVI VATS ($n=38$)	*p* value
Female/male	22/16	18/20	0.253
Age	64.9	65.4	0.842
BMI	25.0	26.7	0.060
CCI	5.6	5.0	0.157
FEV_1 (%)	90.4	87.1	0.470

BMI body mass index, *CCI* Carlson Comorbidity Index, *FEV_1* forced expiratory volume in 1 s, *NITS* non-intubated thoracic surgery, *SVI* spontaneous ventilation with intubation, *VATS* video-assisted thoracic surgery

Table 3 Data of the NITS and SVI VATS lobectomies

	NITS VATS ($n=38$)	SVI VATS ($n=38$)	*p* value
Right upper lobe	14	6	0.038
Right middle lobe	5	7	0.528
Right lower lobe	6	14	0.038
Left upper lobe	7	7	1.00
Left lower lobe	6	4	0.500

NITS non-intubated thoracic surgery, *SVI* spontaneous ventilation with intubation, *VATS* video-assisted thoracic surgery

In the NITS group, the conversion rate to relaxation, intubation, and mechanical one-lung ventilation in the NITS group was 5.2% ($n=2$). In two additional patients, because of hypoxia, both lungs were temporarily ventilated (reinflation) one or more times to reach the normal oxygen saturation level. This means that in these four cases, the normal NITS method was not successful. In the SVI group, this both lung temporary ventilation method to elevate the saturation was not used..

In the SVI group, there were ten cases (26.3%) of spontaneous ventilation via the double-lumen tube with PEEP (3–5 cmH_2O) and FIO_2 (40–100%) was not sufficient to maintain acceptable gas exchange parameters. Five of them (13.1%) were relaxed and mechanical one-lung ventilation was applied, and an additional 5 of the 38 cases (13.1%) received PSV to the dependent lung to support spontaneous ventilation, but they were not relaxed. The reason for conversions was gas exchange insufficiency. From this point of view, the failure rate of spontaneous ventilation method due to hypoxia was 10.5% (4/38) in the NITS group versus 13.1% (5/38) in the SVI group ($p=0.724$).

The perioperative results are shown in Table 5. We did not find significant differences in operation time, duration of drainage, or morbidity, but the surgical and drainage times were slightly shorter in the SVI group. The morbidity rate was 21% in the NITS group and 13.1% in the SVI group ($p=0.364$). Postoperative complications in the NITS group were as follows: prolonged air leak ($n=6$), readministration due to pneumothorax with the need for chest drainage ($n=1$), and bleeding that required reoperation ($n=1$). In the SVI group, the following complications occurred: prolonged air leak ($n=4$) and new-onset atrial fibrillation ($n=1$).

Table 4 Data of the cardio-pulmonary functions

	Analyzed cases in NITS group	NITS	Analyzed cases in SVI group	SVI	*p* value
Pulse minimum (/min)	32	60.3 (45–80)	36	63.6 (40–90)	0.217
Pulse maximum (/min)	32	84.5 (65–105)	36	82.9 (58–130)	0.582
Lowest systolic BP (mmHg)	32	83.1 (65–115)	34	132.3 (90–180)	0.0001
Lowest diastolic BP (mmHg)	32	47.8 (35–70)	34	73.4 (45–120)	0.0001
Circulation support cases	38	21 (55.2%)	38	15 (39.5%)	0.171
Lowest oxygen saturation (%)	32	90.3 (44–99)	36	94.9 (88–99)	0.026
Highest oxygen saturation (%)	32	98 (86–100)	36	99.4 (96–100)	0.065
pCO_2 minimum (kPa)	31	39.6 (28.5–53.7)	32	39.1 (28–49)	0.692
pCO_2 maximum (kPa)	31	62.5 (47–106)	33	54.8 (37.7–90.9)	0.009
Ventilation rate minimum (/min)	9	12.7 (9–18)	36	11.9 (6–18)	0.448
Ventilation rate maximum (/min)	9	19.2 (16–24)	35	18.2 (12–30)	0.424

BP blood pressure, *NITS* non-intubated thoracic surgery, pCO_2 partial pressure of carbon dioxide, *SVI* spontaneous ventilation with intubation

Table 5 Perioperative results of the NITS and SVI lobectomies

	NITS VATS ($n=38$)	SVI VATS ($n=38$)	*p* value
Surgical time (min)	98.7 (55–180)	88.1 (55–120)	0.067
Drainage time (days)	3.5 (1–12)	2.7 (1–10)	0.194
Morbidity	8/38 (21%)	5/38 (13.1%)	0.364
PAL	6/38 (15.7%)	4/38 (10.5%)	0.5
mOLV conversion rate	2/38 (5.2%)	5/38 (13.1%)	0.237
Failure of SV method	4/38 (10.5%)	5/38 (13.1%)	0.724

mOLV mechanical one-lung ventilation, *NITS* non-intubated thoracic surgery, *PAL* prolonged air leak, *SV* spontaneous ventilation, *SVI* spontaneous ventilation with intubation, *VATS* video-assisted thoracic surgery

Table 6 Histological results of the primary lung cancer cases

	NITS VATS ($n=33$)	SVI VATS ($n=26$)
Adenocarcinoma	28	19
Squamosus cell carcinoma	2	4
Small cell lung cancer	0	1
Large cell neuroendocrine carcinoma	0	1
Typical carcinoid	2	1
Carcinosarcoma	1	0
IA	18	11
IB	9	2
IIA	0	2
IIB	1	5
IIIA	5	4
IIIB	0	1
IV	0	1

NITS non-intubated thoracic surgery, *SVI* spontaneous ventilation with intubation, *VATS* video-assisted thoracic surgery

The histological results are shown in Table 6. Primer lung cancer was removed in 33 cases in the NITS group versus 26 cases in the SVI group. Two metastasectomies were performed in the NITS group versus six in the SVI group. Benign lesions were removed in three and six cases in the NITS and SVI groups, respectively. We removed a mean 11.2 mediastinal lymph nodes in the NITS group; versus 14.7 in the SVI group ($p=0.109$). In both groups, 10.5% of the removed lymph nodes were metastatic ($p=1.000$).

Discussion

The main goal of the development of the SVI procedure was to ensure airway safety during spontaneous ventilation thoracic surgery. In our previously published data using the SVI technique, we reduced the duration of mechanical one-lung ventilation by 76.6%, thereby lowering the changes in pulmonary physiology [9]; however, insufficient information was available to determine whether SVI has other advantages over reduction of the mechanical one-lung ventilation period.

The main criticism against SVI is that sufficient spontaneous ventilation through one side of the double-lumen tube is impossible. In this study, there were ten cases (26.3%) of spontaneous ventilation via the double-lumen tube in which a PEEP of 3–5 cmH_2O and FIO_2 of 40–100% were insufficient to maintain the acceptable gas exchange parameters, but it was successful in 73.7% of cases. In addition, 13.1% of the spontaneous ventilation supported with PSV resulted in a normal gas exchange rate. Thus, acceptable gas exchange without the need for conversion to relaxation was provided in 86.8% of the SVI cases and 94.8% of the NITS cases. It is true that the oxygen saturation and the pCO_2 levels were in the normal range in both groups, but there were significant intergroup differences in the lowest oxygen saturation and highest pCO_2 levels: the mean lowest oxygen saturation was significantly higher in the SVI group than in the NITS group (94.9% vs. 90.3%) ($p=0.026$), while the highest mean pCO_2 level was significantly lower in the SVI group than in the NITS group (54.8 vs. 62.5 vs kPa) ($p=0.009$). From these data, it can be concluded that the SVI procedure provides better gas exchange during spontaneous ventilation due to the PEEP of 3–5 cmH_2O.

Regarding the SVI technique, the question arises as to how patients do not cough during SV surgery after ipsilateral vagus blockade, when the contralateral side main stem bronchus is stimulated by the double-lumen tube. We observed that, during the surgery, there was no cough if we did not directly move the ipsilateral main stem bronchus; however, if this kind of movement occurred, which moved the contralateral bronchus as well, the patient coughed. We suggest that this movement causes a change in the location of the balloon of the tube in the contralateral bronchus, and this movement of the tube generates the cough reflex. However, if we moved the lobes (for example, the right upper lobe) during resection and stapled the lobal bronchus, there was no evident cough. Our theory regarding this kind of cough is supported by the literature. The cough receptors (terminals of Aδ-fiber with circumferential arborization in the main airway) are localized almost exclusively to the extrapulmonary bronchi and trachea [12]. They are sensitive to punctate mechanical stimulation (-and rapid changes in luminal pH) and can be activated by a vertical dynamic force. As the force becomes static, activation of the receptor ceases [13, 14]. With this extrapulmonary Aδ nodose mechanosensitive vagal afferent nerve pathway, cough can be produced in anesthetized animals as well [13]. Based on the above discussion, in our SVI procedure, the cough reflex cannot be prevented completely, but it can be reduced to a very low threshold with ipsilateral vagus blockade and low BIS caused by sedation. If dynamic mechanical stimulation of the contralateral main stem bronchus occurs, a cough will also occur; however, if the location of the double tube cuff in the contralateral main stem bronchus remains static, the cough reflex is not activated".

Regarding the ventilation, there is another question about the advantage of SVI with use of PEEP and PSV over relaxed cases. Mechanical ventilation, specifically mechanical one-lung ventilation, may cause overdistension of the alveoli due to high peak pressure and pressure differences and presence of an opening/closing phenomenon in the alveolar system due to ineffective levels of PEEP. The main advantage of SVI ventilation is the regulation of inspiration–expiration. In SVI, the same PEEP and PSV are used if needed, as in the relaxed cases, but the volume and time period of ventilation are controlled by the patient, rather than ventilator parameters. In SVI cases, if the lung stretching receptors detect that the lung parenchyma is overdistended, the patient will stop inspiration with the Hering–Breuer reflex, preventing barotrauma in the lung parenchyma. The ventilator cannot detect this threshold, and it would incorrectly provide more volume, causing overdistension, or less volume, resulting in lower airway pressure leading to atelectasis.

Regarding the anesthesia, further advantage of the SVI over the mOLV, in addition to enabling ventilation regulation by the patient, is the reduced period of relaxation (75% in SVI compared to the traditional mOLV). If the theory of volutrauma of the alveoli caused by mOLV can be accepted as a real pathophysiological phenomenon, the time required for alveolar injury in SVI cases is reduced to 75% and the SVI procedure can attenuate the proinflammatory response. An animal study stated that the cytokine release in mOLV begins within 90 min after the relaxation [15]. In that case, the SVI can reduce the changes in the cytokine release, as it has a mean relaxation time of 25.5 min, as mentioned in our previous study [9]. The pressures applied in SVI (3–5 PEEP and PSV) correspond to the requirement of the protective ventilation during mOLV [16]. Based on the pressures in SVI, it can at least be stated that the SVI is not more harmful than the traditional mOLV.

The quantity of the relaxant drug used is a significant difference between the SVI and mOLV. A much smaller amount of the relaxant drug is used in SVI than in mOLV. This is very important because the relaxant drug can cause proinflammatory cytokine release directly from the macrophages. It has been proven that acetylcholine (ACh) reduces the release of the proinflammatory cytokines from macrophages in a culture on binding to their α7ACh receptors (cholinergic anti-inflammatory pathway) [17]. The relaxant drugs use the same receptor in the neuromuscular junction; if they block the function of the ACh on macrophages, cytokine release can be induced, with its well-known side effects.

The better oxygenation and carbon dioxide exchange of the SVI provides the basis for another very important advantage of the SVI: better cardiopulmonary stability during spontaneous ventilation thoracic surgery. In the SVI cases, the lowest systolic and diastolic blood pressure values during surgery before its medical correction were

Table 7 Perioperative results of the SVI and mOLV VATS lobectomies

	SVI VATS uniportal lobectomy (*n* = 38) Furák current study	mOLV VATS uniportal lobectomy (*n* = 81) Furák [23]	mOLV VATS uniportal lobectomy (*n* = 92) Gonzales-Rivas [24]	mOLV VATS multiportal lobectomy (*n* = 30) AlGhamdi [22]
Surgical time (min)	88.1 (55–120)	96.6 (44–188)	154.1 (60–310)	146.0 ± 47.4
Drainage time (days)	2.7 (1–10)	5.1 (1–25)	2 (1–16)	5.4 ± 5.4
Morbidity (%)	13.1	12.3	15.2	20.0

SVI spontaneous ventilation with intubation, *VATS* video-assisted thoracic surgery, *mOLV* mechanical one lung ventilation

significantly higher than those in the NITS cases (systolic: 132.3 vs. 83.1 mmHg, $p = 0.001$; diastolic: 73.4 vs. 47.8 mmHg, $p = 0.0001$), which means that cardiac function is more stable during the SVI procedure than during the NITS procedure.

In both procedures, the patients are spontaneously ventilated, so the cardiac alteration caused by mediastinal movement can be excluded. Another reason could be the change in cardiac innervation, but it can also be excluded because the same vagus and paravertebral blockade with the same amount of bupivacaine was applied in both methods. In our opinion, the basis of this stability in SVI cases is the better oxygen saturation level, caused by the PEEP of 3–5 cmH_2O and the PSV. With this procedure, better oxygenation and better CO_2 changes cause smaller hypoxic pulmonary vasoconstriction (HPV), thus it decreases less the blood pressure [18].

Regarding cardiac function during thoracic surgery in SVI, NITS, and relaxed cases, the intraoperative period can be subdivided into three sessions.

The first session lasts until the chest is opened. In this session, the only major change in the hemodynamic condition is a decrease in systemic vascular resistance causing lower afterload. This occurs due to administration of drugs for anesthesia induction, regardless of the type of surgery; hence, this period is the same in SVI, NITS, and relaxed cases.

The second session begins after the chest has been opened. If the chest is opened, significant hemodynamic changes occur due to a loss of negative intrapleural pressure and lung collapse causing HPV, resulting in an increase in pulmonary vascular resistance (PVR) and decrease in venous return. If the patient is ventilated in relaxed cases or supported by PEEP and PSV in SVI, the positive pressure and applied PEEP can diminish the effect of these factors. In NITS, transient hemodynamic instability may occur depending on the patient's cardiac condition, intraoperative systemic and pulmonary resistance, and pressure changes during chest opening and lung collapse. This may require the use of vasoconstrictor drugs to stabilize cardiac output. Medical support for cardiac function can thus become more intensive in NITS cases than in intubated patients.

The third session is the stable period after hemodynamic balance is achieved; it is a safe and relatively uneventful period until conclusion of the operation in SVI, NITS, and relaxed cases.

According to our clinical observations, fewer vasoconstrictor drugs are needed during SVI procedures as compared with NITS. We used the same drug dosage for pain control and sedation, and there was no difference between the targeted anesthetic depth. The only differences were the initial mechanical ventilation of the early SVI period until the muscle relaxant is eliminated, and the administration of PEEP and PSV if required. Based on these data, we believe that PSV and PEEP, if required, cause physiological changes that can stabilize cardiac function during spontaneous ventilation [19, 20].

The perioperative results of the SVI group were similar to those of the NITS group. This technique could also be used in oncology patients with nearly the same outcomes. The two groups had no significant differences in surgical time or postoperative period. Our SVI lobectomy results were comparable with the NITS lobectomy results reported by other groups. Hung et al. reported a drainage time of 2.0 days [21], while Jun Liu et al. stated 3.2 days [4] compared to the 3.5 and 2.7 days after NITS and SVI lobectomies in our patients The postopeartive morbidity rate was around 9–12% in the previously mentioned papers compared to our 13.1% result. We found the advantage of SVI in PAL compared to our NITS cases (10.5% vs 15.7%), and PAL in Hungs (11.9%) [21] or AlGhamdis NITS cases (16.7%) [22]. However, the mean surgical time was longer in these studies, 124–177 min, than in our study (98.7 and 88.1 min in the NITS and SVI groups, respectively) [4, 21, 22]. We compared perioperative result of SVI to those of VATS lobectomies with mOLV (Table 7). Analysis of our two studies showed, that drainage time after SVI decreased almost by 50% compared to mOLV cases (2.7 vs. 5.1 days), with operative time and postoperative morbidity showing no significant difference [23]. Comparing results of our uniportal VATS SVI lobectomies to the same data of other uniportal and multiportal VATS mOLV studies, shorter opeartive time after SVI was found, however in corellation with literature data, drainage time and postoperative morbidity had similar outcomes [22, 24]. According to our results, SVI has favourable, and at least similar perioperative results compared to mOLV.

Conclusion

Despite the almost three times higher conversion rate to relaxation during SVI than during NITS, the lowest intraoperative oxygen saturation was significantly higher and the highest pCO_2 level was significantly lower in the SVI method than in the NITS procedure. In SVI VATS lobectomy cases, the intraoperative decrease in blood pressure was smaller than that in NITS cases because of the lesser degree of hypoxic pulmonary vasoconstriction. These data show that the SVI procedure causes smaller changes in normal cardiopulmonary function but similar postoperative surgical and oncological results to those of NITS.

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Declarations

Conflict of interest The authors declare no conflicts of interest.

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