Factors in the Selection and Management of Chest Tubes After Pulmonary Lobectomy: Results of a National Survey of Thoracic Surgeons

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Background. This study determined patterns of chest tube (CT) selection and management after open lobectomy and minimally invasive lobectomy by thoracic surgeons.

Methods. Surveys were sent electronically to 5,175 thoracic surgeons, and 475 were completed. Responses, blinded so individuals could not be identified, were analyzed and compared according to surgeon characteristics (academic/private practice, years in practice, lobectomy volume, and geographic region). All indicated differences were statistically significant ($p < 0.05$ by χ^2 tests).

Results. CT selection: Most surgeons prefer rigid tubes, and the size most commonly used was 28F. Most place 2 CTs after open lobectomy and 1 CT after minimally invasive lobectomy. Academic surgeons are more likely than private surgeons to use 1 tube after open lobectomy, but both prefer 1 tube after minimally invasive lobectomy. Younger surgeons and high-volume surgeons are more likely to use 1 CT than senior surgeons and low-volume surgeons after both open lobectomy and minimally invasive lobectomy. CT management: Academic and younger surgeons remove the CT sooner after open lobectomy. Younger and high-volume surgeons remove the CT with greater drainage amounts. All groups remove CTs sooner after minimally invasive lobectomy than after open lobectomy. Approximately half of surgeons get a daily chest roentgenogram. Younger and low-volume surgeons are most likely to discharge patients with Heimlich valves, although overall use was in less than 5% (49 of 475) of respondents. Most surgeons believe clinical experience rather than training or the literature determined their CT strategy.

Conclusions. This survey determined the difference in CT management among various groups of surgeons. Clinical experience was the most important factor in determining their CT strategy.

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The use of chest tubes (CTs) after pulmonary lobectomy is routine and a universal practice; yet, there are distinct differences among surgeons in the types and sizes of CTs that are used and in how they are managed [1–4]. For such an important component of thoracic surgical practice, there is scant literature that deals with these considerations. Despite efforts by thoracic surgical communities to address the ambiguities regarding CT management and nomenclatures [5], the best practice remains undefined.

With the belief that the necessary start in addressing best practices is to understand current practice patterns, the aim of this study was to identify the current practice patterns and factors that influence the use and management of CTs and to compare use and management strategies among various thoracic surgeon groups.

Material and Methods

We developed a questionnaire that was sent to 5,175 cardiothoracic surgeons. The survey was sent by e-mail on February 1, 2013, and concluded on April 1, 2013. A reminder e-mail was sent 4 weeks after the initial e-mail. A total of 475 surgeons responded by completing the questionnaires. The survey questionnaires (Appendix) contained 33 questions that queried surgeons' preferences in choosing the types and size of the CTs placed after lobectomy and their postoperative management strategies. The factors that influenced the choice of the CT and the management were assessed. Demographic characteristics of the responding surgeons were gathered and correlated with CT choices and management.

Responses, blinded so individual surgeons could not be identified, were analyzed and compared according

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to surgeon characteristics (academic/private practice, years in practice, lobectomy volume, and geographic region). Surgeons who performed 1 to 30 lobectomies were defined as low-volume surgeons, and those who performed 31 to 75 lobectomies and more than 75 lobectomies were defined as medium-volume and high-volume surgeons, respectively. Surgeons were also divided into four subgroups based on years in practice: fewer than 10 practice years (youngest), 10 to 20 years, 20 to 30 years, and 30 or more years (oldest).

For comparison, the Society of Thoracic Surgeons (STS) General Thoracic Surgery Database was similarly queried from 2004 to 2011 for patterns of CT use after lobectomy. Limited comparisons were possible (duration of CTs for open and video-assisted thoracic surgery [VATS] lobectomy and discharge home with CT) because the database addressed fewer of the CT issues than did the questionnaire.

Statistical comparisons were performed using IBM SPSS 20.0 software (IBM Corp, Armonk, NY). All indicated differences are statistically significant ($p < 0.05$ by Pearson χ^2 tests).

Results

Demographics

The surgeons who replied to the survey represent a heterogeneous mixture of backgrounds and experiences (Table 1). Of the 475 surgeons who replied, 222 described their practice as academic, and 253 identified themselves as in private practice, and 64.4% indicated they perform minimally invasive lobectomy. More academic, high-volume, and younger surgeons perform minimally invasive lobectomy than private practice, low-volume, or older surgeons. Furthermore, a higher percentage of lobectomies performed by the former group are minimally invasive ($p = 0.01$).

Table 1. Characteristics of 475 Surgeons Who Responded to the 2013 Survey

Characteristics	Response (N = 475) No. (%)
Type of practice	
Academic	222 (46.7)
Private	253 (53.3)
Years in practice	
<10	143 (30.1)
10–19	131 (27.6)
20–29	122 (25.7)
≥30	79 (16.6)
Lobectomies per year, No.	
0–10	55 (11.6)
11–30	140 (29.5)
31–50	123 (25.9)
51–75	81 (17.1)
76–100	39 (8.2)
>100	37 (7.8)
Geographic location	
West	84 (17.7)
North	109 (22.9)
South	138 (29.1)
East	79 (16.6)
World	63 (13.3)
Perform minimally invasive lobectomy?	
Yes	306 (64.4)
No	169 (35.6)
Minimally invasive lobectomies, %	
0	40 (8.4)
<10	27 (5.7)
10–25	44 (9.3)
25–50	40 (8.4)
50–75	91 (19.2)
>75	104 (21.9)

CT Selection: Number, Type, and Size

Number of CTs: When open lobectomy was performed, academic surgeons and private surgeons were both more likely to use 2 CTs than 1 (Table 2). This was true independently of the lobe removed. When only 1 tube was placed, compared with private surgeons, more academic surgeons used 1 CT in upper lobectomy (49.1% vs 35.2%, $p = 0.01$) and in lower lobectomy (48.6% vs 33.9%, $p = 0.01$).

The youngest surgeons (<10 practice years) were more likely to use 1 CT (55.2%) after open upper lobectomy compared with surgeons who had 10 to 20 practice years (46.6%), 20 to 30 practice years (32%), and 30 or more practice years (24.1%, $p = 0.01$). Similarly, young surgeons were also more likely to used 1 CT after open lower lobectomy ($p = 0.01$). High-volume surgeons were more likely to used 1 CT compared with medium-volume and low-volume surgeons after open upper lobectomy (52.2% vs 46.3% and 30.3%, respectively; $p = 0.01$) and open lower lobectomy (51% vs 43.9% and 30.3%, respectively; $p = 0.01$).

For minimally invasive lobectomy, academic and private surgeons both preferred to use 1 CT rather than 2 after both upper and lower lobectomy (Table 2). Surgeons did not differ geographically (West, North, South, East, World), because the overall preference was 2 CTs for open lobectomy and 1 CT for minimally invasive lobectomy.

Type and size of CT: Most surgeons prefer rigid tubes (Table 2) regardless of the type of practice, years of experience, volume, and geographic location. A range of sizes is used, but 28F is the most common (297 of 475). The next most popular size was 24F (113 of 475), followed by 32F (91 of 475).

CT Management

The mean day of CT removal after open lobectomy for all surgeons was 2.8 days (Table 3). Academic surgeons remove the CTs sooner than private practice surgeons (2.64 vs 2.94 days, $p = 0.04$). The younger surgeons (<10 practice years) removed CTs sooner than surgeons who

Table 2. Number and Types of Chest Tubes Used in Routine Lobectomy

Variable	Type of Practice			Duration of Practice, y					Volume of Practice[a]			
	Academic (No.)	Private (No.)	*p*	<10 (No.)	10–20 (No.)	20–30 (No.)	>30 (No.)	*p*	Low (No.)	Med (No.)	High (No.)	*p* (No.)
CT, No												
Open upper												
1	109	89	0.01	79	61	39	19	0.01	59	57	82	0.01
2	113	164		64	70	83	60		136	66	75	
Open lower												
1	108	85	0.01	71	58	43	21	0.01	59	54	80	0.01
2	114	166		72	72	79	57		134	69	77	
3	0	2		0	1	0	1		2	0	0	
Min upper												
1	107	88	0.06	87	61	34	13	0.01	52	56	87	0.81
2	47	53		30	30	30	15		31	31	43	
Min lower												
1	103	82	0.11	80	58	35	14	0.17	48	53	84	0.63
2	52	64		37	34	30	16		34	37	45	
CT type												
Soft	36	46	0.67	17	31	27	7	0.30	27	20	35	0.20
Rigid	160	173		107	83	83	60		140	91	88	
Both	26	34		19	17	12	12		28	12	20	

[a] Low volume = 1 to 30 lobectomies, medium volume = 31 to 75 lobectomies, high volume = >75 lobectomies.

CT = chest tube.

practiced 10 to 20 years, 20 to 30 years, and 30 or more years (2.65 days vs 2.79, 3.04, and 2.72 days; $p = 0.02$). Geographic location of the surgeon and volume of cases had no effect on the timing of CT removal.

After minimally invasive lobectomy, the mean duration of time CTs stayed in for all surgeons was 2.4 days. There was no statistical difference in CT duration after minimally invasive lobectomy by practice type, experience, volume, or geographic location.

Academic surgeons were willing to remove CTs with higher output compared with private practice surgeons: 52.3% of academic surgeons removed CTs with drainage exceeding 250 mL compared with only 34.8% for private surgeons ($p < 0.01$; Table 4). Younger surgeons and high-volume surgeons were also more willing to remove CTs with higher drainage than were more senior and low-volume surgeons (Table 4). There were no differences according to the geographic location.

Table 3. Chest Tube Management: Day Chest Tube is Removed After Routine Lobectomy

Days	Type of Practice			Duration of Practice, y					Volume of Practice[a]			
	Academic (No.)	Private (No.)	*p*	<10 (No.)	10–20 (No.)	20–30 (No.)	>30 (No.)	*p*	Low (No.)	Med (No.)	High (No.)	*p*
Open lobectomy												
1	11	4	0.01	10	3	0	2	0.01	3	4	8	0.26
2	95	78		58	51	32	32		71	41	61	
3	82	110		49	55	57	31		79	52	61	
4	30	50		23	14	29	14		35	25	20	
5	4	11		3	8	4	0		7	1	7	
Mini lobectomy												
1	25	14	0.5	24	10	3	2	0.32	10	15	14	0.61
2	66	70		55	41	25	25		38	36	62	
3	51	48		28	29	31	11		29	30	40	
4	12	13		8	11	5	1		4	8	13	
5	2	3		3	1	1	0		2	0	3	

[a] Low volume = 1 to 30 lobectomies, medium volume = 31 to 75 lobectomies, high volume = >75 lobectomies.

Table 4. Chest Tube Output Considered Safe for Removal After Routine Lobectomy

	Type of Practice			Duration of Practice, y					Volume of Practice[a]			
Output (mL)	Academic (No.)	Private (No.)	*p*	<10 (No.)	10–20 (No.)	20–30 (No.)	>30 (No.)	*p*	Low (No.)	Med (No.)	High (No.)	*p* (No.)
<100	25	42	0.01	5	15	22	25	0.01	35	17	15	0.01
<150	23	67		17	28	23	22		54	23	13	
<200	58	56		34	28	35	17		54	24	36	
<250	27	23		19	17	12	2		16	16	18	
<300	46	45		45	23	15	8		27	21	43	
<350	43	20		23	20	15	5		9	22	32	

[a] Low volume = 1 to 30 lobectomies, medium volume = 31 to 75 lobectomies, high volume = >75 lobectomies.

Of the surgeons surveyed, 63.4% (241 of 380) put their CT on water seal for 12 to 24 hours before removing it if there is no air leak. This pattern is consistent across practice types and the volume and location of the practice. Most thoracic surgeons (263 of 475) get daily chest roentgenograms, again with no difference among type of practice, volume, and geographic location. Surgeons longer in practice tend to get daily chest roentgenograms less frequently than younger surgeons ($p = 0.05$).

Younger and low-volume surgeons are the most likely to discharge patients with Heimlich valves or similar devices, although these devices are overall used in fewer than 49 of 475 of respondents. CT replacement after removal is uncommon, with 435 of 475 surgeons reporting CT replacement in less than 5% of patients. Academic surgeons more frequently needed to replace CTs than private practice surgeons ($p = 0.01$), whereas years in practice, volume, and geographic location made no difference.

Surgeons felt that their clinical experience, rather than the teaching they received during their residency or published journal articles, was the most important factor in determining the size and type as well as their management of CTs (Fig 1).

STS Database

The mean CT duration was 3.7 days for VATS lobectomy and 5.2 days for open lobectomy (Table 5). The overall use of Heimlich valves or a similar device at time of patient discharge among all surgeons was 6.8%.

Comment

Despite the ubiquitous use of CTs after pulmonary lobectomy, surprisingly, there is no standardized approach to their selection regarding the number, size, or management. Surgeons must balance a myriad of factors when choosing CTs and in managing them postoperatively. Considerations include the potential for clogging and dysfunction of the tube, patient discomfort and pain related to the indwelling CT, and potential risks and discomfort if replacement is required. Our survey was designed to determine the current practice pattern of cardiothoracic surgeons who are performing lobectomy to assess the factors that influence their management and choice of CTs.

Most surgeons reported using 2 CTs after open lobectomy but only 1 after minimally invasive lobectomy. CT duration was longer with open lobectomy than with minimally invasive lobectomy in our survey and in STS database. The reason for different CT practice patterns after open operations and minimally invasive operations remains unclear. Presumably, this is related to our survey's finding that most surgeons feel their practice patterns are more determined by their clinical experience than by any other factor. Open thoracotomy is associated with a greater degree of chest wall trauma and bleeding than thoracoscopic or robotic procedures [6]. The nodal dissection for lymphadenectomy may be more extensive in open operations than in a thoracoscopic operation, leading to higher CT output [7]. Many VATS surgeons perform lobectomy with minimal fissure dissection ("fissureless"), which tends to decrease the length of any postoperative air leak [8–10]. All of these considerations together may explain why the mean duration of CTs in our survey and the STS database after open lobectomy was longer than after minimally invasive lobectomy. An interesting trend without an obvious explanation is that younger, academic, and high-volume surgeons prefer 1 CT after open and minimally invasive operations compared with older, private, lower-volume surgeons, who are more likely to use 2 CTs.

The mean CT duration was 2.8 days after open lobectomy and 2.4 days after minimally invasive lobectomy. This result is much shorter than the duration of CTs reported in the STS database (Table 5). The discrepancy may be partly because the STS database includes more extensive operations such as bilobectomy and sleeve lobectomy. Also, the population of the surgeons participating in the STS database may differ from the participants in the current survey.

Various sizes and types of CTs are currently available for surgeons to use. Both considerations may have an important ramification for patients after pulmonary resection given the potential for kinking and clogging. Key to CT size selection is the flow rate of air or liquid that can be accommodated by the tube. The flow is determined by the Fanning equation ($v = \pi^2 r^5 P/fl$), where v is the flow, r is the radius, 1 is the length, P is the

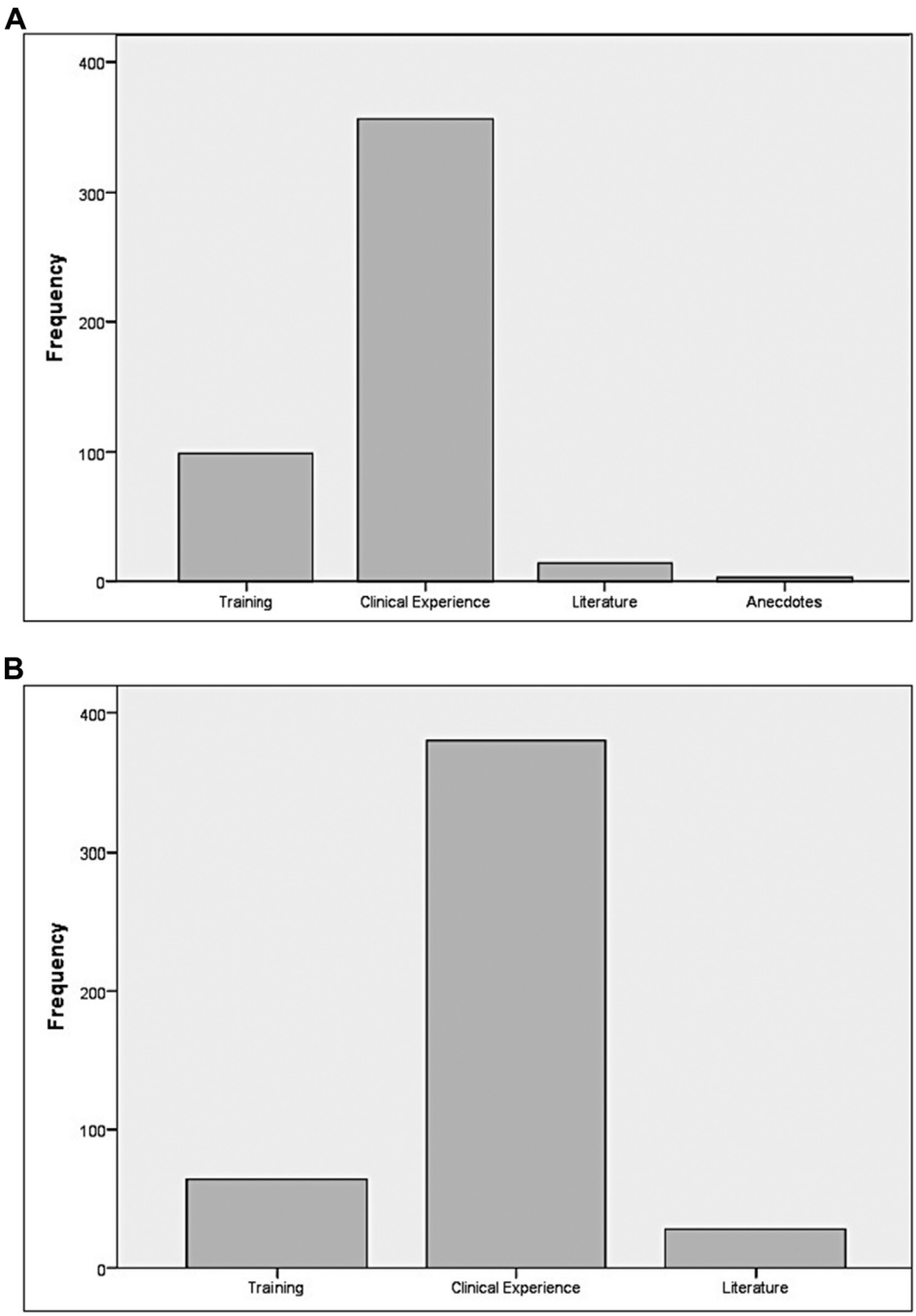

Fig 1. (A) Influences in choosing the type and number of chest tubes. (B) Influences in shaping the current chest tubes management.

pressure, and *f* is friction factor [11] The internal diameter (bore) of the tube is the critical determinant to the flow. Traditionally, surgeons have used large bore (28F to 32F) and rigid plastic tubes. Recently, silicone elastomer flexible tubes and smaller tube sizes have been introduced to reduce pleural irritation and chest pain while maintaining sufficient drainage capacity. Several retrospective reviews of cardiac and thoracic surgical experiences have confirmed the safety and efficacy of these CTs compared with traditional CTs [12–15]. However, there are case reports of death and complications when smaller silicone elastomer drains have been used after thoracic surgical procedures related to their clogging [16, 17].

In a large retrospective review of 410 thoracic surgical cases, Nakurama and colleagues [18] reported that Blake (19F and 24F) drains efficiently removed fluid and air after pulmonary resection without complications related to their use. However, in our survey of current practices, 70% (333 of 475) of surgeons continue to favor use of rigid tube. The 28F was the most popular size.

Table 5. The Society of Thoracic Surgeons General Thoracic Surgery Database: Lobectomy Procedures for Years 2004 to 2011

		VATS (n = 14,798)		Open (n = 26,914)	
Variable	Level	No.	%	No.	%
Chest tube used during the admission	Missing	438	2.96	542	2.01
	No	307	2.07	473	1.76
	Yes	14,053	94.97	25,899	96.23
Patient discharged with chest tube	Missing	13	0.09	171	0.66
	No	12,894	91.75	24,037	92.81
	Yes	1146	8.15	1,691	6.53
Chest tube duration, d	Mean	12,677	3.7	23,683	5.2
	Median		3.0		4.0

VATS = video-assisted thoracic surgery.

There is a considerable discrepancy among surgeons regarding the amount of CT output considered to be a safe amount for CT removal. This divergence is a reflection of a dearth of prospective randomized studies regarding this topic coupled with the strong influence of personal experience and training on daily management. There is a limited amount of literature regarding this subject. Cerfolio and colleagues [19] reported that it is safe to remove CTs with an output of less than 450 mL/d after pulmonary resection. Other authors are more conservative and recommend a limit of 200 mL/d as being safe [20, 21]. Our survey also reflects this variability among surgeons regarding safe CT output. It is interesting to note that private practice, more experienced, and lower-volume surgeons tend to be more conservative regarding CT output in contrast to academic practice, younger, and high-volume surgeons who tend to remove CTs sooner and with higher drainage volumes. The result is that CT replacement, though infrequent, was more often necessary for academic and younger surgeons.

Most surgeons reported obtaining daily chest roentgenograms despite multiple recent publications documenting that a routine daily chest roentgenogram is not necessary [22–25]. This underlines our survey's finding that the published literature has a limited effect on the clinical management of CTs.

Our current study has some limitations. First, the surgeons provided subjective data on their current practice; therefore, their data are subjected to recall bias that could explain the difference in CT duration and rate of Heimlich valve use between the survey and the STS database. However, despite discrepancies, the survey and the STS database both showed that the surgeons removed CTs earlier with VATS lobectomy (2.4 days and 2.8 days, respectively, for VATS and open lobectomy in the survey and 3 days and 4 days in STS database).

Second, the response rate for the survey was 475 of 5,175. The reason for the response rate is multifactorial. Many surveys were undoubtedly sent to cardiothoracic surgeons who practice cardiac surgery only and do not perform lobectomy. The e-mail addresses used might not have been current, and thus, the survey did not reached the surgeons. Finally, a survey of this nature tends to have low response rates in general. A similar survey among cardiac surgeons in use of CT after cardiac operations had response rate of 14% (110 of 770) [13]. Although the percentage of responses was low in our study, the number of responders to the survey (425) was large, with equal and diverse representation of surgeons in both academic and private practice, different geographic regions, years in practice, and volume of practice. We believe that the result of the survey reflects the general practice pattern of cardiothoracic surgeons and may identify evolving trends in CT management.

Our survey did not include some aspects of CT management, such as use of a digital drainage system. We did not include the drainage system in the survey because there are so many different commercial systems available using different technology and software to estimate the airflow.

In conclusion, there are real differences among various types of thoracic surgeons in the number and types of CTs used and their management policy after lobectomy. The surveyed surgeons felt that clinical experience is the key factor that determines their CT management and choice. A formal clinical guideline by the STS would be helpful in identifying best CT selection and management strategies.

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