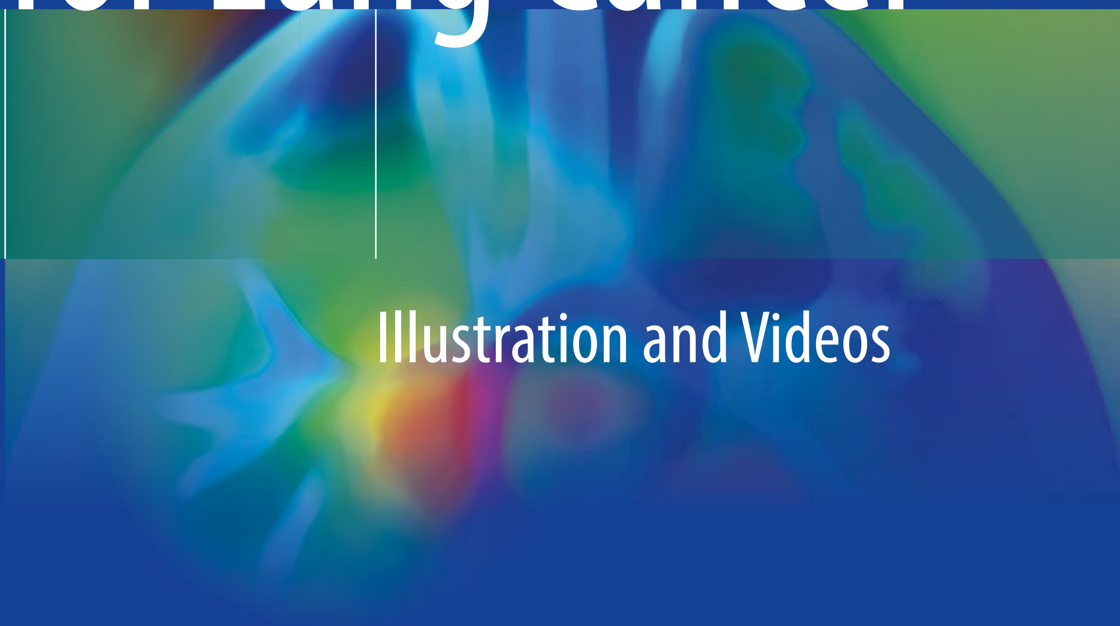
Hiroaki Nomori

Anatomical Segmentectomy for Lung Cancer



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Preface

In 2012, Professor Okada and I jointly published "Illustrated Anatomical Segmentectomy for Lung Cancer" from Springer. However, because it was illustrated, several surgeons have asked me to show the detailed procedures by video. That is the reason why I published this textbook, "Anatomical Segmentectomy for Lung Cancer. Illustration and Videos."

My continued journey as a thoracic surgeon started in the early 1980s at the National Cancer Center Tokyo. My mentors, Drs. Shichiro Ishikawa and Tsuguo Naruke at the institute, always told me, "Be aware that surgeons sometimes fall into the go-it-alone mind." I have intended to keep the teaching until now. I started to perform pulmonary segmentectomy since the early 2000s, when small-sized peripheral lung cancers increased in number because of spread of CT screening in Japan. Despite my knowledge of roentgenologic anatomy of pulmonary segments learned from Dr. Shigeto Ikeda, who was also my mentor at the National Cancer Center Tokyo, it was not easy to correctly identify the segmental anatomy at the time of operation. In the early stage of acquiring the surgical techniques, I even spent more than 5 h (!) to complete an anatomical segmentectomy. Since then, I have conducted segmentectomy for over 750 patients with lung cancer up to 2023. Now, I think I can show my technique of anatomical segmentectomy with video.

This textbook contains over 60 procedures of segmentectomy. Since the procedures span nearly 20 years, I ask for your understanding that the techniques are a little different depending on periods. But the anatomy is clearly shown in all procedures in both the textbook and video. While video-assisted thoracoscopic surgery (VATS) or robot-assisted thoracoscopic surgery (RATS) is becoming popular even for segmentectomy these days, all procedures in the text are under open thoracotomy. Of course, I expect VATS/RATS to become a standard approach for segmentectomy in future, but at the moment, I cannot show accurate anatomy for segmentectomy under VATS/RATS. Important points for segmentectomy are to perform local curability and preserve function of target lobes. To do it, anatomical dissection is important, which requires open thoracotomy for me. As surgical techniques evolve, the techniques described in this book will be modified and improved in the future. However, I am hoping that the textbook will remain to be of help in understanding detailed segmental anatomy that will not change forever.

Kashiwa, Japan　　Hiroaki Nomori

Contents

Part I

General Statement

1 History of Segmentectomy for Lung Tuberculosis

Before writing this chapter, I have to say that I referred to the textbook for segmentectomy written by Dr. Masatoshi Shiozawa from Japan in 1955.

Segmentectomy was developed for surgical treatment for tuberculosis. In 1930s, the surgical treatment for tuberculosis had two ways, i.e., surgical dissection and collapse therapy, of which latter included thoracoplasty, artificial pneumothorax, and extrapleural plombage. A group which promoted the collapse was that lung tuberculosis was not local disease, which could not be cured by surgical dissection. A group which promoted surgical dissection was that the complete dissection would be a radical cure for tuberculosis. However, the surgical treatment had not been applied for tuberculosis until 1930s, due to lack of procedure for dissecting pulmonary vessels and bronchus. While Lilienthal [1], Freedlander [2], Rienhoff [3], and Graham [4] had improved the procedures from 1933, which increased cases of success, the summary math reported that surgical death was 34% in 212 cases, mostly of which was due to postoperative bronchial stump fistula [4].

From 1947, a planned administration of streptomycin, general anesthesia with tracheal intubation, blood transfusion, and the improvement of surgical techniques had decreased surgical death to 5%, by Thornton, Jones, Clagett, and Overholt [5–8]. However, at that time, lobectomy was representative for surgical procedures, while segmentectomy was almost not conducted.

Lung segmentectomy was first conducted for a patient with bronchial ectasis by Churchill in 1939 [9], followed by a report for a few cases by Blades [10]. However, there were several problems because of lack of segmental anatomy at that time. In mid-1940s, Appleton [11] and Boyden [12], who were anatomists, demonstrated the anatomy of lung segments, that was followed by anatomical segmentectomy by Clagett [13]. In 1948, Overholt [14] devised a technique for cutting segmental margin as the following: (1) after cutting segmental artery and bronchus, lung was inflated to make inflation-deflation line at the segmental margin; (2) lung tissue was cut along the inflation-deflation line and also along with segmental vein; and (3) the lung cut line was opened. He described that the reason to open the cut plane was to prevent deformation of the preserved lobe, which would cause pulmonary dysfunction. By his technique, the postoperative complications such as bronchial fistula and empyema was reportedly decreased from 20–30% to almost nothing. The technique for cutting lung tissue in this textbook is partially based on the Overholt's procedure.

In 1949, Ramsay [15] and Kent [16], who were anatomists, reported the importance of segmental vein for segmental dissection, followed by adding surgical refinements by Rubenstein [17], resulting in increasing safety of the segmentectomy.

One of causes for promoting segmentectomy for tuberculosis was a development of chest X-ray tomography in 1949 by Temple [18], Felson [19], Kane [20], Hornykiewytsch [21–26], and Adler [27]. Today, we usually use computed tomography in lung segmentectomy, of which method is essentially the same as the one 70 years ago.

The change of surgical procedures for lung tuberculosis 70 years ago is interested for the moment in our own day for treating lung cancer. From 1947 to 1953, in only 6 years, Overholt [28], Mathey [29], and Eerland [30] had changed the surgical procedures for lung tuberculosis, i.e., starting with pneumonectomy, followed by lobectomy, and finally to segmentectomy (Table 1.1). It can be seen how thoracic surgeons at that time were eager to learn the segmental dissection. At the present time even with information age, we have not been able to go along with their pace 70 years ago.

Afterwards, the treatment for tuberculosis was changed to antituberculosis drugs, which reduced surgical treatments for tuberculosis, becoming the segmentectomy to be unfamiliar procedure. However, nowadays, with increasing small lung cancers due to popularization of CT, segmentectomy comes with the spotlight for surgical treatment.

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Table 1.1 Annual changes of surgical procedures for lung tuberculosis between 1947 and 1953

Year	Overholt			Mathey			Eerland		
	Pneumonectomy	Lobectomy	Segmentectomy	Pneumonectomy	Lobectomy	Segmentectomy	Pneumonectomy	Lobectomy	Segmentectomy
1947	81%	15%	4%	75%	25%	0%	5 cases	2 cases	0 case
1949	62	23	15	30	40	30	44	32	2
1951	33	31	33	14	55	31	38	66	108
1952				10	10	80	26	39	133
1953							11	19	56

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2 History of Segmentectomy for Lung Cancer

While until 1940s, pneumonectomy had been only one surgical method to treat lung cancer, it had surgical death frequently up to 40%. In 1950, Churchill made lobectomy succeeded for lung cancer [1]. In 1960, Cahan reported radical lobectomy for lung cancer with dissection of hilar and mediastinal lymph nodes [2]. Since then, lobectomy has been a standard surgical procedure for lung cancer until now for over 60 years.

In the late 1980s, several authors in north America reported that segmentectomy had similar prognosis and lower complication rate compared to lobectomy for small lung cancers [3–5]. In particular, Jensik with St. Lukes Medical Center was vigorous promoters for the segmentectomy.

In 1990s, a detection of small-sized lung cancer was increased due to popularization of CT, which was of particular note in Japan. In 1992, Tsubota and their colleagues started a prospective and multicentric study of segmentectomy for lung cancers smaller than 2 cm in size [6]. On the other hand, during the Tsubota's study, Ginsberg and Rubenstein reported the shocking results of Phase III study between lobectomy versus limited dissection by North American Lung Cancer Study, i.e., a limited dissection by wedge dissection or segmentectomy had three times of local recurrence as many as lobectomy ($p = 0.008$) and lacked advantage for postoperative pulmonary function [7]. However, their study had the following problems: (1) one third of limited dissection was wedge dissection; (2) in a total 771 cases of the study, only 276 cases (36%) were randomized; (3) the study included lung cancer over 2 cm in size; and (4) postoperative pulmonary function was not conducted in over one third of the patients. Despite of strong criticism of the two invited commentators [8, 9], this result had continued to affect negatively for the development of segmentectomy thereafter, because of only one Phase III study.

Despite the great difficulties due to the result from LCSG, Tsubota and their colleagues had continued the prospective and multicentric study for lung cancer smaller than 2 cm, which resulted in 92% of 5-year survival and 11% of pulmonary function loss [10]. Several authors from Japan reported with a single-center study that there was no significant difference of prognosis between lobectomy and segmentectomy (Table 2.1). In 1997, Kodama et al., in 46 patients with T1N0M0 peripheral type non-small cell lung cancer (NSCLC), reported a 5-year survival to be 93% and local recurrence to be 8%, which were similar to those by lobectomy [11]. In 2001, Okada et al., for 90 patients with T1N0M0 NSCLC smaller than 2 cm, reported a 5-year survival to be 87% and local recurrence to be 0% [12]. In 2003, Koike et al. compared 74 patients treated by limited dissec-

Table 2.1 Recurrence and survival between lobectomy and limited resection

			Lobectomy			Limited resection		
Author	Year	Tumor stage	Number of cases	Local recurrence (%)	5-year survival (%)	Number of cases	Local recurrence (%)	5-year survival (%)
LCSG	1995	T1N0	122	2.1	89.1	125	6.3	83.1
Kodama	1997	T1N0*	46	N/A	93	77	N/A	88
Okada	2001	T1N0*	139	N/A	87.7	70	N/A	87.1
Koike	2003	T1N0*	159	1.3	90.1	74	2.7	89.1
Keenan	2004	T1+2N0	147	7.5	67 (4-year)	54	11.1	62 (4-year)
Okada	2006	T1N0*	262	6.9	89.1	305	4.9	89.6

LCSG Lung Cancer Study Group, *N/A* not available, *T1N0** smaller than 2 cm

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Table 2.2 Postoperative decrease of pulmonary function between lobectomy versus limited resection

Author	Year	Tumor stage	Lobectomy			Limited resection		
			Number of cases	FEV_1	VC	Number of cases	FEV_1	VC
LCSG	1995	T1N0	58	−11.1	−5.7	71	−5.2	0.52
Keenan	2004	T1+2N0	147	−9.2	−4.2	54	−3.2	−2.7
Harada	2005	T1N0[a]	45	−18	−17	38[b]	−3.2	−2.7
Okada	2006	T1N0[a]	168	−16.8	−16	168[b]	−9.1	−10.4

FEV_1 forced expiratory volume in 1 s, *VC* vital capacity
LCSG Lung Cancer Study Group
[a]T1N0: smaller than 2 cm
[b]Only segmentectomy

tion (segmentectomy in 60 and wedge resection in 14) and 159 patients treated by lobectomy and reported that local recurrence was seen in 5 and 9 patients, respectively, and 5-year survival was 89% and 90%, respectively, of which differences were not significant [13]. In 2006, a multicenter (3 institutes) study in Japan compared 305 patients treated by limited surgery and 262 patients treated by lobectomy for cT1N0M0 smaller than 2 cm, of which 5-year recurrence-free survivals was 85.9% and 83.4%, respectively, of which difference was not significant [14]. In the late-2000s, several authors from North America also endorsed the reports from Japan. In 2006, El-Sherif reported that the relapse-free survival showed no difference between limited resection (almost wedge resection) and lobectomy for stage IA NSCLC [15].

The biggest purpose of segmentectomy is to preserve pulmonary function. Table 2.2 shows the difference of postoperative pulmonary function between limited resection and lobectomy in studies until the mid-2000s. While the Lung Cancer Study Group in 1995 described that there was no significant difference of postoperative pulmonary function, their result actually showed the superiority of FEV_1 in limited resection [7]. In 2004, Keenan reported that a decrease of FEV1 after limited resection was 3.2%, which was lower than 9.2% after lobectomy [16]. Harada reported that a decrease of FEV_1 2 months after segmentectomy was 13%, which was significantly lower than 20% after lobectomy [17].

These studies established a bridgehead for a phase III trial in Japan, i.e., JCOG0802/WJOG4607L [18], which enrolled 1106 patients (intention-to-treat population) between 2009 and 2014; lobectomy in 554 patients and segmentectomy in 552. At a median follow-up of 7.3 years, the 5-year overall survival was 94.3% in segmentectomy and 91.1% in lobectomy; segmentectomy showed superiority and non-inferiority over lobectomy with stratified Cox regression model (HR, 0.663; 95% CI, 0.484–0.927; $p < 0.001$ for non-inferiority and $p = 0.0082$ for superiority). The 5-year relapse-free survival was 88% for segmentectomy and 87.9% for lobectomy, of which difference was not significant ($p = 0.9889$). Local relapse was seen in 10.5% in segmentectomy, which was significantly higher than 5.4% in lobectomy ($p = 0.0018$). With regard to pulmonary function 1 year after surgery, segmentectomy showed 3.5% higher than lobectomy ($p < 0.0001$). The study concluded that segmentectomy should be the standard surgical procedure for cT1N0M0 NSCLC smaller than 2 cm. This study would become a milestone for surgical treatment for cT1N0M0 NSCLC smaller than 2 cm.

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3 Nomenclature

3.1 Nomenclature of Segments and Sub-segments

See Fig. 3.1.

3.1.1 Right Upper Lobe

1. S^1 [Segmentum.apicalis]
   (a) S^1a [Subseg. dorsalis]
   (b) S^1b [Subseg. ventralis]
2. S^2 [S.dorsalis]
   (a) S^2a [Subseg.dorsalis]
   (b) S^2b [Subseg.horizontalis]
3. S^3 [S.ventralis]
   (a) S^3a [Subseg.lateralis]
   (b) S^3b [Subseg.medialis]

3.1.2 Right Middle Lobe

1. S^4 [S.medium lateralis]
   (a) S^4a [Subseg. lateralis]
   (b) S^4b [Subseg.medialis]
2. S^5 [S.medium medialis]
   (a) S^5a [Subseg.lateralis]
   (b) S^5b [Subseg.medialis]

3.1.3 Left Upper Lobe

3.1.3.1 Upper Division (S^{1+2}+S^3)

1. S^{1+2} [S.apicodorsalis]
   (a) S^{1+2}a [Subseg. apicalis]
   (b) S^{1+2}b [Subseg.dorsalis]
   (c) S^{1+2}c [Subseg.horizontalis]

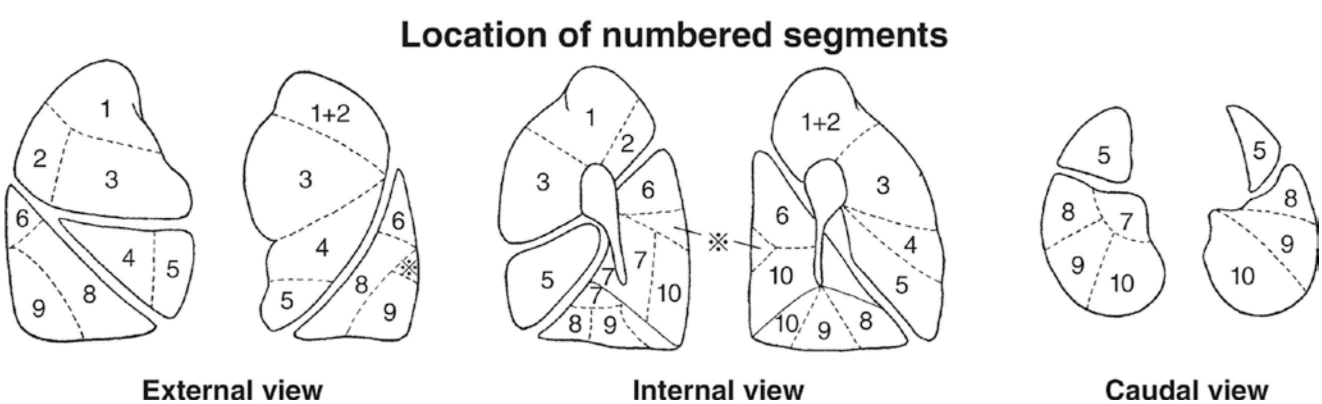

Fig. 3.1 Location of segments. (Reprinted from Nomori H, Okada M. Illustrated Anatomical Segmentectomy for Lung Cancer. Springer Japan, 2012 with permission)

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2. S^3 [S.ventralis]
   (a) S^3a [Subseg.lateralis]
   (b) S^3b [Subseg.medialis]
   (c) S^3c [Subseg.superius]

3.1.3.2 Lingular Division (S^4+S^5)

1. S^4 [S.lingulare superius]
   (a) S^4a [Subseg.lateralis]
   (b) S^4b [Subseg.medialis]
2. S^5 [S.lingulare inferius]
   (a) S^5a [Subseg.superius]
   (b) S^5b [Subseg.inferius]

3.1.4 Lower lobe (Bilateral)

1. S^6 [S.superius]
   (a) S^6a [Subseg.superius]
   (b) S^6b [Subseg.lateralis]
   (c) S^6c [Subseg.medialis]
2. S*[S.subsuperius]
3. S^7 [S.mediobasalis] (Only right side)
   (a) S^7a [Subseg.dorsalis]
   (b) S^7b [Subseg.ventralis]
4. S^8 [S.ventrobasale]
   (a) S^8a [Subseg.lateralis]
   (b) S^8b [Subseg.basalis]
5. S^9 [S.laterobasalis]
   (a) S^9a [Subseg.lateralis]
   (b) S^9b [Subseg.basalis]
6. S^{10} [S.dorsobasalis]
   (a) $S^{10}a$ [Subseg.dorsalis]
   (b) $S^{10}b$ [Subseg.lateralis]
   (c) $S^{10}c$ [Subseg.medialis]

3.2 Nomenclature of Segmental and Sub-segmental Bronchus

See Fig. 3.2.

3.2.1 Right Upper Lobe

1. B^1 [R.apicalis]
   (a) B^1a [Rm.dorsalis]
   (b) B^1b [Rm.ventralis]
2. B^2 [R.dorsalis]
   (a) B^2a [Rm.dorsalis]
   (b) B^2b [Rm.horizontalis]
3. B^3 [R.ventralis]
   (a) B^3a [Rm.latelasis]
   (b) B^3b [Rm.medialis]

3.2.2 Right Middle Lobe

1. B^4 [R.medius lateralis]
   (a) B^4a [Rm.lateralis]
   (b) B^4b [Rm.medialis]
2. B^5 [R.medius medialis]
   (a) B^5a [Rm.lateralis]
   (b) B^5b [Rm.medialis]

3.2.3 Left Upper Lobe

3.2.3.1 Upper Division Bronchus

1. B^{1+2} [R.apicodorsalis]
   (a) $B^{1+2}a$ [Rm.apicalis]
   (b) $B^{1+2}b$ [Rm.dorsalis]
   (c) $B^{1+2}c$ [Rm.horizontalis]
2. B^3 [R.ventralis]
   (a) B^3a [Rm.lateralis]
   (b) B^3b [Rm.medialis]
   (c) B^3c [Rm.superior]

3.2.3.2 Lingular Division Bronchus

1. B^4 [R.lingualis superior]
   (a) B^4a [Rm.lateralis]
   (b) B^4b [Rm.medialis]
2. B^5 [R.lingualis inferior]
   (a) B^5a [Rm.superior]
   (b) B^5b [Rm.inferior]

3.2.4 Lower Lobe (Bilateral)

1. B^6 [R.superior]
   (a) B^6a [Rm.superior]
   (b) B^6b [Rm.lateralis]
   (c) B^6c [Rm.medialis]
2. B* [R.subsuperior]
3. B^7 [R.mediobasalis] (Only right side)
   (a) B^7a [Rm.ventralis]
   (b) B^7b [Rm.dorsalis]
4. B^8 [R.ventrobasalis]
   (a) B^8a [Rm.lateralis]
   (b) B^8b [Rm.basalis]
5. B^9 [R.laterobasalis]
   (a) B^9a [Rm.lateralis]
   (b) B^9b [Rm.basalis]
6. B^{10} [R.dorsobasalis]
   (a) $B^{10}a$ [Rm.dorsalis]
   (b) $B^{10}b$ [Rm.lateralis]
   (c) $B^{10}c$ [Rm.medialis]

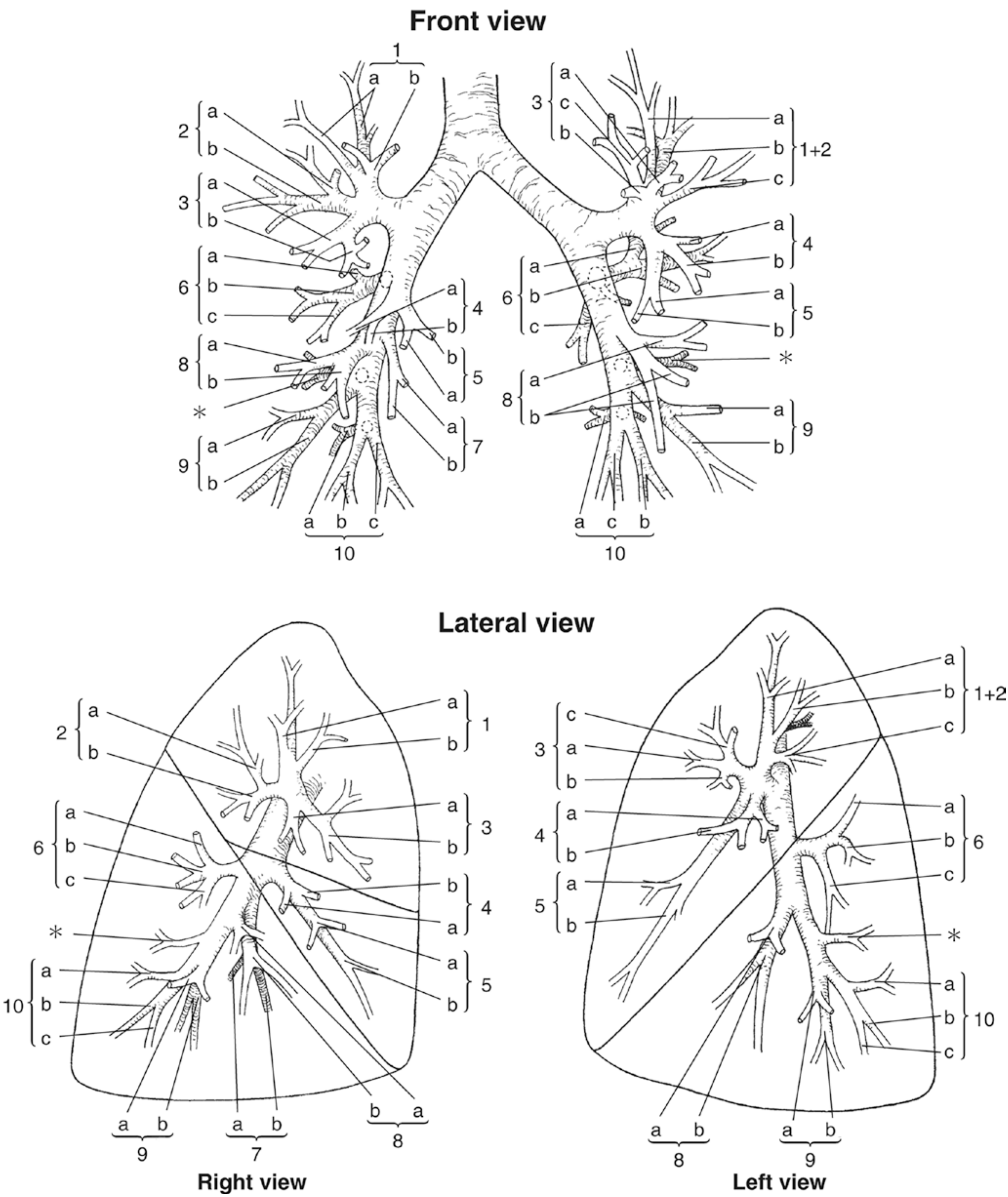


Fig. 3.2 Front and lateral views of segmental and sub-segmental bronchus. (Reprinted from Nomori H, Okada M. Illustrated Anatomical Segmentectomy for Lung Cancer. Springer Japan, 2012 with permission)

3.3 Nomenclature of Segmental and Sub-segmental Arteries

See Fig. 3.3.

3.3.1 Right Upper Lobe

1. A^{1} [R.apicalis]
   (a) A^{1}a [Rm.dorsalis]
   (b) A^{1}b [Rm.ventralis]
2. A^{2} [R.dorsalis]
   (a) A^{2}a [Rm.dorsalis]
   (b) A^{2}b [Rm.horizontalis]
3. A^{3} [R.ventralis]
   (a) A^{3}a [Rm.latelasis]
   (b) A^{3}b [Rm.medialis]

3.3.2 Right Middle Lobe

1. A^{4} [R.medius lateralis]
   (a) A^{4}a [Rm.lateralis]
   (b) A^{4}b [Rm.medialis]
2. A^{5} [R.medius medialis]
   (a) A^{5}a [Rm.lateralis]
   (b) A^{5}b [Rm.medialis]

3.3.3 Left Upper Lobe

3.3.3.1 Upper Division Bronchus

1. A^{1+2} [R.apicodorsalis]
   (a) A^{1+2}a [Rm.apicalis]
   (b) A^{1+2}b [Rm.dorsalis]
   (c) A^{1+2}c [Rm.horizontalis]
2. A^{3} [R.ventralis]
   (a) A^{3}a [Rm.lateralis]
   (b) A^{3}b [Rm.medialis]
   (c) A^{3}c [Rm.superior]

3.3.3.2 Lingular Division Bronchus

1. A^{4} [R.lingualis superior]
   (a) A^{4}a [Rm.lateralis]
   (b) A^{4}b [Rm.medialis]
2. A^{5} [R.lingualis inferior]
   (a) A^{5}a [Rm.superior]
   (b) A^{5}b [Rm. inferior]

3.3.4 Lower Lobes (Bilateral)

1. A^{6} [R.superior]
   (a) A^{6}a [Rm.superior]
   (b) A^{6}b [Rm.lateralis]
   (c) A^{6}c [Rm.medialis]

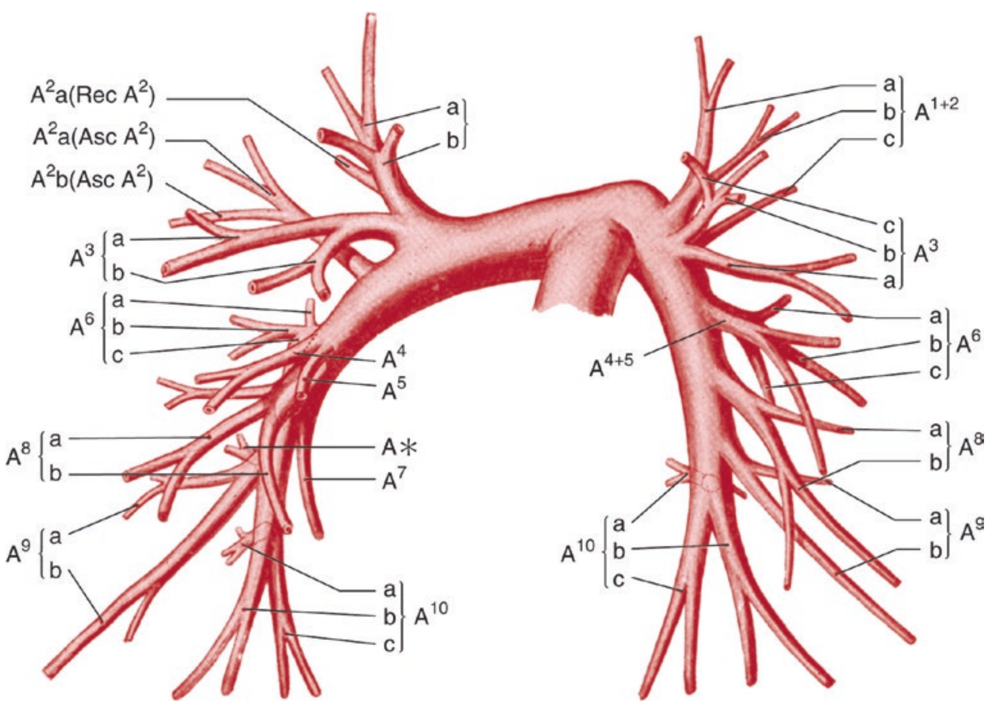


Fig. 3.3 Front view of segmental and sub-segmental arteries. (Reprinted from Nomori H, Okada M. Illustrated Anatomical Segmentectomy for Lung Cancer. Springer Japan, 2012 with permission)

2. A* [R.subsuperior]
3. A^7 [R.mediobasalis] (Only right side)
   (a) A^7a [Rm.ventralis]
   (b) A^7b [Rm.dorsalis]
4. A^8 [R.ventrobasalis]
   (a) A^8a [Rm.lateralis]
   (b) A^8b [Rm.basalis]
5. A^9 [R.laterobasalis]
   (a) A^9a [Rm.lateralis]
   (b) A^9b [Rm.basalis]
6. A^{10} [R.dorsobasalis]
   (a) A^{10}a [Rm.dorsalis]
   (b) A^{10}b [Rm.lateralis]
   (c) A^{10}c [Rm.medialis]

3.4 Nomenclature of Segmental and Sub-segmental Veins

See Fig. 3.4.

3.4.1 Right Upper Lobe

1. V^1 (Apical vein)
   (a) V^1a: between S^1a and S^1b
   (b) V^1b: between S^1b and S^3b
2. V^2 (Posterior vein)
   (a) V^2a: between S^1a and S^2a
   (b) V^2b: between S^2a and S^2b
   (c) V^2c: between S^2b and S^3a
   (d) V^2t: below S^2a
   (e) VX^1a: (between S^1a and S^1b)
3. V^3 (Anterior vein)
   (a) V^3a: between S^3a and S^3b
   (b) V^3b: below S^3b
   (c) V^3c: between S^3bi and S^3bii

3.4.2 Right Middle Lobe

1. V^4 (Lateral vein)

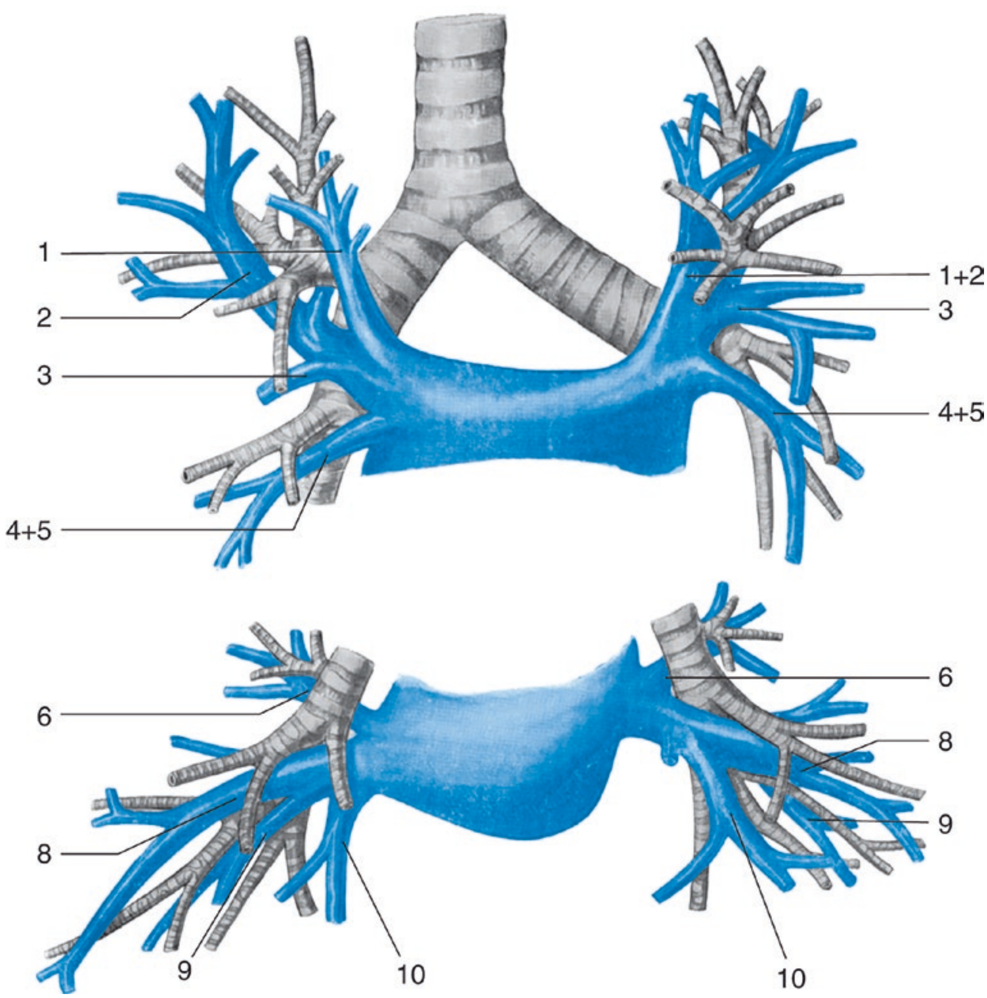


Fig. 3.4 Front and rear views of segmental veins. (Reprinted from Nomori H, Okada M. Illustrated Anatomical Segmentectomy for Lung Cancer. Springer Japan, 2012 with permission)

(a) V^4a: between S^4a and S^4b
(b) V^4b: between S^4b and S^5b
2. V^5 (Medial vein)
(a) V^5a: between S^5a and S^5b
(b) V^5b: below S^5b

3.4.3 Left Upper Lobe

1. V^{1+2} (Apico-posterior vein)
   (a) $V^{1+2}a$: between $S^{1+2}a$ and S^3c
   (b) $V^{1+2}b$: between $S^{1+2}a$ and $S^{1+2}b$
   (c) $V^{1+2}c$: between $S^{1+2}b$ and $S^{1+2}c$
   (d) $V^{1+2}d$: between $S^{1+2}c$ and S^3a
2. V^3 (Anterior vein)
   (a) V^3a: between S^3a and S^3b
   (b) V^3b: between S^3b and S^4b
   (c) V^3c: between S^3b and S^3c
3. V^4 (Lingular superior vein)
   (a) V^4a: between S^4a and S^4b
   (b) V^4b: between S^4b and S^5a
4. V^5 (Lingular inferior vein)
   (a) V^5a: between S^5a and S^5b
   (b) V^5b: below S^5b

3.4.4 Lower Lobes (Bilateral)

1. V^6 (Superior vein)
   (a) V^6a: between S^6a and S^6b+c
   (b) V^6b: between S^6b and S^{8-9}
   (c) V^6c: between S^6c and $S^{10}a$
2. V^7 (Medio-basal vein) (only right side)
   (a) V^7a: between S^8b and S^7a
   (b) V^7b: between S^7a and S^7b
3. V^8 (Antero-basal vein)
   (a) V^8a: between S^8a and S^8b
   (b) V^8b: between S^8b and S^9b
4. V^9 (Latero-basal vein)
   (a) V^9a: between S^9a and S^9b
   (b) V^9b: between S^9b and $S^{10}b$
5. V^{10} (Postero-basal vein)
   (a) $V^{10}a$: between $S^{10}a$ and $S^{10}c$
   (b) $V^{10}b$: between $S^{10}b$ and $S^{10}c$
   (c) $V^{10}c$: among $S^{10}c$

4 General Knack of Segmentectomy

4.1 Preoperative Pathological Diagnosis

For segmentectomy, preoperative pathologic diagnosis is necessary. If the tumor is pathologically diagnosed by wedge resection, a precise segmentectomy becomes hard due to staple line. Needle aspiration biopsy under CT is useful before segmentectomy, especially for a small tumor deeply located or ground-glass attenuation (GGA) tumor (Figs. 4.1 and 4.2) [1, 2]. Bronchoscopic biopsy frequently results in false negative for these tumors. When the tumor can be seen or palpated during surgery, intraoperative needle aspiration is also useful.

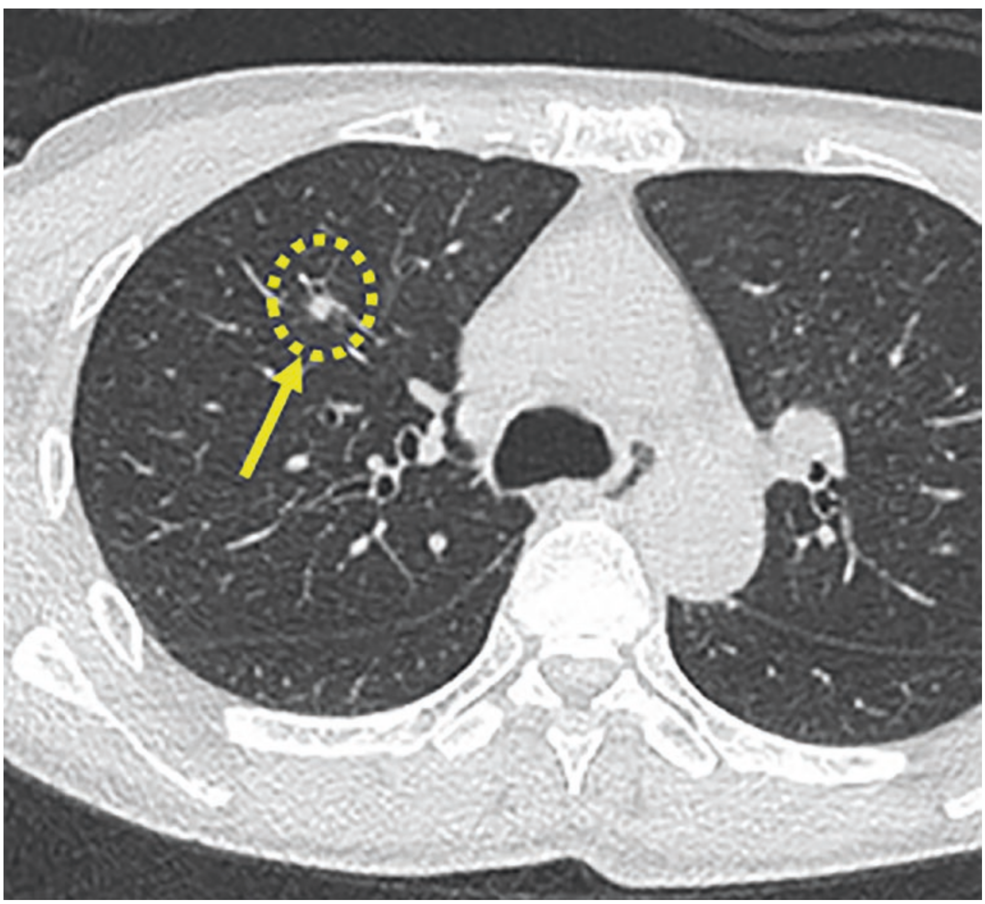


Fig. 4.1 [A nodule in the right upper lobe 0.5 cm in size, which exists adjacent to peripheral bronchus]

H. Nomori, *Anatomical Segmentectomy for Lung Cancer*, https://doi.org/10.1007/978-981-99-5857-3_4

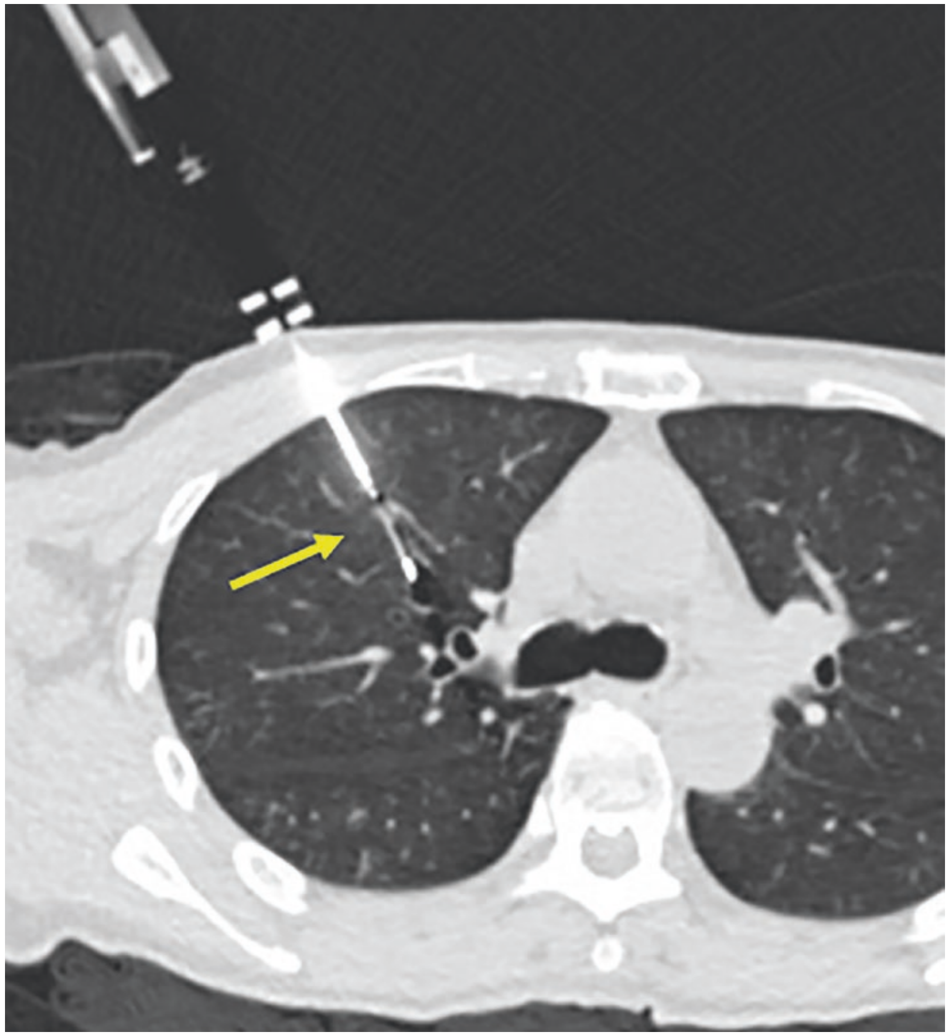


Fig. 4.2 [The needle hit the lesion under CT, which diagnosed it as adenocarcinoma]

4.2 Tumor localization by Multi-Director Computed Tomography (MDCT) and 3D Views

A thin contrast CT (1 mm in slice width) can show 3D views of pulmonary bronchus, artery, and pulmonary vein, which can show a rough anatomical position of tumor (Figs. 4.3, 4.4, and 4.5). On axial, coronal, and sagittal views of CT, branching patterns of artery, vein, and bronchus are checked, which are more accurate than the 3D views (Fig. 4.6). Of MDCT views, the sagittal view is most useful to predict the vessel and bronchial anatomy during surgery. In addition, after intubation of tracheal tube, the branching pattern of segmental bronchus is finally checked by bronchoscopy, which is more accurate than the 3D views. Intraoperative identification of segmental bronchus is important because the branching of segmental bronchus is simpler and less confusing than those of artery and vein. The bronchial identification during surgery can identify the artery and vein accurately. On MDCT, the slice width is better to be 1 mm; the 5 mm width cannot show accurate anatomy. Because the lung should be dissected at least 2 cm away from the tumor during segmentectomy, the vessels or bronchus within 2 cm from the tumor should be identified on MDCT. If the lung tissue 2 cm away from the tumor is not limited within one segment, a neighboring subsegment or segment is dissected.

Fig. 4.3 [3D view of bronchus]

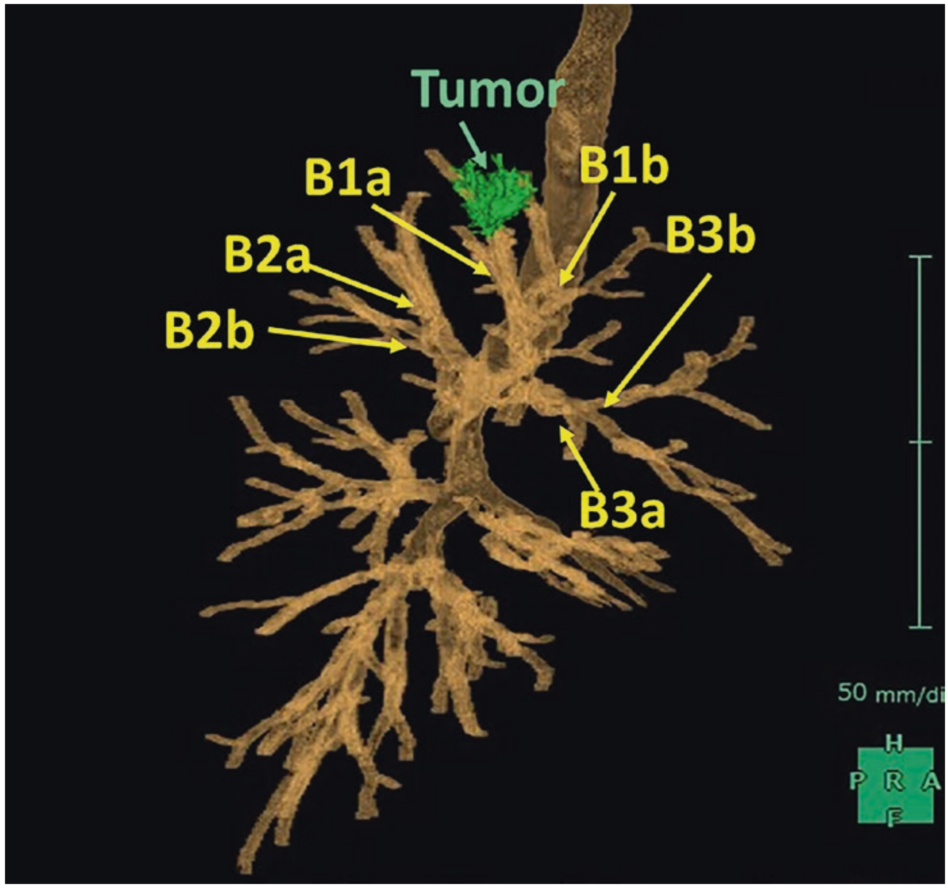


Fig. 4.4 [3D view of artery]

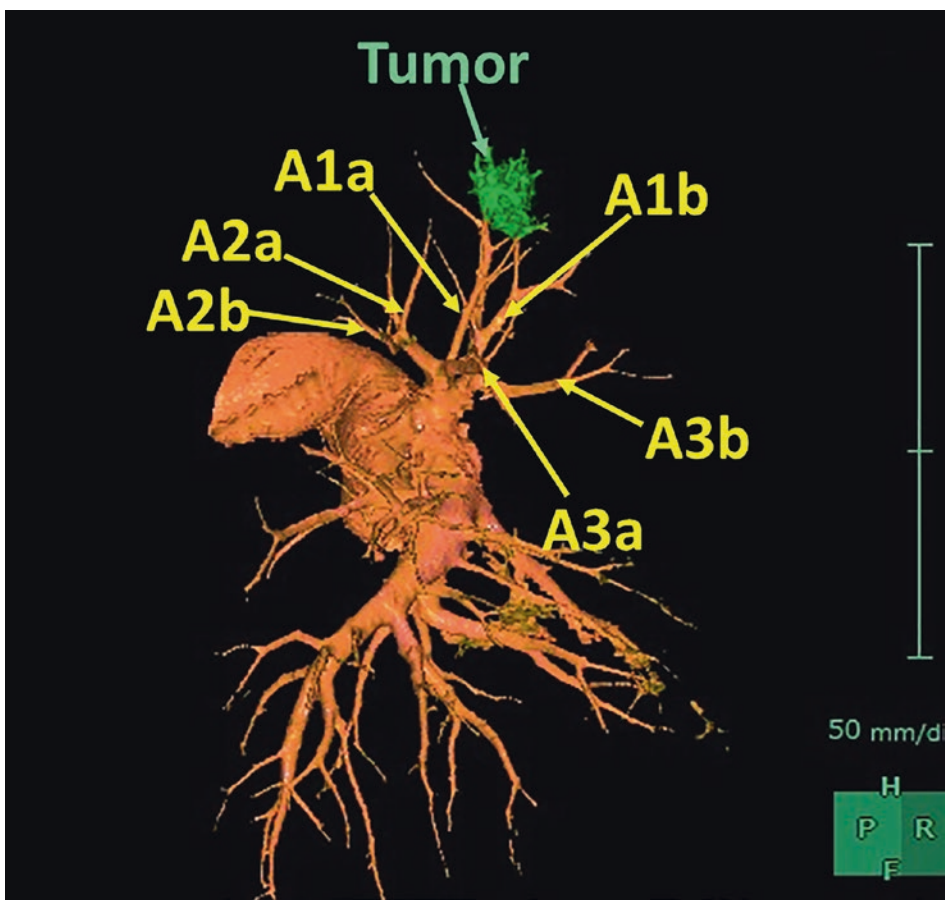


Fig. 4.5 [3D view of vein]

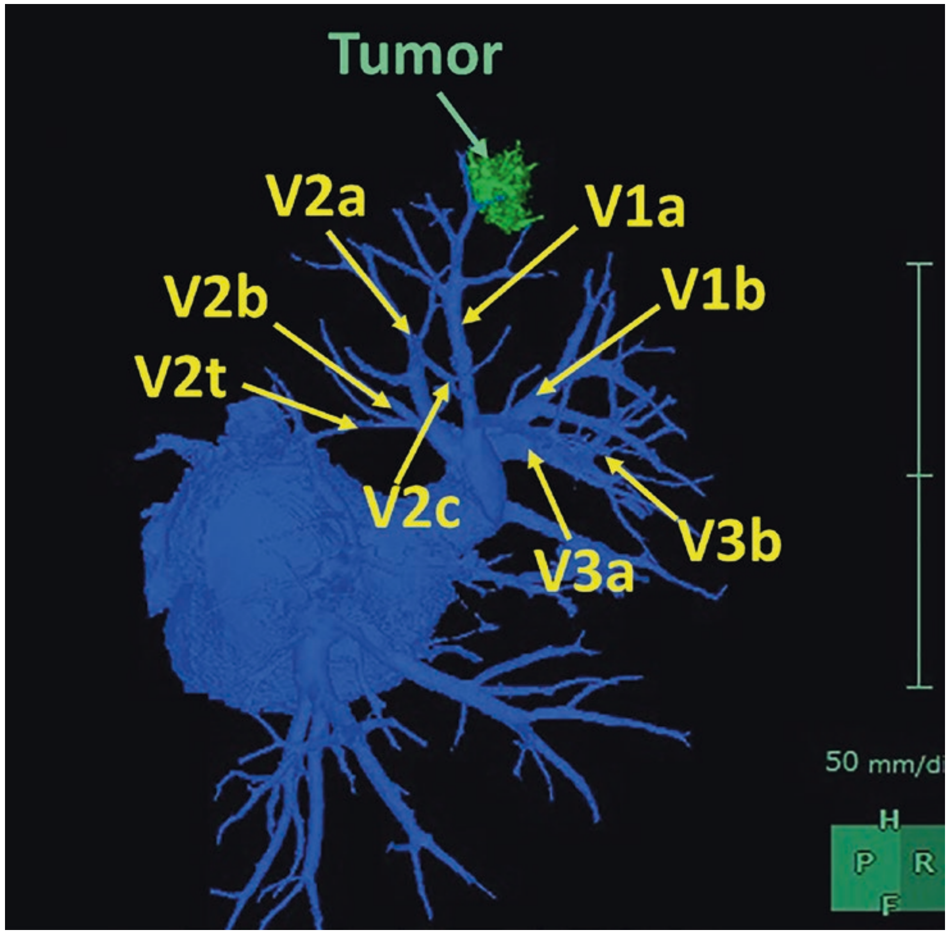
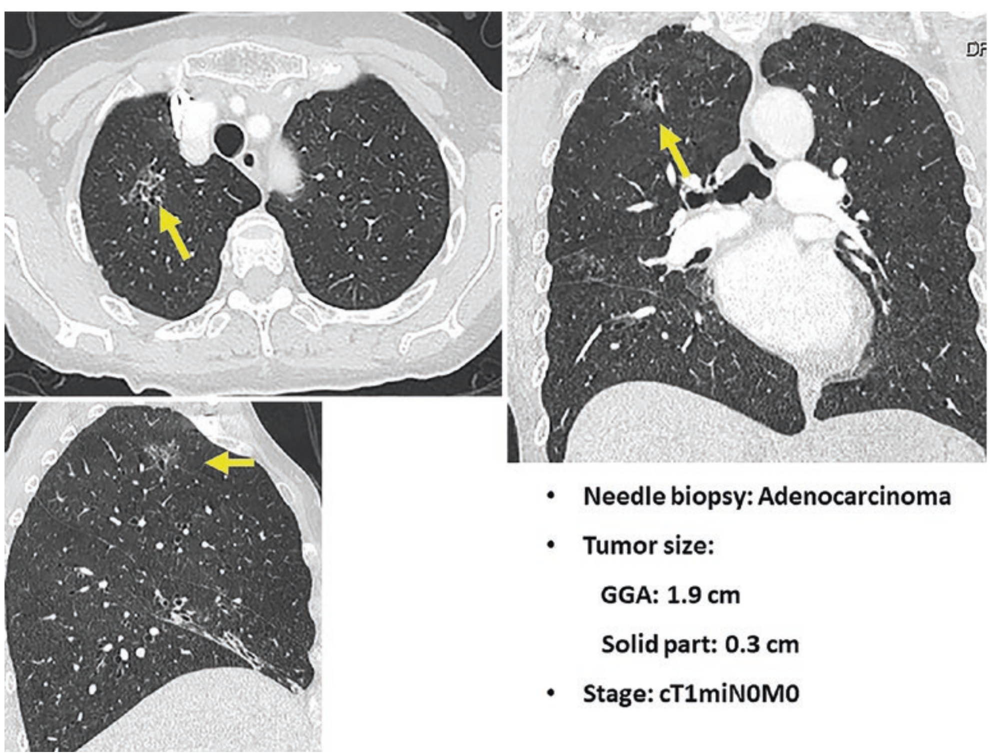


Fig. 4.6 [Axial, sagittal, and coronal views]



4.3 Marking Using Contrast Medium

A small tumor deeply located in lung tissue or ground glass attenuation (GGA) lesion can be hardly localized by inspection or palpation during surgery. For these tumors, preoperative marking by using a lipid soluble contrast medium (lipiodol) under CT is useful [3–6]. Approximately 0.5 ml of lipiodol is injected under CT (Fig. 4.7). Under fluoroscopy during surgery, the marked lesion is put in a ring-shaped forceps (Fig. 4.8). Tumor edges are marked by threading (Fig. 4.9), which is useful during the segment dissection. After the dissection, the surgical margin can be confirmed under fluoroscopy (Fig. 4.10). Lipiodol, because of lipid solubility, stays at the injected lung tissue for more than 1 month. However, because lipiodol is not allowed to use in lung tissue in general, an approval of ethics committee of each institution is necessary before using it.

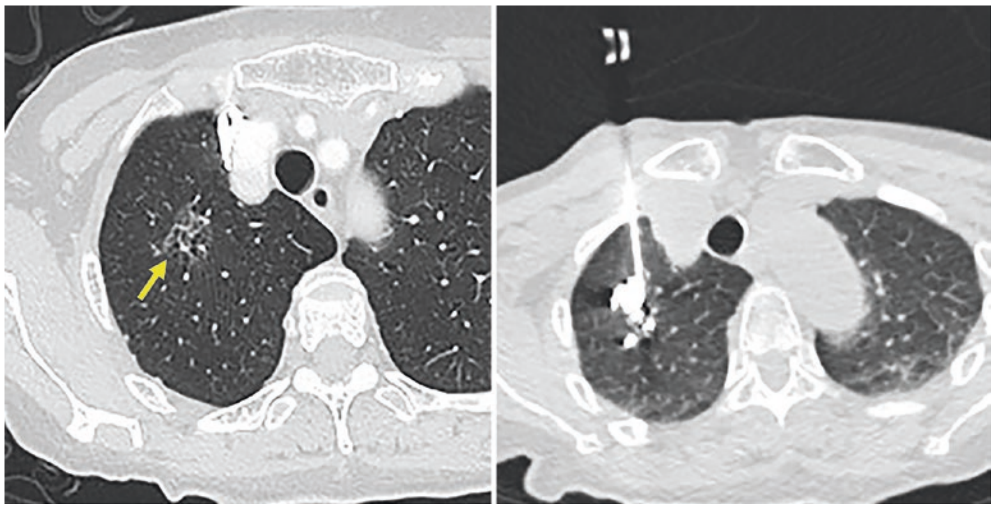


Fig. 4.7 [Preoperative marking by lipiodol] Left: adenocarcinoma with GGA (indicated by an arrow). Right: a needle hit the tumor under CT followed by injecting approximately 0.5ml of lipiodol

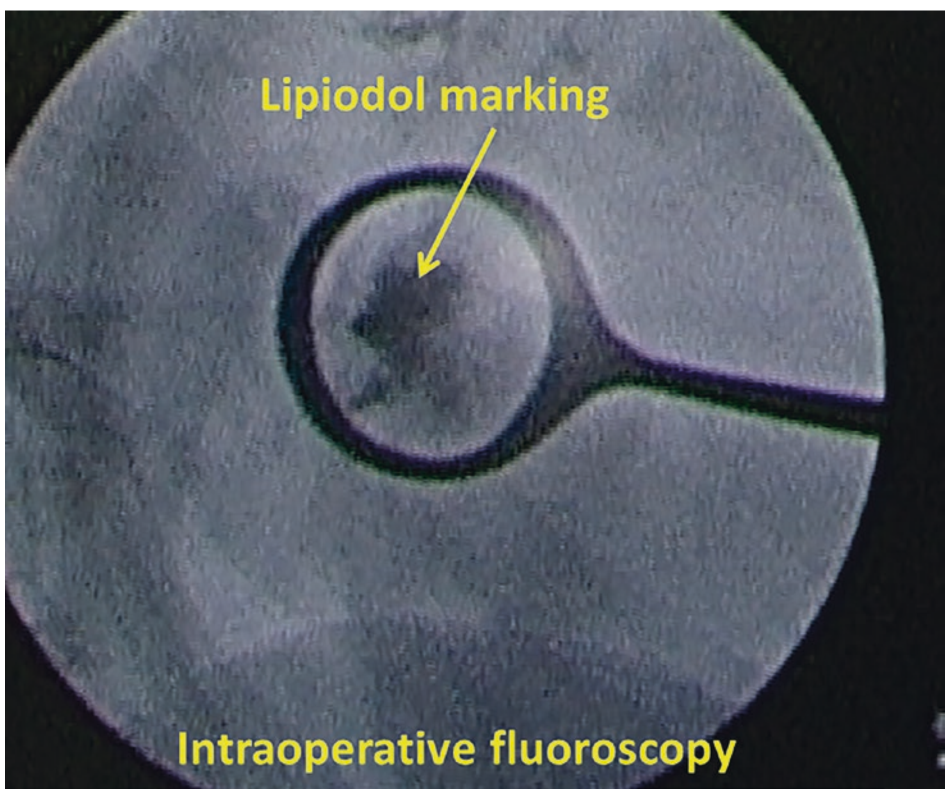


Fig. 4.8 [Intraoperative finding] The marked lesion is put in a ring-shaped forceps under fluoroscopy

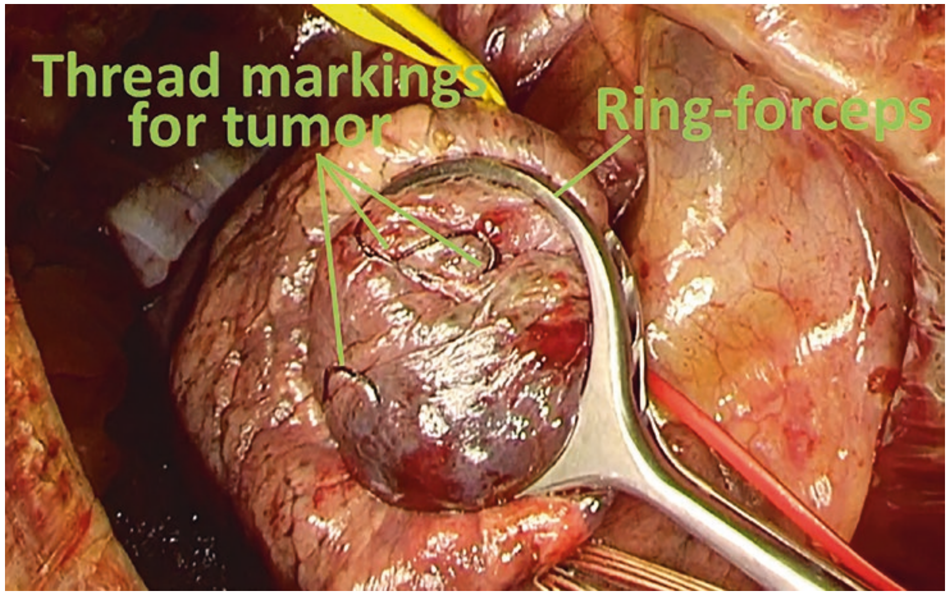


Fig. 4.9 [Intraoperative finding] Edges of tumor are marked by threading

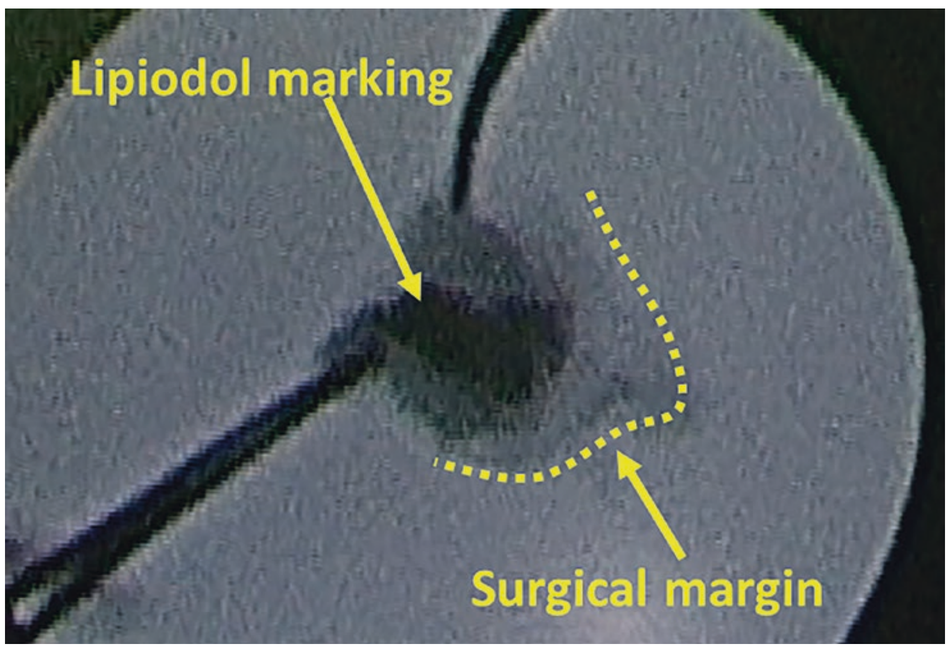


Fig. 4.10 [Fluoroscopy after dissection of the segment] The surgical margin is confirmed to be enough under fluoroscopy

4.4 Which Approach Is Recommended for Segmentectomy; Wide Thoracotomy, Limited Thoracotomy, or Video/Robotic-Assisted Thoracic Surgery

While I have usually used open thoracotomy for segmentectomy, I have never experienced segmentectomy under complete video-assisted thoracic surgery (VATS) or robotic-assisted thoracic surgery (RATS). The important points for segmentectomy are as follows: (1) Prevention of surgical margin recurrence; (2) prevention of recurrence from hilar lymph nodes; and (3) preserving lung function compared to lobectomy. To complete these points, I recommend open thoracotomy rather than VATS/RATS, except for simple segmentectomy, such as right S2 and S3, left S1 + 2, and bilateral S6 and S8. Even for these simple segmentectomy, keeping surgical margin is important. To keep enough surgical margin, I usually use a ring-shaped forceps 4 cm in diameter to put the tumor and surrounding lung tissue inside, which is hard to use under VATS or RATS. In addition to cut lung tissue under VATS or RATS, stapler is only available because an electrocautery is hard to use. However, the cutting lung tissue by only using stapler sometimes causes shrinkage of preserved lobe, especially for segments located in the center of lobe, such as right S1, left S3, and bilateral S9/S10. Adding more, the hilar node dissection is important for invasive small lung cancer, which would be difficult under VATS or RATS.

Previously, we compared pain score after surgery among wide thoracotomy, limited thoracotomy, and complete video-assisted thoracotomy (VATS) (Figs. 4.11, 4.12, and 4.13) [7–18]. In the study, wide or limited thoracotomy was conducted for segmentectomy, the complete VATS was only for lobectomy [7]. There were no significant differences in pain from 1 to 4 days postoperatively between VATS and limited thoracotomy, whereas wide thoracotomy showed significantly higher pain scores than limited thoracotomy and VATS (p = 0.02–0.0001) (Fig. 4.14). However, chronic pain, i.e., frequency of requiring analgesics, from 1 to 3 months after surgery did not differ significantly among the procedures (Fig. 4.15).

While I expect complete VATS/RATS to be available for all kinds of segmentectomy in future, I think now that open thoracotomy is preferable for segmentectomy to to take sufficient surgical margin, preserve pulmonary function, and dissect hilar nodes. In other words, I cannot show accurate anatomy of each segmentectomy under VATS/RATS, which are shown in the video of this textbook under open thoracotomy.

Fig. 4.11 [Video-assisted thoracoscopic surgery]

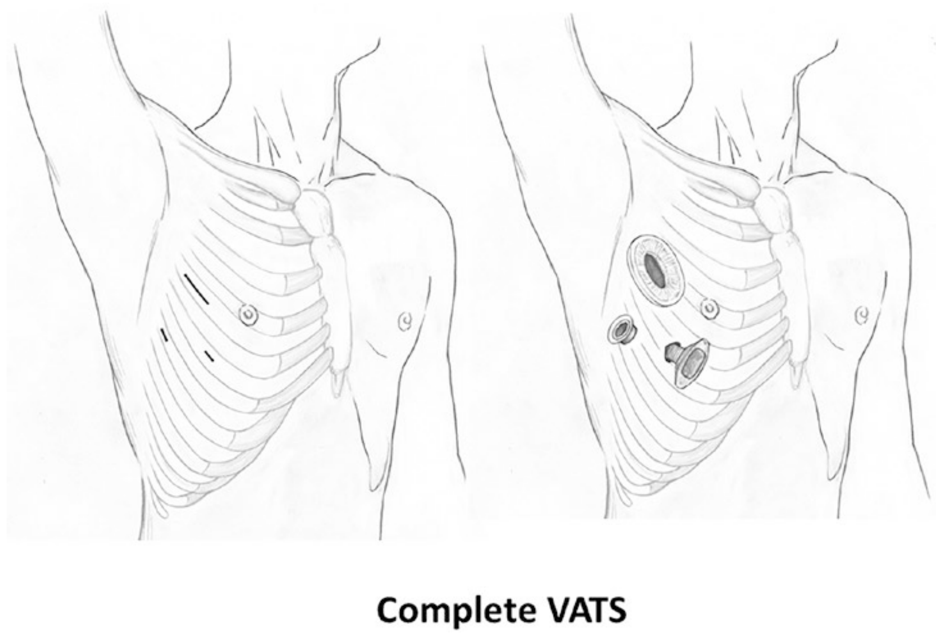
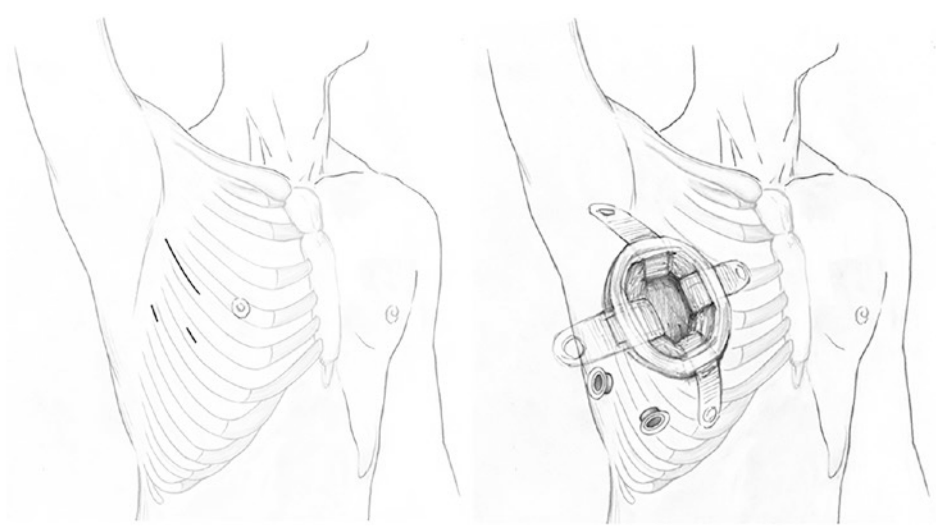


Fig. 4.12 [Limited thoracotomy]



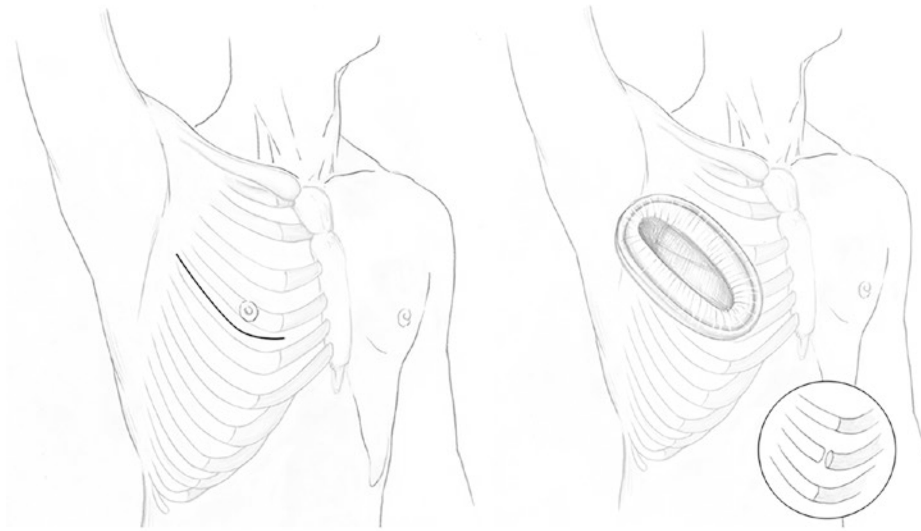


Fig. 4.13 [Widely opened anterolateral thoracotomy with disconnection of rib cartilage]

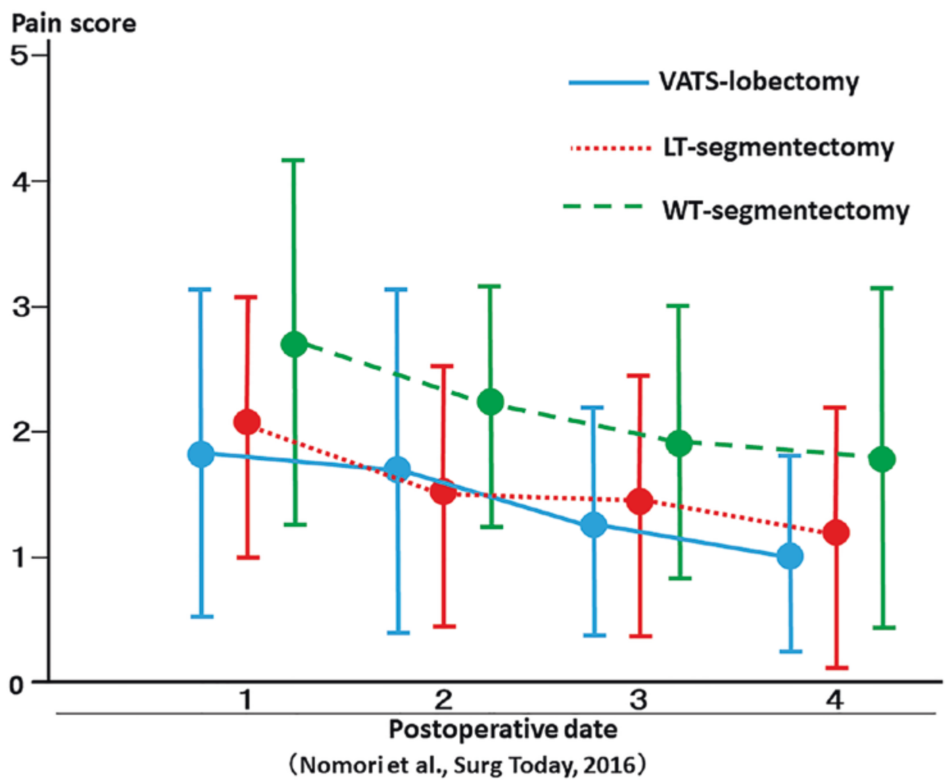


Fig. 4.14 [Pain scores in the acute phase after surgery] Each circle shows average pain scores from 1 to 4 postoperative dates. Blue lines show VATS-lobectomy. Red lines show limited thoracotomy for segmentectomy. Green lines show wide thoracotomy for segmentectomy. *VATS* video-assisted thoracoscopic surgery, *LT* limited thoracotomy, *WT* widely opened anterolateral thoracotomy

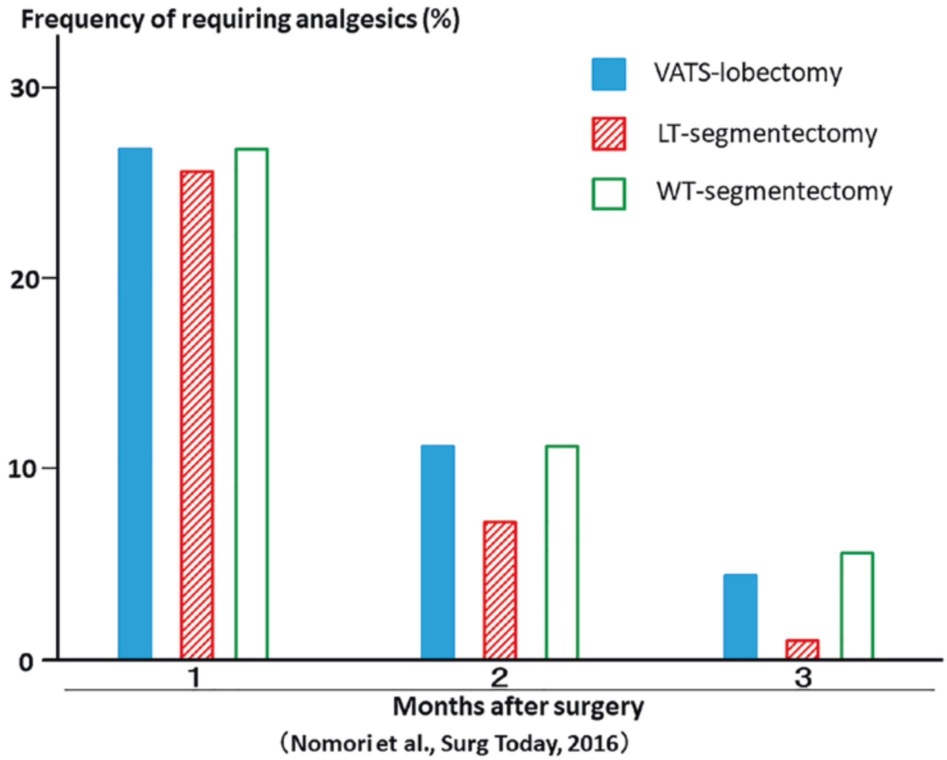


Fig. 4.15 [Frequency of requiring analgesics from 1 to 3 months after surgery] Blue bars show VATS-lobectomy. Red bars show limited thoracotomy for segmentectomy. Green bars show wide thoracotomy for segmentectomy. *VATS* video-assisted thoracoscopic surgery, *LT* limited thoracotomy, *WT* widely opened anterolateral thoracotomy. There is no significant difference among the three procedures

4.5 Exposing Segmental Bronchus

After exposing the surface of segmental bronchus, the bronchus is grasped with tweezers. The lateral and back sides of the segmental bronchus are peeled off from the segmental vein, lymph nodes, and other tissues using a thin cotton bar (Fig. 4.16).