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# Single-incision thoracoscopic surgery and conventional video-assisted thoracoscopic surgery: a retrospective comparative study of perioperative clinical outcomes†

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## Abstract

**OBJECTIVES**: To assess the feasibility, safety and postoperative wound pain of single-incision thoracoscopic surgery (SITS) for Stage I lung cancer in patients who had previously undergone surgery compared with conventional video-assisted thoracoscopic surgery (c-VATS).

**METHODS**: Lobectomy by SITS (60) and c-VATS (20) was performed for Stage I lung cancer between 2011 and 2014. In SITS, an ∼5-cm small incision was placed at the fourth or fifth intercostal space from the anterior to posterior axillary line. C-VATS was performed via three or four ports using trocars only. The evaluation items were general operative outcomes, pain stress using the Numeric Rating scale (NRS) on postoperative days 3, 7 and 30, and some pathological symptoms related to the neuropathic wound pain through the operative course. The number of days of use of analgesic agents was also evaluated for 1 month after surgery.

**RESULTS**: SITS showed similar perioperative outcomes (postoperative hospital stay, blood loss, surgical time, drainage duration, creatine phosphokinase ($CPK_{max}$), creactive protein ($CRP_{max}$) and frequency of postoperative complications) to those of c-VATS. Additionally, the average NRS in SITS decreased on postoperative days 7 and 30 (Day 7: 2.4 ± 0.4 vs 4.2 ± 0.3, $P = 0.041$, Day 30: 1.7 ± 0.4 vs 3.3 ± 0.3, $P = 0.038$) and the number of days analgesic agents were administered was also reduced (SITS: 8.1 ± 0.9 vs c-VATS 13.1 ± 1.2 days, $P = 0.045$). The frequency of allodynia, hyperalgesia, hypaesthesia and numbness was significantly reduced in the SITS group.

**CONCLUSIONS**: Although conclusive evidence has not yet been obtained, SITS is more minimally invasive in regard to postoperative wound pain compared with c-VATS. This procedure should be considered as a treatment option for early-stage lung cancer.

**Keywords:** Single-incision thoracoscopic surgery • Lung cancer • Minimally invasive

## INTRODUCTION

Video-assisted thoracoscopic surgery (VATS) for lung cancer has rapidly spread over the last several years with the technical innovation of surgical devices worldwide. The reasons for this rapid spread may be its low invasiveness in consideration of aesthetic outcomes and pain stress on the patient and health economic merits, such as shortened hospital stays. However, allodynia and hypaesthesia, which have been attributed to intercostal nerve disorder, is often induced by conventional VATS and is difficult to manage following surgery, suggesting that surgery employing approaches through several intercostal regions is more stressful than expected for operators.

VATS for lung cancer through an ∼4-cm incision only has recently been initiated in some countries [1, 2]. Thoracoscopic surgery through a single port is termed uniportal VATS or single-incision thoracoscopic surgery (SITS), and the incision size was previously reported to be 4–7 cm. Based on an analysis of postoperative factors, the 2-year outcomes for lung cancer were considered satisfactory [3].

In the present study, we compared surgical factors between SITS for early lung cancer with an incision size of 4–7 cm and conventional VATS (c-VATS), which was defined as surgery through three to four ports alone. The postoperative wound pain scale, neuropathic wound pain including allodynia, hyperalgesia, hypaesthesia, numbness, aching sensation and amount of analgesics administered after surgery were investigated as low-invasiveness evaluation items. This was an initial study that closely evaluated the low invasiveness of SITS and c-VATS with regard to pain in detail.

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## METHODS

A retrospective review of prospectively maintained database identified 80 patients with clinical stage I non-small-cell lung cancer who underwent curative thoracoscopic surgery at Nippon Medical Chiba Hokusoh Hospital during March 2011–December 2014. The final decision to perform SITS or c-VTAS in each patient was determined at the surgeon's discretion. Almost all patients without severe cardiopulmonary complications underwent both operative procedures. Patients who were indicated for SITS but converted to thoracotomy were placed in the SITS group based on the intention-to-treat principle. All surgeries were lobectomy, and SITS and c-VATS were performed in 60 and 20 patients by the same surgeon (Kyoji Hirai), respectively. Informed consent to use the data-use agreement was obtained from all patients before surgery. In SITS, an ∼5-cm incision was made on the anterior (upper and lower lobectomy) or middle (lower lobectomy) axillary line (Fig. 1A), followed by the attachment of a Wrap Protector mini (Hakko, Inc., Japan). The protective procedures to intercostal nerve were provided by surgeon and assistants. The procedure was atraumatically performed as much as possible in order to prevent contact of the thoracoscope and forceps with the intercostal nerve. The thoracoscope was mostly handled at an angle of more than 45° from the chest wall (Fig. 1B). Surgery was performed using a 10-mm 30° oblique-viewing thoracoscope and facing/inverted dual monitors without any specific device. c-VATS was defined as thoracoscopic surgery through three or four port holes. The Wrap Protector mini was used to open incisions, and a small rib retractor was not used. Trocars (Endopath, 12-mm Ethicon, USA) were used in the port holes. The energy device, HARMONIC scalpel (Ethicon, USA) was used in mediastinal lymph node dissection. Various surgical factors (operative outcomes), the incidence of complications, postoperative complications and 30-day mortality were evaluated.

Postoperative wound pain was monitored using the Numeric Rating Scale (NRS). NRS was evaluated on postoperative days 3, 7 and 30. Additionally, the frequency of aching sensation, allodynia, hypaesthesia, numbness and hyperalgesia related to neuropathic pain was evaluated by detailed interview and a writing brush throughout the course. The total number of days with analgesic treatment for wound pain within 1 month after operation was also investigated. Some non-steroidal anti-inflammatory drugs, pregabalin and tramadol hydrochloride were administered as analgesic agents.

### Statistical analysis

The quantitative variables are presented as medians (±standard deviation) or ranges as appropriate. The continuous variables were compared using the Mann–Whitney *U*-test and categorical variables were analysed with the $\chi^2$ test or Fisher's exact test as appropriate. All statistical analyses were carried out with the software SPSS version 17 for Windows (IBM Corp., Armonk, NY, USA). *P*-values of <0.05 were considered to indicate statistical significance for all parameters.

## RESULTS

### Preoperative data and resected lobe of lung

From 2011 to 2014, we performed 60 lobectomies for Stage I lung cancer by SITS and 20 lobectomies by c-VATS. The preoperative patient's characteristics are summarized in Table 1. As given in Table 1, there was no significant difference in both groups with regard to sex, age, forced expiratory volume 1.0 s ($FEV_{1.0}$) and tumour size.

### Postoperative data

We have analysed the results of lobectomies by SITS and c-VATS. The distribution of lobectomies in both groups is shown in Fig. 2. All lung lobes were resected in both groups and the most of the lobectomies done in SITS were right upper lobectomies. Postoperative outcomes are described in Table 2. The data of the SITS group are shown as follows. The median operative time was 168 min (range: 95–276), and the median of blood loss was 95 ml (range: 15–475). The mean number of dissected lymph nodes was 13.6 (range: 6–24). The mean days of drainage duration and hospital stays after surgery were 1.4 (1–5) and 7.2 (5–14), respectively. There was no significant difference in both groups with regard to the operative time, the amount of blood loss, the number of dissected lymph nodes, drainage duration, hospital stays and the maximum of CRP and CPK after operation. However, the maximum of CPK tended to be lower in SITS than in c-VATS (347 vs 432 IU/ml, $P = 0.068$). One patient (1.7%) in the SITS group required conversion to open surgery due to strong adhesion of lymph node to the pulmonary artery. The rate of postoperative

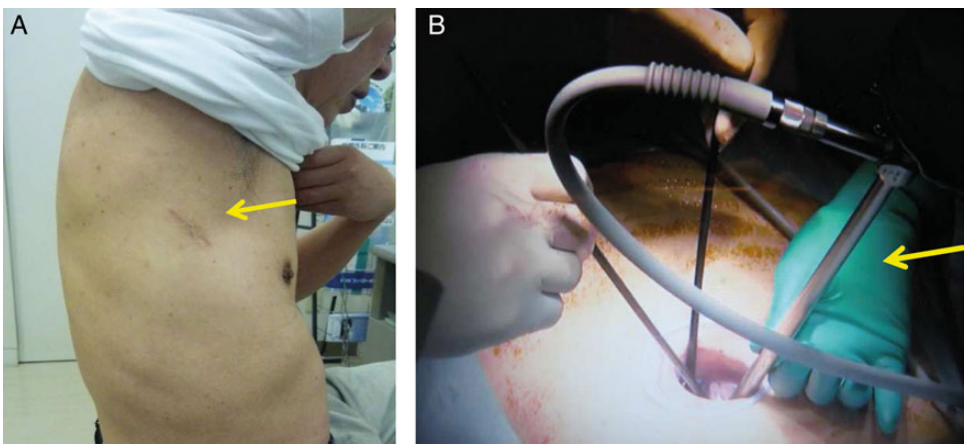


**Figure 1:** (**A**) Skin incision 3 months after right upper lobectomy (**B**) Instrumentation.

complications did not differ significantly between the two groups (16.7 vs 25.0%, $P = 0.408$). There were no deaths in either group.

The NRS on postoperative days 7 and 30 was significantly less in the SITS group than that in the c-VATS group (Fig. 3, Day 7: 2.4 ± 0.4 vs 4.2 ± 0.3, $P = 0.041$, Day 30: 1.7 ± 0.4 vs 3.3 ± 0.3, $P = 0.038$). The number of days of use of analgesic agents within a month after surgery was less in the SITS group (Fig. 4, 8.1 ± 0.9 vs 13.1 ± 1.2 days, $P = 0.045$). The pathological symptoms of wound pain except aching sensation, showing allodynia, hypaesthesia, hyperalgesia and numbness through the postoperative course were significantly less in the SITS group than in the c-VATS group (allodynia: 11.7 vs 35.0%, $P = 0.017$; hypaesthesia: 16.7 vs 50.0%, $P = 0.003$; hyperalgesia: 13.3 vs 30.0%, $P = 0.027$; numbness: 11.7 vs 35.0%, $P = 0.017$; Fig. 5).

**Table 1:** Clinical characteristics of the study population

| | c-VATS ($n = 20$) | SITS ($n = 60$) | $P$-value |
|---|---|---|---|
| Sex (%) | | | |
| Male | 12 (60.0) | 33 (57.5) | 0.841 |
| Female | 8 (40.0) | 27 (42.5) | |
| Age | 65.5 (60–86) | 72.5 (64–82) | 0.542 |
| $FEV_{1.0}$ (l) | 1.95 (1.44–2.45) | 2.02 (1.44–2.65) | 0.832 |
| Tumour size (mm) | 18 (8–32) | 24 (11–35) | 0.741 |

In all cases, lobectomy was performed by the same surgeon.
c-VATS: conventional video-assisted thoracoscopic surgery; SITS: single-incision thoracoscopic surgery; $FEV_{1.0}$: forced expiratory volume 1.0 s.

## DISCUSSION

Low invasiveness for the chest wall, i.e. aesthetic outcomes and reductions in wound pain, are generally considered to be advantages of c-VATS for lung cancer [4, 5]. Greater importance is attached to wound pain-reducing effects than aesthetic outcomes because surgery for lung cancer is frequently performed in elderly patients. However, contrary to expectation by operators, postoperative wound pain is prolonged in some patients treated with c-VATS. This wound pain includes elements of intercostal nerve disorder-associated neuropathic pain and appears as an aching sensation, numbness and hypaesthesia, secondary hyperalgesia at sites distant from the actual wound. These types of pain may influence the patients' return to society and reduced ADLs of patients, and be difficult to treat at outpatient clinics.

Thoracoscopic surgery enabled an early discharge, which is not possible after thoracotomy, but is performed through more than three ports in most cases. Cylindrical trocars are placed between the costal bones in many cases, which may be stressful to the chest wall and damage the intercostal nerve at several sites [6]. All respiratory surgeons may understand that pain at the trocar-

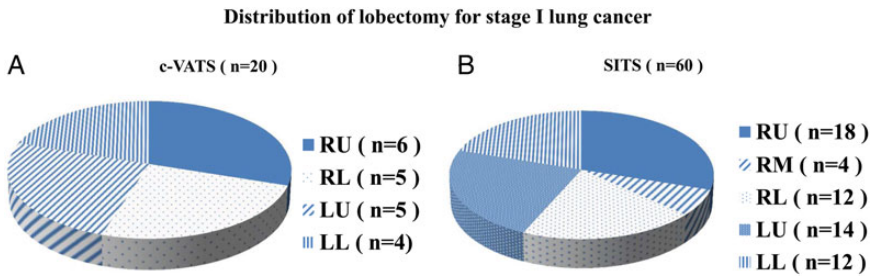


**Figure 2:** Distribution of lobectomy for Stage I lung cancer. (**A**) c-VATS group and (**B**) SITS group. c-VATS: conventional video-assisted thoracoscopic surgery; SITS: single-incision thoracoscopic surgery; RU: right upper; RM: right middle; RL: right lower; LU: left upper; LL: left lower.

**Table 2:** Postoperative outcomes in the group of c-VATS and SITS

| | c-VATS ($n = 20$) | SITS ($n = 60$) | $P$-value |
|---|---|---|---|
| Operation time (range) (min) | 155 (105–225) | 168 (95–276) | 0.321 |
| Blood loss (range) (ml) | 85 (15–435) | 95 (15–475) | 0.311 |
| The number of dissected lymph nodes, $n$ (range) | 12.8 (5–25) | 13.6 (6–24) | 0.821 |
| Drainage duration (range) (days) | 1.5 (1–7) | 1.4 (1–7) | 0.542 |
| Hospital stays after surgery | 7.4 (5–15) | 7.2 (5–14) | 0.891 |
| $CPK_{max}$ (IU/ml) | 432 (220–665) | 347 (155–625) | 0.068 |
| $CRP_{max}$ (mg/dl) | 5.8 (3.2–11.5) | 5.2 (1.8–11.2) | 0.545 |
| The number of autosuture's cartridges that was used, $n$ (range) | 5.2 (3–7) | 4.1 (1–6) | 0.235 |
| Postoperative complications, $n$ (%) | 5 (25.0) | 10 (16.7) | 0.408 |
| Prolonged air leak (>5 days), $n$ (%) | 2 (10.0) | 4 (6.7) | 0.624 |
| Wound infection, $n$ (%) | 1 (5.0) | 2 (3.3) | 0.734 |
| Atelectasis, $n$ (%) | 1 (5.0) | 2 (3.3) | 0.734 |
| Pneumonia, $n$ (%) | 1 (5.0) | 2 (3.3) | 0.734 |
| Conversion to thoracotomy (%) | 0 | 1 (1.7) | |

c-VATS: conventional video-assisted thoracoscopic surgery; SITS: single-incision thoracoscopic surgery; $CPK_{max}$: creatine phosphokinase; $CRP_{max}$: creactive protein.

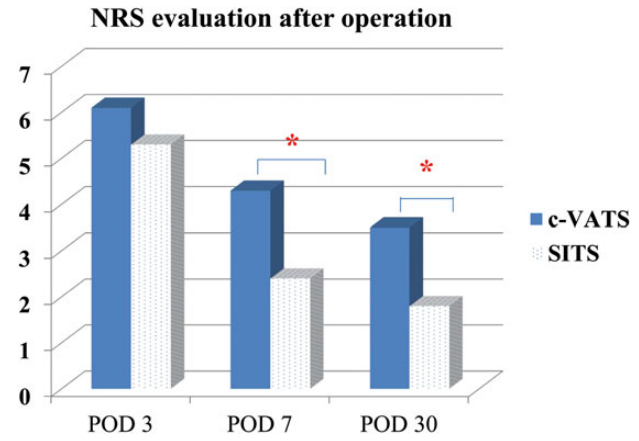


**Figure 3:** NRS evaluation after operation. The NRS was significantly lower in the SITS group than in the c-VATS group at 7 and 30 days after operation. *$P < 0.05$. NRS: Numeric Rating scale; c-VATS: conventional video-assisted thoracoscopic surgery; SITS: single-incision thoracoscopic surgery; POD: postoperative day.

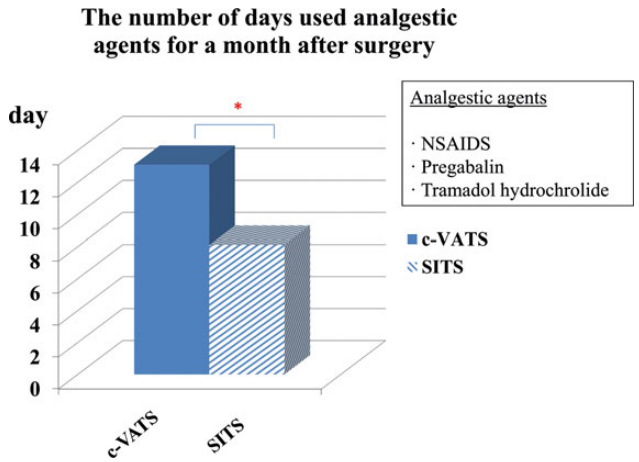


**Figure 4:** The number of days that were used with analgesic agents within a month after surgery. The number of days analgesic agents were used was significantly less in the SITS group than in the c-VATS group. NSAIDS, pregabalin and tramadol hydrochloride were administered as analgesic agents. *$P < 0.05$. NSAIDS: non-steroidal anti-inflammatory drugs; c-VATS: conventional video-assisted thoracoscopic surgery; SITS: single-incision thoracoscopic surgery.

placed site mainly used to operate a thoracoscope is likely to be protracted. SITS for lung cancer has been performed since 2011 [4], and its safety and efficacy have occasionally been reported. Rocco *et al.* have also reported the effectiveness of single-port VATS for diagnosis and surgical treatment [7, 8]. We investigated some surgery-related factors and the details of wound pain-reducing effects between SITS and c-VATS to evaluate low invasiveness.

No significant differences were noted in any of the various surgical factors examined including operative time, blood loss, postoperative creatine phosphokinase ($CPK_{max}$), creactive protein ($CRP_{max}$) or drainage duration, or the number of dissected lymph nodes between the two groups. The procedure was switched to thoracotomy due to haemorrhage in 1 patient treated with SITS; however, no severe complications were encountered in the postoperative course. The rate of conversion to thoracotomy in the SITS group (1.7%) would be within the permissible range. Although the evaluation of wound pain revealed no significant difference in the NRS between the two groups at 3 days after

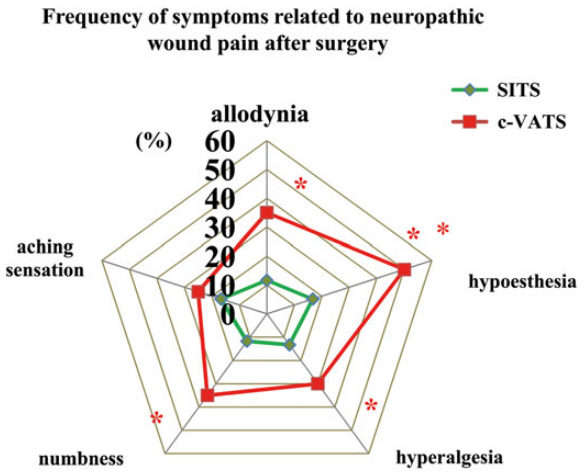


**Figure 5:** Frequency of symptoms related to neuropathic wound pain after surgery. Frequency of allodynia, hypaesthesia, hyperalgesia and numbness but not aching sensation was significantly lower in the SITS group than in the c-VATS group. *$P < 0.05$, **$P < 0.01$. c-VATS: conventional video-assisted thoracoscopic surgery; SITS: single-incision thoracoscopic surgery.

operation, the NRS was clearly decreased in the SITS group on postoperative days 7 and 30. In addition, except for aching sensation, the frequencies of allodynia, hypaesthesia, hyperalgesia and numbness around the wound showed lower in the SITS group throughout the postoperative course. The total number of days with analgesic treatment was also less in the SITS group, reflecting these findings. The outcome of postoperative wound pain was more favourable in the SITS than the c-VATS group, and the levels of satisfaction with wound pain and aesthetic outcomes were higher.

When postoperative wound pain was compared between thoracoscopic surgery through trocars alone and conventional thoracotomy, chest wall invasiveness was not consistent with the intensity and protraction of pain in some cases. Previous studies attributed this contradictory phenomenon to the involvement of anterior cingulate gyrus activity in the mechanism of transition from acute to chronic pain [9].

Moreover, Bachiocco *et al.* [10] have published that the frequency of post-thoracotomy pain syndrome (PTPS) depended on the patient's personality. Individual variations in changes in anterior cingulate gyrus activity following surgery may influence this phenomenon. As for the frequency of PTPS, there was no difference between VATS and thoracotomy [11, 12]. Since SITS only invades a single intercostal region loading almost no intercostal stress, unlike c-VATS, wound pain induced by SITS causes intercostal nerve disorder less, and pain is mainly nociceptive. Therefore, the postoperative wound may be less painful. All thoracic surgeons should be eager to master the operative technique that prevents neuropathic pain during surgery and such a technique would be strongly desirable for all patients [13–15].

Regarding the surgical procedure, we did not use a specific surgical device, which is similar to other institutions performing SITS. The total number of automatic suturing devices used in SITS was smaller than that in c-VATS. The use of automatic suturing devices to process blood vessels was basically refrained, and transfixing sutures were applied to thick blood vessels. Since SITS is applied through a fourth or fifth intercostal approach, SITS is more advantageous for interlobular vascular treatment than c-VATS. In addition, mediastinal lymph node dissection could be applied in SITS

without deteriorating treatment quality of lymph node dissection in c-VATS. In patients for whom sub-carinal lymph node dissection was considered important, the position of the small incision was usually moved more towards the posterior axillary line. The mean length of the small incision for SITS is currently from 5 to 4 cm in our institution. The incidence of neuropathic pain was low because the Wrap Protector mini was used to open the incision, and the procedure was atraumatically performed as much as possible in order to prevent contact of the thoracoscope and forceps with the intercostal nerve. In SITS, a thoracoscope and automatic suturing device are inserted nearly perpendicularly to the plane of the chest incision, and do not make contact with the intercostal nerve. In contrast, in surgery through trocars, the devices may be inserted at an angle of 45° or less to the chest wall depending on the patient's physique. Accordingly, the possibility of crushing the intercostal nerve is increased. Moreover, difficulties are associated with performing surgery by inserting trocars in patients with a barrel-shaped thorax, low height and severe obesity, and the intercostal nerve may be readily damaged. An assistant operating a thoracoscope through a port hole pays attention to the intercostal region since crushing of the intercostal nerve may lead to the postoperative development of intercostal nerve disorder.

Although lobectomy was performed in this study, SITS using an automatic suturing device is sufficiently applicable to lung biopsies of lesions before a definite diagnosis and partial lung resection for metastatic tumours, and resection margins can be secured at ease because tumours can be palpated. SITS is also more advantageous than c-VATS for intraoperative air leaks between the lobes because interlobular regions can be readily approached in SITS. Regarding the usefulness of SITS, there is no need for trocars, and a smaller amount of analgesics is used, suggesting its superiority for health economics. In surgery through three or four port holes, operators try to collect excised pulmonary lobe specimens through a small incision, which may damage the specimen and influence the pathological diagnosis. In contrast, specimens can be readily taken out of the body in SITS applied through an ∼5-cm small incision in the chest, suggesting that it is a reasonable surgical procedure. The frequency of pathological symptoms around the wound related to neuropathic pain following SITS was clearly low, which led to better postoperative ADLs in patients and decreased the frequency of taking oral analgesics compared with those after VATS, suggesting that SITS is a promising treatment option for Stage I lung cancer.

**Conflict of interest:** none declared.

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