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THORACIC

Usefulness of near-infrared angiography for identifying the intersegmental plane and vascular supply during video-assisted thoracoscopic segmentectomy†

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Abstract

OBJECTIVES: Segmentectomy by video-assisted thoracoscopic surgery (VATS) permits anatomical resection for diagnosis and treatment of small lung nodules but requires that intersegmental planes and segmental vessels be identified accurately. Near-infrared angiography with systemic injection of indocyanine green (ICG) can precisely identify the intersegmental plane. The purpose of this study was to confirm the usefulness of ICG angiography during VATS segmentectomy.

METHODS: We retrospectively reviewed the records of 22 consecutive patients who underwent VATS segmentectomy performed with near-infrared angiography between November 2014 and October 2015. Segments were localized and anatomical vascular supply was identified on preoperative computed tomography scans. VATS segmentectomy was performed using an anterior approach with 2 ports and 1 non-spreading minithoracotomy, with ICG injected systemically after arterial ligation.

RESULTS: VATS was feasible for all 22 segmentectomies, and in all patients, the intersegmental plane was identified accurately by ICG angiography. This angiography method was also useful in patients whose anatomical vascular segmentation was difficult to identify and, in a few patients, to assess the distribution of an artery before sectioning, to determine the vascular supply of the remaining lung and to distinguish between segmental and intersegmental veins. The postoperative course was uneventful for 18 patients and complicated for 2 patients who had prolonged air leak (10 and 15 days) with pneumonia, 1 patient with gastroparesis and 1 with colonic ileus. The drain was removed before the 3rd postoperative day in all but 2 patients, and the mean hospital stay was 5.4 ± 4.5 days. Anatomopathological examination indicated that 4 benign lesions and 18 primary lung cancers were completely removed, including 14 that were Stage IA, 2 Stage IIA and 2 Stage IIIA.

CONCLUSIONS: Indocyanine green angiography provides technical support for identifying the intersegmental plane and the vasculature during VATS segmentectomy. It contributes to the quality of diagnostic and therapeutic excisions of small nodules that are often not visible and not palpable during VATS.

Keywords: Lung neoplasm • Solitary pulmonary nodule • Video-assisted thoracic surgery (VATS) • Indocyanine green

INTRODUCTION

Evolving imaging technology has altered the presentation pattern of lung tumours at diagnosis [1]. Computed tomography (CT) is increasingly used for lung cancer screening [2–4] and for initial evaluation in emergency units, leading to more frequent discovery of small non-specific nodules [5]. Diagnosis and therapeutic procedures for these nodules should lead to appropriate oncological resection but, ideally, should also limit the extent of pulmonary resection and of surgical trauma through the use of minimally invasive techniques such as video-assisted thoracic surgery (VATS) [6]. Intentional segmentectomy allows the surgeon to avoid the difficulties related to the lack of manual palpation of nodules during VATS while respecting the rules of anatomical oncologic resections that spare pulmonary function [7]. This is possible when preoperative CT indicates that a nodule is well localized in a pulmonary segment. The question is not yet definitively answered, but there is a growing body of evidence that intentional segmentectomy for Stage Ia lung cancer is adequate from an oncological point of view, as long as certain criteria are met (e.g. a margin of 2 cm or at least the diameter of the tumour) [8].

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Anatomical segmentectomy is a more parenchyma-saving procedure than lobectomy and permits diagnosis and effective treatment of early stage lung cancers [9], with better postoperative outcomes, particularly in elderly patients who have several comorbidities [10]. However, many difficulties arise in VATS segmentectomy [11], including the identification of intersegmental planes [12], to ensure proper excision with respect to oncological margins and the conservation of lung function. During thoracotomy, lung reinflation after clamping or section of the segmental bronchus is often used to identify the intersegmental plane, but the lack of working space during VATS makes lung reinflation poorly suited for VATS. Peeling along the intersegmental veins is the other most often used technique during thoracotomy, but it needs manual (ideally, even bimanual) palpation and is therefore also not a suitable technique to be used in VATS [11, 12].

Near-infrared angiography with indocyanine green (ICG) is routinely used in our institution to assess the vascularization of bowel anastomoses in colorectal surgery [13] and the vascularization of the parathyroid glands in endocrine surgery [14, 15]. Animal studies on dogs [16] and pigs [17] have demonstrated the feasibility of using near-infrared imaging to identify the intersegmental plane in the lung, using the arterial segmentation instead of the bronchial segmentation commonly used during thoracotomy. These animal results have been confirmed in humans by a Japanese team, in 31 patients during segmentectomy by thoracotomy and in 13 patients during segmentectomy by VATS [18, 19]. It avoids lung reinflation that is poorly suited to VATS because of the lack of working space. In this study, we sought to assess the feasibility and the usefulness of ICG angiography during VATS segmentectomy, particularly for identifying the intersegmental plane.

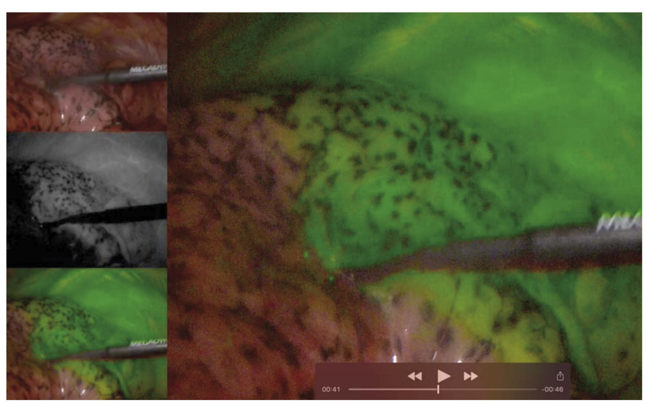
MATERIALS AND METHODS

We retrospectively analysed the records of patients who underwent VATS segmentectomy from November 2014 to October 2015 in the University Hospitals of Geneva. The local ethics committee approved the study. During this period, all patients with suspicious lung nodules less than 2 cm in diameter including patients with proven non-small-cell lung cancer staged preoperatively cT1aN0 (according to the seventh edition of the American Joint Committee on Cancer/Union for International Cancer Control lung cancer staging) were treated with intentional segmentectomy.

Surgical approach and indocyanine green angiography

The surgical strategies had been confirmed in our institution's cancer multidisciplinary meetings. Multiplanar CT reconstructions were analysed preoperatively to identify all pulmonary arteries intended for sectioning and their relationship with veins and bronchi. A conventional anterior approach with 3 ports was used in all patients: a minithoracotomy in the third or fourth anterior intercostal space with a wound protector Alexis® (Applied Medical Resources Corporation, Rancho Santa Margarita, CA, USA) without rib spreading, a 10-mm camera port in the seventh intercostal space anteriorly and a second 10-mm port approximately 2 spaces below posteriorly. In case of conversion to thoracotomy, an axillary thoracotomy was performed, extending the utility incision. Intercostal blockade using local anaesthesia was routinely done at the beginning of the thoracoscopy.

The main step of the segmentectomy was to isolate and cut all arterial branches supplying the segment(s) to be resected. We used either Ligasure® 5 mm (Covidien, Mansfield, MA, USA) or endoGIA Ultra with Tristaple® technology (Covidien). In a few patients, veins and bronchi were sectioned before the arteries to facilitate the dissection of the arteries. The standard camera was then switched for the Pinpoint® camera (PinPoint Endoscopic Fluorescence Imaging System, NOVADAQ, Mississauga, ON, Canada) before systemic intravenous injection of 5 ml of reconstituted ICG solution (2.5 mg/ml), corresponding to 12.5 mg of ICG. ICG is a water-soluble molecule that acts as a contrast agent for near-infrared imaging. It re-emits light with a precise wavelength of 835 nm in response to excitation by a light with a wavelength between 790 nm and 805 nm [20]. After intravenous injection, its half-life is about 4 min, and it is eliminated from the liver in about 15 min. The endoscopic system Pinpoint, which is routinely used in our institution, allows the visualization of near-infrared light emitted by excited ICG and also light in the visible spectrum. A specific function combines both enhanced real-time imaging with perfusion in green added to standard imaging. The intersegmental plane between devascularized and well-vascularized segments was viewed on the dedicated screen. The well-vascularized lung appears green and the non-vascularized segment(s) appears in physiological colours on this screen rapidly (a few seconds to minutes) after ICG injection (Video 1). The limits of the segment were marked along the border by electrocautery. If necessary, ICG can be injected again, to a maximum dose of 5 mg/kg. The intersegmental planes were then divided using EndoGIA staplers. The completeness of the excision was controlled by palpation and sectioning of the segment. Frozen sections were obtained for diagnosis of the nodule for margin studies and when lymph node involvement was suspected. Segmentectomy was completed by lymph node dissection in the case of primary lung cancer and converted to lobectomy when there were inadequate margins or lymph node involvement discovered intraoperatively. One chest tube was inserted. Postoperative drainage was monitored by a digital chest drainage unit Thopaz® (Medela, Baar, Switzerland). The chest tube was removed when air leak stopped, clear fluid drainage was less than 300 ml/day and a chest radiograph revealed no significant air or fluid in the pleural space. Day of discharge was dependent upon the control of analgesia with oral medication and upon social conditions. Postoperative complications, as classified by Dindo *et al.* [21], were recorded.



Video 1: Right S3 segmentectomy with intraoperative near-infrared angiography.

Data analysis

Descriptive statistics were calculated using Excel® (Microsoft, Seattle, WA, USA) and XL-Stat® (Addinsoft, Paris, France). Results are expressed as mean ± standard deviation.

RESULTS

Patient characteristics and outcomes

During the study period, 22 scheduled VATS segmentectomies were performed via thoracoscopy, all without intraoperative technical problems. In all patients, preoperative positron emission tomography-CT, including a multiplanar CT with contrast enhancement, permitted detailed anatomical study of the vascularization. Clinical tumour stage was T1–N0–M0 according to the preoperative positron emission tomography-CT in all patients. The preoperative characteristics of patients and tumours are presented in Tables 1 and 2. There were 11 males and 10 females (1 female operated twice for bilateral lesions); their mean age was 67 ± 9.6 years. The mean forced expiratory volume in 1 s and carbon monoxide diffusing capacity was 95.5 ± 17.4% predicted and 80.5 ± 17.3% predicted, respectively. Nine patients had forced expiratory volume in 1 s and/or carbon monoxide diffusing capacity <80% predicted.

Eighteen procedures were diagnostic (the nature of the tumour was not known preoperatively) and 4 were therapeutic for known primary lung cancer. Preoperative diagnosis was not obtained in 18 patients either because of technical difficulties (small size of the nodule, pure ground glass nodule or difficult location) or because this step was deemed not necessary because of a high degree of suspicion that would lead to resection even in the case of a negative biopsy. The segmentectomy was extended to a lobectomy in 3 cases for oncologic reasons (Table 2), by VATS in 2 patients and by thoracotomy in 1 patient. Two patients had lymph node invasion requiring a lobectomy and 1 patient had an insufficient margin after segmentectomy, requiring a lobectomy. There was no significant intraoperative blood loss and no postoperative mortality.

There were no adverse events related to ICG injection. The intersegmental planes in all 22 patients could be delineated after 1 or 2 injections of ICG. Furthermore, ICG angiography helped us avoid incomplete resection or leaving a devascularized part of a segment in 3 patients whose segmental arteries or veins were difficult to distinguish (Table 3).

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Anatomopathological results

The 22 nodules were found by anatomopathological examination in the resected specimen, corresponding to 18 lung cancers and 4 benign lesions (Table 4). Six of the 18 patients with lung cancer were preoperatively understaged. Three patients had preoperatively unrecognized N + disease; 1 patient had intraoperatively recognized N1 disease and underwent a lobectomy and 2 patients had N2 disease: 1 patient had N2 disease recognized intraoperatively and underwent a lobectomy and in the other, final pathological analysis showed micro-N2 disease and completion lobectomy was not performed after the case was discussed at the lung cancer multidisciplinary meeting. This patient also underwent postoperative chemotherapy. Three patients had upstaging because of the final size of the tumour, from T1a to T1b (Table 4).

Table 1: Patient characteristics (*n* = 22)

Patient	Age (years)	BMI (kg/m^2)	Side	Planned segmentectomy	Diagnosis	FEV_1 (%)	DLCO (%)
1[a]	73	36.3	L	10	UN	97	87
2	71	28.7	R	2	UN	80	UN
3	83	18.2	L	6	ADCA	109	92
4	62	31.6	R	3	UN	51	76
5	71	27.7	R	1 + 2	UN	107	79
6	68	24.6	L	6	UN	110	93
7	62	24.4	L	1 + 2	ADCA	95	96
8	60	21.8	R	6	UN	88	58
9[a]	73	36.3	R	1	UN	101	85
10	78	24.7	L	2 + 1a	UN	108	61
11	69	19.4	R	8 + 9	UN	68	46
12	61	27.1	R	2 + 1a	UN	109	90
13	52	26.9	R	3	UN	114	60
14	75	21.5	L	3	CT	102	84
15	62	15.4	L	1 + 2	UN	126	79
16	50	16.2	L	1 + 2	UN	86	50
17	75	22.1	L	1 + 2	UN	115	97
18	63	18.2	L	1 + 2 + 3	SCC	85	93
19	47	27.8	L	1 + 2	UN	94	93
20	77	25.5	R	6	UN	97	87
21	65	24.3	L	7 + 8 + 9 + 10	UN	80	114
22	78	34.5	L	1 + 2	UN	79	70

[a]Same patient.

BMI: body mass index; UN: unknown (diagnostic procedure); ADCA: adenocarcinoma; CT: carcinoid tumour; SCC: squamous cell carcinoma; FEV_1: forced expiratory volume in 1 s (% predicted); DLCO: carbon monoxide diffusing capacity (% predicted).

Table 2: Tumour characteristics ($n = 22$)

Patient	Diagnosis	Characteristics of the nodule			Side	Surgical procedure			Anatomopathological results		
		Size (mm)	Shape	PET-CT (SUV_{max})		Planned segmentectomy	Reason to extend the resection	Final segmentectomy or lobectomy	Type	pTNM	Stage
1[a]	UN	8	Spiculated	3.7	L	10		10	ADCA 15 mm	pT1a N0	IA
2	UN	12	Spiculated	2.3	R	2		2	Lymphangioma	Benign	
3	ADCA	24	Spiculated	3.1	L	6	Lymph node invasion (intraoperative N2)	LLL	ADCA 15 mm	pT1b N2	IIIA
4	UN	12	Spiculated	3	R	3		3	ADCA 13 mm	pT1a N2	IIIA
5	UN	20	GGO	4	R	1 + 2		1 + 2	ADCA 25 mm	pT1b N0	IA
6	UN	20	GGO	1	L	6		6	ADCA 19 mm	pT1a N0	IA
7	ADCA	20	Spiculated	14.5	L	1 + 2	Devascularization of anterior segment	1 + 2 + 3	ADCA 30 mm	pT1b N0	IA
8	UN	12	Spiculated	3.2	R	6		6	ADCA 15 mm	pT1a N0	IA
9[a]	UN	14	Spiculated	2.5	R	1		1	ADCA 15 mm	pT1a N0	IA
10	UN	13	Spiculated	1.3	L	2 + 1a		2 + 1a	ADCA 19 mm	pT2 N0	IIA
11	UN	19	Spiculated	14.2	R	8 + 9		8 + 9	Basaloid SCC 28 mm	pT1 bN0	IA
12	UN	14	GGO	UN	R	2 + 1a		2 + 1a	ADCA 10 mm	pT1a N0	IA
13	UN	7, 15, 17	3 Solid nodules	3.2	R	3		3	3 Tuberculoma 17 mm, 15 mm, 7 mm	Benign	
14	CT	18	Solid	2.3	L	3		3	Typical CT 17 mm	pT1a N0	IA
15	UN	10	Spiculated	9.5	L	1 + 2		1 + 2	Tuberculoma 10 mm	Benign	
16	UN	10	Spiculated	1	L	1 + 2		1 + 2	Inflammatory pseudotumour 8 mm	Benign	
17	UN	12	Spiculated	2.6	L	1 + 2		1 + 2	ADCA 10 mm	pT1a N0	IA
18	UN	25	Spiculated	2.3	L	1 + 2 + 3	Insufficient margin	LUL	ADCA 22 mm	pT1b N0	IA
19	UN	11	Spiculated	5.4	L	1 + 2	Lymph node invasion (intraoperative N1)	LUL	ADCA 15 mm	pT1a N1	IIA
20	UN	17	Solid	3,9	R	6		6	Typical CT 20 mm	pT1a N0	IA
21	UN	8, 10, 12	3 Solid nodules	UN	L	7 + 8 + 9 + 10		7 + 8 + 9 + 10	3 ADCA 7 mm, 11 mm, 12 mm	3 pT1a N0	IA
22	UN	24	GGO	UN	L	1 + 2		1 + 2	2 ADCA 10 mm, 27 mm	2 pT1b N0	IB

[a]Same patient.

UN: unknown (diagnostic procedure); ADCA: adenocarcinoma; CT: carcinoid tumour; GGO: ground-glass opacity; PET-CT: positron emission tomography–computed tomography; SUV_{max}: maximum standardized uptake value; 1a: posterior part of apical segment; LLL: left lower lobe; LUL: left upper lobe; SCC: squamous cell carcinoma.

Table 3: Usefulness of near-infrared angiography ($n = 22$)

Patient	Side	Surgical procedure: Planned segmentectomy	Surgical procedure: Final segmentectomy or lobectomy	Operative time (min)	Intersegmental planes identification	Additional support of near-infrared thoracoscopy
1[a]	L	10	10	139	Perfect	
2	R	2	2	128	Perfect	
3	L	6	LLL	195	Perfect	
4	R	3	3	119	Perfect	
5	R	1 + 2	1 + 2	152	Perfect	
6	L	6	6	145	Perfect	
7	L	1 + 2	1 + 2 + 3	127	Perfect	Proven devascularization of anterior Segment 3 by non-intentional arterial ligation, leading to its resection
8	R	6	6	140	Perfect	
9[a]	R	1	1	128	Perfect	
10	L	2 + 1a	2 + 1a	181	Perfect	
11	R	8 + 9	8 + 9	135	Perfect	
12	R	2 + 1a	2 + 1a	108	Perfect	
13	R	3	3	75	Perfect	
14	L	3	3	118	Perfect	
15	L	1 + 2	1 + 2	148	Perfect	
16	L	1 + 2	1 + 2	116	Perfect	
17	L	1 + 2	1 + 2	109	Perfect	Doubt about an artery for Segment 1 or 3: First ICG injection before its ligation Second ICG injection showing perfect devascularization of Segments 1 + 2 (artery for Segment 1)
18	L	1 + 2 + 3	LUL	172	Perfect	
19	L	1 + 2	LUL	216	Perfect	
20	R	6	6	125	Perfect	
21	L	7 + 8 + 9 + 10	7 + 8 + 9 + 10	126	Perfect	Doubt about a double artery for Segment 6: First ICG injection with clamped second artery Second ICG injection after declamping, leading to its preservation (artery for Segment 10)
22	L	1 + 2	1 + 2	116	Perfect	

[a]Same patient.
LLL: left lower lobe; LUL: left upper lobe; ICG: indocyanine green.

Postoperative course

The postoperative course was uneventful for 18 patients whose chest tube was removed on postoperative Day 1 or 2. The 4 other patients had complications: 2 had prolonged air leaks that delayed chest tube removal to postoperative Days 10 and 15 (Dindo-Clavien Grade I), 1 patient, who had diabetes, had gastroparesis treated by fibroaspiration and prokinetics (Dindo-Clavien Grade IIIa) and 1 patient with a previous history of colectomy and abdominal aneurysm had colonic ileus that was treated by rectal tube (Dindo-Clavien Grade II). The mean hospital stay was 5.4 ± 4.5 days. No patient required new chest drainage or rehospitalization.

DISCUSSION

The use of near-infrared angiography to identify the intersegmental plane has been described in a few animal studies [16] and human series [18, 19, 22] but very rarely during thoracoscopy and only by one surgical team from Japan [18, 19]. Tarumi *et al.* reported 44 patients undergoing segmentectomy with ICG angiography. However, only 13 of these 44 segmentectomies were performed by VATS. Therefore, to our knowledge, our series of 22 patients undergoing VATS segmentectomy with infrared angiography is so far the largest published. In the series of Tarumi *et al.*, the intersegmental plane could not be accurately identified in 2 of the 13 VATS patients. In our series, near-infrared angiography identified the intersegmental plane perfectly in all 22 patients and helped identify the vascular anatomy, which allowed the planned resection to proceed in 2 patients. In one of these patients, an arterial branch was only sectioned after a first ICG injection, confirming that this branch indeed belonged to the segment to be resected. In a second patient, the artery was clamped, which led to the devascularization of the adjacent segment, and therefore, this branch was not sectioned. In the third patient, the pulmonary resection was extended to avoid the infarction of an unexpectedly devascularized adjacent segment.

Pulmonary segmentectomy circumvents the need for diagnostic lobectomy for benign, multiple and undetermined lesions, both for metastasis and for Stage 1 lung cancer. It also circumvents the need for a second intervention (totalization lobectomy) when lung cancer is undiagnosed by frozen section after wedge resection. For instance, intraoperative frozen sectioning cannot always differentiate between primary lung adenocarcinoma and metastasis from colorectal adenocarcinoma.

Table 4: Anatomopathological results for malignant lesions (n = 18)

Patient	Preoperative characteristics		Anatomopathological results			Preoperative understaging
	Size of the nodule on CT scan (mm)	cTNM	pTNM	Type	Stage	
1[a]	8	cT1a N0	pT1a N0	ADCA 15 mm	IA	No
3	24	cT1b N0	pT1b N2	ADCA 15 mm	IIIA	Yes (N0–N2)
4	12	cT1a N0	pT1a N2	ADCA 13 mm	IIIA	Yes (N0–N2)
5	20	cT1a N0	pT1b N0	ADCA 25 mm	IA	Yes (T1a–T1b)
6	20	cT1a N0	pT1a N0	ADCA 19 mm	IA	No
7	20	cT1a N0	pT1b N0	ADCA 30 mm	IA	Yes (T1a–T1b)
8	12	cT1a N0	pT1a N0	ADCA 15 mm	IA	No
9[a]	14	cT1a N0	pT1a N0	ADCA 15 mm	IA	No
10	13	cT1a N0	pT2 N0	ADCA 19 mm	IIA	No
11	19	cT1a N0	pT1 bN0	Basaloid SCC 28 mm	IA	Yes (T1a–T1b)
12	14	cT1a N0	pT1a N0	ADCA 10 mm	IA	No
14	18	cT1a N0	pT1a N0	Typical CT 17 mm	IA	No
17	12	cT1a N0	pT1a N0	ADCA 10 mm	IA	No
18	25	cT1b N0	pT1b N0	ADCA 22 mm	IA	No
19	11	cT1a N0	pT1a N1	ADCA 15 mm	IIA	Yes (N0–N1)
20	17	cT1a N0	pT1a N0	Typical CT 20 mm	IA	No
21	8, 10, 12	3 cT1a N0	3 pT1a N0	3 ADCA 7 mm, 11 mm, 12 mm	IA	No
22	24	cT1b N0	2 pT1b N0	2 ADCA 10 mm, 27 mm	IB	No

[a]Same patient.
CT: computed tomography; UN: unknown (diagnostic procedure); ADCA: adenocarcinoma; CT: carcinoid tumour; SCC: squamous cell carcinoma.

However, segmentectomy is not considered an oncologically adequate resection for Stage >1 lung cancer (including N1+ disease) or when the resection margins are less than 2 cm or less than the size of the tumour. It is the reason why intraoperative frozen section must sometimes be used. In 3 patients from our series, segmentectomy was completed intraoperatively by lobectomy for oncological reasons.

Limitations

The main limitation of using near-infrared angiography is the cost of the equipment. In our institution, different surgical teams use the fluorescence equipment, reducing the cost per patient. We use standard thoracoscopic equipment for most of the operation and the fluorescence equipment only for a few minutes. Accordingly, the equipment quickly becomes available for other surgical teams. The ICG dye is not expensive, and its use in humans for more than 50 years makes it very safe. Another limitation is the need to carefully study the vascular pulmonary anatomy preoperatively. In our opinion, a multiplanar CT scan with contrast enhancement is mandatory preoperatively, and 3D reconstructions are very helpful in planning the surgery. The ICG angiography only takes a few minutes and therefore does not significantly prolong the operating time.

In the study by Tarumi *et al.* [19], the main limitation was the necessity to use large doses of ICG (3 mg/kg), close to the reported toxic dose of 5 mg/kg. Kasai *et al.* [18], from the same Japanese team, tried to reduce the dose to 0.5 mg/kg in some of their patients, but they reported that the visualization was not as good with this dosage. In our study, we used a standard dose of 12.5 mg for every patient, irrespective of their weight, which proved to be sufficient for excellent intersegmental plane visualization. We initially tried an even smaller dose, 8.75 mg, which is the standard dosage used in our institution in other indications [13, 14]; however, this was not sufficient for the lung, and we had to increase the dose a little bit. Nevertheless, there is still a big difference in ICG dosage compared with the Japanese studies (about 12 times less for a 50 kg patient, 18 times less for a 75 kg patient). We think this is probably due to the difference in imaging equipment, with different sensibilities to detect near-infrared light. The Japanese team used an Olympus imaging equipment (Olympus Co., Ltd, Tokyo, Japan) and we used a Pinpoint camera. This much smaller dosage of ICG also significantly reduced the cost of the procedure.

The relative short duration of the clear delimitation of the intersegmental plane reported by the Japanese team has also been observed in this study; after IV injection of ICG in a peripheral vein, the ICG very quickly arrives in the pulmonary arteries, a few seconds after the peripheral line has been purged. After a few more minutes, the dye arrives in the whole lung, probably mainly via the systemic, bronchial circulation. It is therefore very important to be ready to mark the line with electrocautery rapidly after ICG injection. Because the imaging equipment has a combined view (normal colour view combined with the near-infrared view), we did not find that it was a limitation to have only a few minutes to mark the line with electrocautery. Moreover, with the dosage of ICG we used, multiple injections are possible without toxicity.

CONCLUSION

In conclusion, our study shows that near-infrared angiography improves the quality of the VATS segmentectomy by allowing a precise anatomic resection corresponding to the vascular segmentation. It is simple and fast to implement, and it helps to ensure oncologically correct resection of small lung lesions that are often not visible or palpable. Further studies with more patients are needed to confirm these promising preliminary results.

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