Original Article

A novel approach for the complete extraction of large tumours in video-assisted thoracoscopic surgery

Masato Aragaki, Kichizo Kaga, Yasuhiro Hida, Tatsuya Kato, Yoshiro Matsui

Department of Cardiovascular and Thoracic Surgery, Hokkaido University Faculty of Medicine, Kita-ku, Sapporo, Hokkaido, 060-8638, Japan

Abstract

Background: Video-assisted thoracoscopic (VATS) lobectomy has recently become the standard for treating lung cancer. However, the complete removal of large tumours from the chest cavity is often difficult. Therefore, we developed a novel approach to extract large tumours from the wound without rib resection or fracture (the eXtraction of resected specimens through the Lower INterCostal route [XLINC] method).

Subjects and Methods: In XLINC, a skin incision is made on the tenth intercostal space, and the resected lung tissue is extracted. This retrospective study included patients who underwent VATS lobectomy using XLINC in our institution from 2016 to 2018. As a control group, six patients who had undergone thoracotomy during VATS surgery due to a large tumour diameter were included in the conversion group.

Results: Four men and six women (median age = 66 years, maximum median tumour diameter = 59 mm) were included in the study. The median length of the wound incision for XLINC was 4.5 (range: 4–8) cm. The median operative time was 183 min, and the estimated blood loss was 50 ml. Rib resection was not required, and no fractures were noted. The median length of hospital stay was 8 days. No patients developed major complications caused by XLINC. There were no significant differences, except in operation time and amount of blood loss, between the two groups. However, the XLINC group used fewer post-operative analgesics.

Conclusion: Our report suggests that XLINC might be a simpler, less invasive procedure that could be used in patients with large tumours.

Keywords: Extraction of resected specimens through the Lower INterCostal route method, lung cancer, reduced port surgery, video-assisted thoracoscopic surgery

Address for correspondence: Dr. Masato Aragaki, Department of Cardiovascular and Thoracic Surgery, Hokkaido University Faculty of Medicine, West-7, North-15, Kita-ku, Sapporo, Hokkaido, 060-8638, Japan.
E-mail: aramasa1022@hotmail.co.jp
Received: 25.10.2019, **Accepted:** 14.11.2019, **Published:** 28.01.2020

INTRODUCTION

Since its introduction in the early 90s, video-assisted thoracoscopic (VATS) lobectomy has been employed in many facilities and has become a frequently performed procedure in patients with primary lung cancer.[1-4] In general, in patients with a tumour of 3 cm or less, it is possible to extract the resected lung from a 3 to 4 cm surgical wound. However, for tumours >3 cm, even if an additional skin incision is made, it is often necessary to resect the rib, because the intercostal space does not expand. Although more patients can undergo pulmonary resection with thoracoscopic surgery because of improved surgical techniques, there are cases in which excised tissues cannot be extracted from a small wound because of the

Access this article online	
Quick Response Code:	Website: www.journalofmas.com
	DOI: 10.4103/jmas.JMAS_255_19

How to cite this article: Aragaki M, Kaga K, Hida Y, Kato T, Matsui Y. A novel approach for the complete extraction of large tumours in video-assisted thoracoscopic surgery. J Min Access Surg 0;0:0.

large size of the tumour. Therefore, we developed a new method to extract the resected lung with large tumours through the tenth intercostal space without cutting the ribs (the eXtraction of resected specimens through the Lower INterCostal route [XLINC]). This paper presents our initial experience with this technique.

SUBJECTS AND METHODS

Subjects

Between January 2017 and December 2018, 290 consecutive patients underwent lung resection for lung tumours in our institution. Of these, 156 patients (53.83%) underwent anatomical lung resection with a complete VATS procedure, and 10 patients (3.4%) had resected specimens removed using the XLINC technique (XLINC group). From 2011 to 2014, intrathoracic operation was possible with thoracoscopic surgery, but because of a large tumour diameter, there were six cases, in which the open thoracotomy was expanded to remove the resected tissue. These cases were used as a control group (conversion group). Patient information was retrieved retrospectively from our hospital database. All patients provided written informed consent for the operation and for inclusion of their personal data in a scientific database and appropriate permissions and releases were obtained. This study was registered with Researchregistry.com (Id no: researchregistry 5190).

Surgical procedure

The two-window or three-portal method for VATS lobectomy is a standard approach for lung tumours. The two-window method is one of the preferred approaches for complete VATS lobectomy, in which two 2–3 cm incisional wounds are made along a posterolateral incision line. After resecting the lobe of the lung, we add an incision at the tenth intercostal space to remove the resected lung tissue [Figure 1]. Before making an incision, the surgeon pushes the incision site of the tenth intercostal space with a finger from the body surface to confirm the correct position from the thoracic cavity using a thoracoscope [Figure 2]. This process is designed to prevent unexpected laparotomy or diaphragm injury. The length of the skin incision can be shorter than the maximum tumour diameter. Even with this length, the resected lung lobe can be removed from the incision because of the absence of costal cartilage [Figure 3]. After thoracotomy, a tissue collection bag is inserted into the thoracic cavity, and the bag is used to remove the specimen from the tenth intercostal space.

Statistical analysis

Descriptive statistics are reported as median (range). The Fisher's exact test was used to evaluate categorical

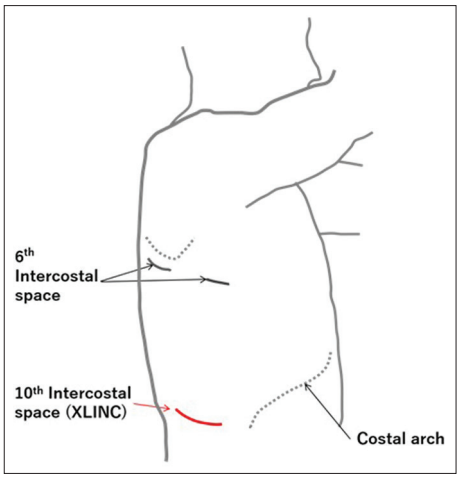

Figure 1: Skin incision of the XLINC procedure the two-window method was used in the sixth intercostal space as our standard approach for VATS lobectomy. The XLINC method was used in the tenth intercostal space. VATS: video-assisted thoracoscopic surgery; XLINC: eXtraction of resected specimens through the Lower INterCostal route method

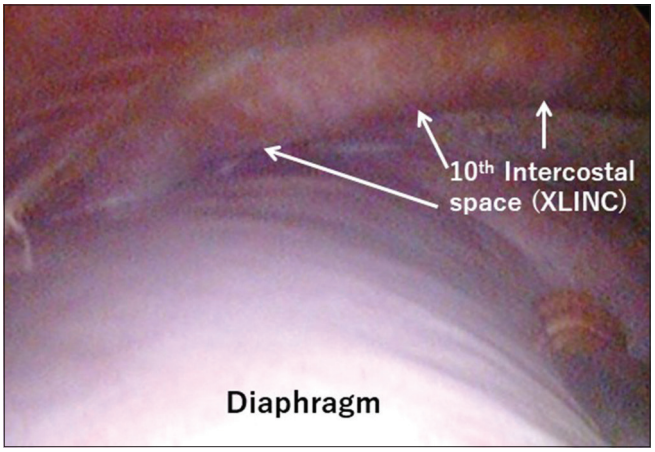

Figure 2: Intraoperative image field of thoracoscopic view from the thoracic cavity confirming the position of the diaphragm and tenth intercostal space XLINC: eXtraction of resected specimens through the Lower INterCostal route method

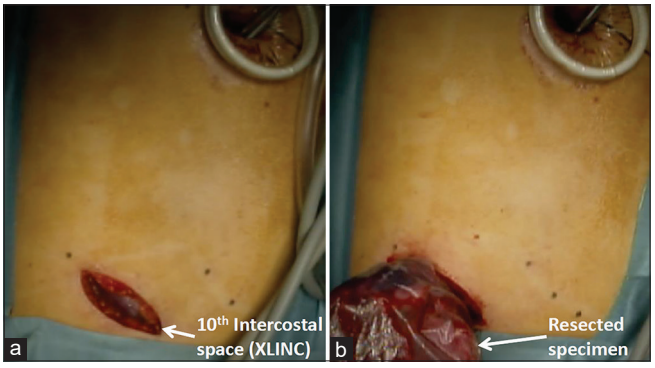

Figure 3: Surgical view of XLINC during complete VATS lobectomy (a) Before and (b) after lung extraction VATS: video-assisted thoracoscopic surgery; XLINC: eXtraction of resected specimens through the Lower INterCostal route method

variables, and the *t*-test was used to evaluate continuous variables. Statistical analyses were performed using JMP software (SAS Institute, Cary, North Carolina, USA).

RESULTS

The patients' characteristics and clinical findings of the XLINC group, as obtained from the hospital database and medical records, are summarised in Table 1. The study included 4 men and 6 women, with a median age of 66 (range: 45–81) years. The diagnoses were 9 primary lung cancers and 1 metastatic lung tumour. The histologic types of the primary lung cancers were as follows: adenocarcinoma ($n = 6$), squamous cell carcinoma ($n = 1$), pleomorphic carcinoma ($n = 1$) and large cell carcinoma ($n = 1$). Two cases of mucinous adenocarcinoma were included in the primary lung adenocarcinoma cases. The tumour size was evaluated three-dimensionally. In addition to the major and minor axes at the largest split face seen on a computed tomography (CT) image of a horizontal section, the tumour in the craniofacial direction was also measured. Among these three measurements, the maximum value was considered the maximum diameter of the tumour, and the minimum value was considered the minimum diameter. The median maximum diameter of the tumour according to CT was 59 (range: 44–125) mm, and the median minimum diameter was 45 (range: 32–85) mm [Table 1].

The operative procedures were right upper lobectomy ($n = 3$), right lower lobectomy ($n = 4$), left upper lobectomy ($n = 1$) and left lower lobectomy ($n = 2$). The median length of the incision wound via XLINC was 4.5 (range: 4–8) cm. The median maximum diameter of the tumour by pathological evaluation of the resection specimen was 63 (range: 38–185) mm and the median minimum diameter was 41.5 (range: 30–80) mm. The median operative time was 183 (range: 128–330) min and the estimated blood loss was 50 (range: 0–170) ml [Table 1]. No patients developed rib fractures or needed rib resection during lung extraction. In terms of pathological findings, there were no crushed lesions in the resected specimens as a result of the extraction.

Regarding the post-operative course, the median duration of drainage was 2 (range: 1–28) days, and the median length of hospital stay was 8 (range: 6–31) days. For post-operative pain control, epidural anaesthesia and oral post-operative non-steroidal anti-inflammatory drugs were administered to all patients. In addition, one patient took acetaminophen and two patients took both acetaminophen and tramadol. Post-operative pain was objectively measured using the

Table 1: Patient characteristics of eXtraction of resected specimens through the Lower INterCostal route method group

Case number	Sex	Age (years)	Disease	Pre-operative tumour size on CT scan	Operative procedure	Length of incision for the XLINC (cm)	Pathological tumour size (mm)	Operation time (min)	Bleeding (ml)	Drainage (days)	Hospital stay (days)	Post-operative complication	Analgesics
1	Male	65	Adenocarcinoma	44×36×35	LUL + ND2a-2	4	48×45×30	231	0	3	12	None	NSAIDs
2	Female	60	Metastatic lung tumour	50×49×33	RUL + ND2a-2	4	60×45×40	177	0	2	8	None	NSAIDs
3	Male	81	Adenocarcinoma	41×41×32	RUL + ND1	4	52×48×32	200	170	2	6	None	NSAIDs
4	Female	72	Adenocarcinoma	52×45×45	RLL + ND2a-2	4	55×45×43	152	50	1	7	None	NSAIDs, acetaminophen
5	Female	77	Adenocarcinoma	86×65×52	LLL + ND2a-2	8	67×63×40	256	50	2	8	None	NSAIDs, acetaminophen, tramadol
6	Male	45	Pleomorphic carcinoma	75×65×45	RLL + ND2a-2	6	80×65×45	330	75	28	31	Chylothorax	NSAIDs
7	Male	72	Mucinous adenocarcinoma	165×91×79	LLL + ND2a-2	8	185×85×60	153	125	13	16	Prolonged air leak	NSAIDs
8	Female	64	Squamous cell carcinoma	50×44×40	RLL + ND2a-2	5	38×34×31	128	50	2	6	None	NSAIDs
9	Female	48	Large cell carcinoma	66×63×60	RUL + ND2a-2	7	66×60×54	186	100	3	9	None	NSAIDs, acetaminophen, tramadol
10	Female	67	Mucinous adenocarcinoma	125×108×85	RLL + ND2a-2	8	150×150×80	180	0	2	6	None	NSAIDs

LUL: Left upper lobectomy, RUL: Right upper lobectomy, RLL: Right lower lobectomy, LLL: Left upper lobectomy, CT: Computed tomography, NSAIDs: Non-steroidal anti-inflammatory drugs, XLINC: Extraction of resected specimens through the Lower INterCostal route method

Visual Analogue Scale,[5] and we were able to achieve pain control in all patients post-operatively. Furthermore, no patients were taking analgesics 3 months after surgery; thus, there was no onset of chronic pain. Regarding post-operative complications, a chylothorax was observed in one patient and a prolonged pulmonary fistula was observed in another patient, but no complications or functional impairments associated with XLINC were observed [Table 1].

Patient characteristics in the conversion group are shown in Table 2. Comparing the XLINC and conversion groups, there were no significant differences in sex, age, tumour size, operative procedure, hospital stay or number of analgesics. However, there was a significant difference in the operation time and amount of bleeding between the two groups [Table 3].

DISCUSSION

We developed a novel technique, the XLINC procedure, to extract large tumours from wounds in patients with lung cancer. No complications were reported.

Recently, VATS has become a standard procedure for pulmonary lobectomy, and various new techniques have been developed to further improve minimally invasive surgery.[6-8] These surgical procedures can be summarised as reduced port surgeries. Due to the improvements in surgical procedures, there are fewer surgical wounds, and pulmonary lobectomy can be performed with a smaller surgical incision. However, techniques for treating large tumours are more complicated, as the removal of resected tissue through the surgical wound is related to both surgical wound length and to the amount the intercostal width that can be expanded.

The expansion of the intercostal space width not only depends on the length of the intercostal muscle incision but also on its location (anterior or posterior side). Typically, the intercostal space can be widened more easily on the anterior side of the chest wall. However, the ribs are fixed to the vertebra and sternum through the joint, and some ribs form a costal arch. For this reason, there is a limit to how much the intercostal space can be expanded even if the incision site is devised or the incision wound is expanded. Thus, to sufficiently expand the intercostal space, rib resection is occasionally required. Even if the surgical wound is sufficiently long, when trying to forcibly pass large tissue in situations where the width of the intercostal space is not sufficiently large, the extraction can place excessive stress on the ribs and nerves. This can cause

Table 2: Patient characteristics of conversion group

Case number	Sex	Age (years)	Disease	Pre-operative tumour size on CT scan	Operative procedure	Pathological tumour size (mm)	Operation time (min)	Bleeding (ml)	Hospital stay (days)	Post-operative complication	Analgesics
1	Male	73	Squamous cell carcinoma	71×65×56	RLL + ND2a-2	50×50	280	380	8	None	NSAIDs
2	Male	81	Pleomorphic carcinoma	79×70×65	LLL + ND2a-2	67×59	303	980	9	pAf	NSAIDs
3	Male	71	Squamous cell carcinoma	56×55×48	LUL + ND2a-2	50×50	215	0	15	None	NSAIDs, acetaminophen, tramadol
4	Male	65	Squamous cell carcinoma	62×60×49	RLL + ND2a-2	58×46	455	820	12	None	NSAIDs, acetaminophen, tramadol
5	Female	32	Sclerosing hemangioma	55×50×45	LUL + ND2a-2	50×40	337	0	10	None	NSAIDs, acetaminophen, tramadol, pregabalin
6	Male	77	Squamous cell carcinoma	60×45×43	RUL + ND2a-2	60×45	911	1805	45	Acute exacerbation of interstitial lung disease	NSAIDs, acetaminophen, tramadol, opioid analgesic

LUL: Left upper lobectomy, RUL: Right upper lobectomy, RLL: Right lower lobectomy, LLL: Left lower lobectomy, CT: Computed tomography, NSAIDs: Non-steroidal anti-inflammatory drugs, pAf: Paroxysmal atrial fibrillation

Table 3: Comparison of eXtraction of resected specimens through the Lower INterCostal route method and conversion group

	XLINC group (*n*=10)	Conversion group (*n*=6)	*P*
Age (years)	66 (45-81)	72 (32-81)	0.8505
Gender			
Female	6	1	0.1451
Male	4	5	
Pre-operative tumour size			
Maximum diameter (mm)	59 (41-165)	61 (56-79)	0.5068
Minimum diameter (mm)	45 (32-85)	48.5 (43-65)	0.9616
Operative procedure			
RUL	3	1	0.8089
RLL	4	2	
LUL	1	2	
LLL	2	1	
Pathological tumour size			
Maximum diameter (mm)	63 (38-185)	54 (50-67)	0.2465
Minimum diameter (mm)	41.5 (30-80)	48 (40-59)	0.6801
Operation time (min)	183 (128-330)	320 (215-911)	0.0194
Blood loss (ml)			0.0140
Hospital stay (days)	8 (6-31)	11 (8-45)	0.3193
Number of Analgesics	1 (1-3)	3 (1-4)	0.0519

LUL: Left upper lobectomy, RUL: Right upper lobectomy, RLL: Right lower lobectomy, LLL: Left lower lobectomy, XLINC: Extraction of resected specimens through the Lower INterCostal route method

unexpected rib fractures and prolonged post-operative pain. Post-thoracotomy syndromes are representative of post-operative pain. Therefore, we believe that a thoracotomy should not be performed unnecessarily.[9-12] However, standard thoracotomy is often chosen as an operative approach when tumours are large.

Several methods for removing excised lung tissue from the surgical wound in VATS lung resection have been reported. Among these, methods of extracting excised tissue through a subxiphoid or subcostal wound have been reported.[13-15] However, there are some concerns when using these methods, which have limited their widespread use. These include: (1) the possibility that laparotomy will be required, (2) the need to repair the diaphragm and diaphragm-adhering section because of the approach to the thoracic cavity via the transdiaphragmatic route, (3) anatomical hindrance of the heart with regard to the surgical approach to the left thoracic cavity and a left/right difference regarding the ease of approach and (4) the need to place only the lower half of the body in the half-lateral decubitus position or to secure the abdomen to the surgical field because of the approach from the abdomen. Due to these concerns, we developed the XLINC, which is a method of removing excised organs from the lower intercostal space.

The eleventh rib, which forms the lower border of the tenth intercostal space, is a floating rib as it does not form part of the costal arch. Therefore, using our technique, it is easy to widen the space in the head–tail direction to remove the tissue. In addition, the diaphragm adheres to the ventral side of the tenth intercostal space. However, by confirming that the tenth intercostal space is in place using a finger from the body's surface, it is possible to confirm the placement of the diaphragm-adhering portion. Approaching the dorsal side of the diaphragm-adhering part allows for direct access to the thoracic cavity without dissection of the diaphragm-adhered part or laparotomy, which precludes chest closure and reduces the risk of complications. Although the operation time and amount of blood loss were significantly lower than those in the conversion group, it is unlikely that the addition of XLINC would increase the operation time and/or the amount of blood loss.

The other strengths of this method are: (1) that it is not affected by the surgical side or heart compression, (2) it can be used in the normal lateral decubitus position and (3) in theory, it has fewer associated complications. However, the most notable merit of this technique is that it precludes the need for a standard thoracotomy. Regarding post-operative pain using XLINC, patients do not need to undergo standard thoracotomy surgery. Therefore, post-operative pain after XLINC should be compared to that after standard thoracotomy. In the present study, the conversion group consisted of cases in which the surgical wound was expanded for the purpose of extracting the tumour because the tumour diameter was large. Although there was no significant difference, the XLINC group used fewer post-operative analgesics than the conversion group and tended to have fewer days of hospitalisation, suggesting that it may be less invasive [Table 3].

Nevertheless, one of the disadvantages of XLINC is that the maximum wound length is limited by the location of the diaphragm-adhering portion. Thus, the wound length may be limited to approximately 8–10 cm. However, if there is an 8-cm incision at the tenth intercostal space, the surgical wound would be large enough to insert one surgeon's hand into the thoracic cavity. The minimum length of skin incision required to extract a tumour is difficult to determine. In our experience, a tumour with a maximum diameter of 5 cm could be removed through a 4 cm incision. Thus, we believe that a tumour could be extracted without much difficulty, even if it is the size of a fist.

In the future, we aim to examine the possibility of a VATS lobectomy using only an XLINC wound and to compare the extent of post-operative pain in the acute and chronic periods in patients who undergo open chest surgery or VATS lobectomy using XLINC.

CONCLUSION

XLINC was introduced as a novel method for removing excised lung tissue during VATS lobectomy. There were no complications associated with this procedure, and it did not affect the operation time, blood loss, drainage period or period of hospital stay. Our results suggest that this method could lead to an increase in the number of patients who are eligible for VATS lobectomy, as well as improve the post-operative pain of patients with large lung tumours due to the avoidance of standard thoracotomy with rib osteotomy.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Roviaro G, Rebuffat C, Varoli F, Vergani C, Mariani C, Maciocco M. Videoendoscopic pulmonary lobectomy for cancer. Surg Laparosc Endosc 1992;2:244-7.
2. Kirby TJ, Mack MJ, Landreneau RJ, Rice TW. Initial experience with video-assisted thoracoscopic lobectomy. Ann Thorac Surg 1993;56:1248-52.
3. Walker WS, Carnochan FM, Pugh GC. Thoracoscopic pulmonary lobectomy. Early operative experience and preliminary clinical results. J Thorac Cardiovasc Surg 1993;106:1111-7.
4. Whitson BA, Groth SS, Duval SJ, Swanson SJ, Maddaus MA. Surgery for early-stage non-small cell lung cancer: A systematic review of the video-assisted thoracoscopic surgery versus thoracotomy approaches to lobectomy. Ann Thorac Surg 2008;86:2008-16.
5. Chapman CR, Casey KL, Dubner R, Foley KM, Gracely RH, Reading AE. Pain measurement: An overview. Pain 1985;22:1-31.
6. Rocco G. One-port (uniportal) video-assisted thoracic surgical resections – A clear advance. J Thorac Cardiovasc Surg 2012;144:S27-31.
7. Gonzalez-Rivas D, Paradela M, Fieira E, Velasco C. Single-incision video-assisted thoracoscopic lobectomy: Initial results. J Thorac Cardiovasc Surg 2012;143:745-7.
8. Iwasaki M, Nishiumi N, Maitani F, Kaga K, Ogawa J, Inoue H. Thoracoscopic surgery for lung cancer using the two small skin incisional method. Two windows method. J Cardiovasc Surg (Torino) 1996;37:79-81.
9. Katz J, Jackson M, Kavanagh BP, Sandler AN. Acute pain after thoracic surgery predicts long-term post-thoracotomy pain. Clin J Pain 1996;12:50-5.
10. Classification of chronic pain. Descriptions of chronic pain syndromes and definitions of pain terms. Prepared by the international association for the study of pain, subcommittee on taxonomy. Pain Suppl 1986;3:S1-226.
11. Perttunen K, Tasmuth T, Kalso E. Chronic pain after thoracic surgery: A follow-up study. Acta Anaesthesiol Scand 1999;43:563-7.
12. Song JG, Shin JW, Lee EH, Choi DK, Bang JY, Chin JH, *et al*. Incidence of post-thoracotomy pain: A comparison between total intravenous anaesthesia and inhalation anaesthesia. Eur J Cardiothorac Surg 2012;41:1078-82.
13. Kato M, Onishi H, Furugaki K, Yunotani S, Matsumoto K, Tsuruta N, *et al*. New approach to complete video-assisted thoracoscopic lobectomy in T2 and T3 non-small cell lung cancer. Anticancer Res 2015;35:3585-9.
14. Gonzalez-Rivas D, Lirio F, Sesma J, Abu Akar F. Subxiphoid complex uniportal video-assisted major pulmonary resections. J Vis Surg 2017;3:93.
15. Oda M, Matsumoto I, Waseda R, Watanabe G. Total port-access lobectomy via a subcostal trans-diaphragmatic approach for lung cancer. Interact Cardiovasc Thorac Surg 2013;16:211-3.