doi:10.1510/icvts.2009.211219

INTERACTIVE CARDIOVASCULAR AND THORACIC SURGERY

Interactive CardioVascular and Thoracic Surgery 9 (2009) 925–931

www.icvts.org

Editorial - Thoracic oncologic

Lung function evaluation before surgery in lung cancer patients: how are recent advances put into practice? A survey among members of the European Society of Thoracic Surgeons (ESTS) and of the Thoracic Oncology Section of the European Respiratory Society (ERS)

Anne Charloux[a,*], Alessandro Brunelli[b], Chris T. Bolliger[c], Gaetano Rocco[d], Jean-Paul Sculier[e], Gonzalo Varela[f], Marc Licker[g], Mark K. Ferguson[h], Corinne Faivre-Finn[i], Rudolf Maria Huber[j], Enrico M. Clini[k], Thida Win[l], Dirk De Ruysscher[m], Lee Goldman[n], on behalf of the European Respiratory Society and European Society of Thoracic Surgeons Joint Task Force on Fitness for Radical Therapy

[a]*Service de Physiologie et d'Explorations Fonctionnelles, Pôle de Pathologie Thoracique, Nouvel Hopital Civil, Hopitaux Universitaires de Strasbourg, BP426, Strasbourg Cedex 67091, France*

[b]*Division of Thoracic Surgery, Umberto I Regional Hospital, Ancona, Italy*

[c]*Division of Pulmonology, Department of Medicine, Faculty of Health Sciences, University of Stellenbosch, Cape Town, South Africa*

[d]*Division of Thoracic Surgery, National Cancer Institute, Pascale Foundation, Naples, Italy*

[e]*Department of Intensive Care Unit and Thoracic Oncology, Institut Jules Bordet, Centre des Tumeurs de l'Université Libre de Bruxelles (ULB), Brussels, Belgium*

[f]*Division of Thoracic Surgery, Salamanca University Hospital, Spain*

[g]*Department of Anesthesiology, Pharmacology and Intensive Care, Faculty of Medicine, University Hospital of Geneva, Geneva, Switzerland*

[h]*Department of Surgery, The University of Chicago, Chicago, USA*

[i]*Department of Clinical Oncology, The Christie NHS Foundation Trust, Manchester, UK*

[j]*Division of Respiratory Medicine, Medizinische Klinik-Innenstadt, Ludwig-Maximilians-University, Munich, Germany*

[k]*Institute of Respiratory Diseases, University of Modena-Reggio Emilia, Pavullo, Italy*

[l]*Respiratory Medicine, Lister Hospital, Stevenage, UK*

[m]*Department of Radiation Oncology (Maastro Clinic), Maastricht University Medical Center, GROW, Maastricht, The Netherlands*

[n]*Department of Medicine, Columbia University, New York, USA*

Received 7 May 2009; received in revised form 22 July 2009; accepted 21 August 2009

Keywords: Lung cancer; Lung surgery; Guidelines; Survey

In recent years, an abundant literature related to preoperative evaluation of lung cancer patients has been published. Therefore, the European Respiratory Society (ERS) and the European Society of Thoracic Surgeons (ESTS) agreed to form a task force with the aim of developing new guidelines and recommendations to evaluate the fitness of lung cancer patients undergoing radical treatment. One of the first priorities of the task force members was to assess the state-of-the-art of functional evaluation and perioperative treatment of these patients. A multiple-choice survey covering several aspects of this subject was designed and administered online. This survey aimed at assessing how the recent advances in preoperative evaluation of lung function have been put into practice. More specifically, we focused on the cardiologic evaluation before lung resection, the role of diffusing capacity of the lung for carbon monoxide (DLCO) in predicting complications, and the interpretation of split function studies. We asked the physicians to specify the role of exercise tests in their algorithms, and how high-tech or low-tech exercise tests are selected in their current practices. The perioperative management of patients was also considered, with questions aimed at investigating the indications for physiotherapy and rehabilitation, and the criteria for admission in intensive care units (ICU). Eventually, since several studies showed there is a positive impact of specialization and volume on the results of surgical cancer treatment, physicians were invited to give their opinion on the qualification of the surgeon as well as the specialization of the centers required to manage lung cancer patients.

Questionnaire design

A web-based questionnaire was designed by the 14 experts of the ERS/ESTS Task Force. All members of the ESTS and of the Oncology group of the ERS were invited to respond from December 2007 to April 2008 using a commercially available, online survey designer (www.surveymonkey.com).

*Corresponding author. Tel.: +33 (0)3 88 69 55 08 79.
E-mail address: anne.charloux@chru-strasbourg.fr (A. Charloux).

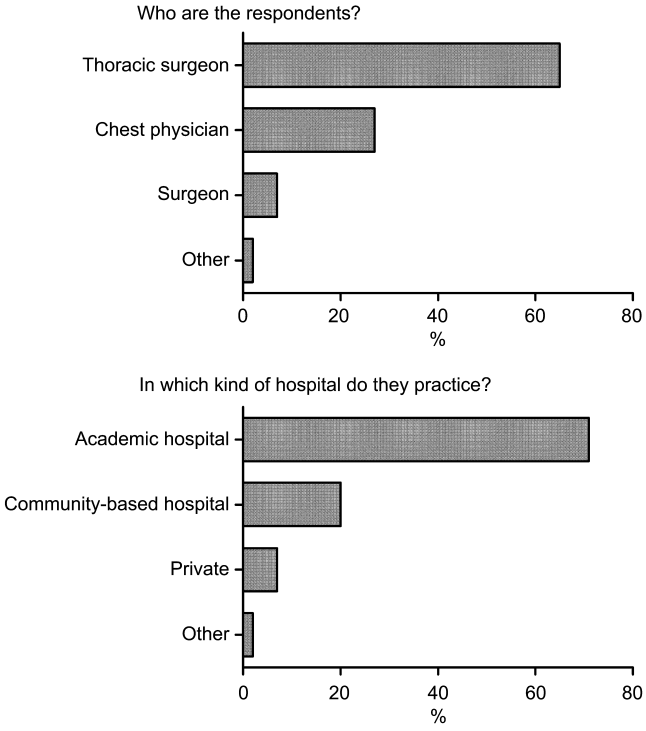

Fig. 1. Characteristics of respondents.

The questionnaire consisted of 47 questions covering the various issues addressed by the task force. In this article, we focused on preoperative assessment and patients' care management, which were covered by 32 questions.

Respondents

The number of respondents to the 32 questions of this survey ranged from 179 to 265 (6.8% and 17.9% of the 1485 successfully delivered E-mails, respectively). This survey reflects the practice of physicians from 38 countries (87% of European countries). Interpretation of these data should of course take into account who provided the responses. This survey reflects mainly the practice of surgeons who accounted for 72% of respondents (including 7% of general surgeons), chest physicians accounting for 27% of respondents. Respondents worked for the most part in academic hospitals (72%), but also in community-based hospitals (20%), and in private hospitals (7%) (Fig. 1). Responses from physicians working in academic hospitals did not differ significantly from those of physicians working in community-based or in private hospitals. However, it is likely, given the low response rate, that this survey is biased towards physicians and surgeons interested in the functional assessment before lung cancer surgery, and may not reflect all the ESTS and ERS members' opinion.

Preoperative work-up

Is the preoperative work-up standardized, and who performs it?

It is worth noting that almost half of physicians have a multidisciplinary approach to the preoperative work-up, as recommended in guidelines [1, 2]. Nonetheless, for one-third of the respondents of this survey, the preoperative work-up is still performed by chest physicians alone (Table 1). Another interesting result is that more than half of physicians performed a standardized functional evaluation before lung cancer surgery. However, only one-third of respondents follows published recommendations. The latter point suggests that published guidelines might be outdated, may conflict with the physicians' own experience and opinion, or cannot be implemented in some centers because of the lack of availability of technical resources, or because of economic and logistic issues. Whatever the reasons, this also indicates that more research is needed to improve, validate and implement recommendations.

Cardiologic evaluation

Few guidelines provided detailed recommendations about the cardiologic evaluation before lung resection [1, 2]. This shortcoming likely explains some results of this survey, such as the divergent opinion about recommendation of β-blockers before lung surgery (29% recommend them in patients with known coronary disease, 31% in patients with known or suspected coronary disease, and 35% respondents never recommend them) and the high rate (55%) of system-

Table 1
Is the preoperative work-up formalized, and who performs it?

	Response count	Response percent
At your institution, fitness of lung cancer patients before lung resection: (262 responses)		
Is a multidisciplinary team approach	112	42.7
Is based on published guidelines or recommendations (the American College of Chest Physicians, the British Thoracic Society guidelines, C. Bolliger's algorithm ...)	84	32.1
Is based on an institutional algorithm	46	17.6
Adherence to guidelines or formalization of the successive steps of functional assessment is difficult because of medical, technical or logistic issues	20	7.6
In your center, who performs the work-up for a lung cancer patient presenting with a non-metastatic disease? (179 responses)		
Chest physician	62	34.6
Thoracic surgeon	30	16.8
Medical oncologist	4	2.2
Surgeon	2	1.1
Radiation oncologist	0	0.0
A multidisciplinary team including most of these specialists	79	44.1
Other	2	1.1

atic use of echocardiography (Table 2). The ERS/ESTS task force [3] concluded that patients with ischemic heart disease generally do not benefit from newly prescribed perioperative β-blockade, but that β-blockers should be continued in patients who are already taking them and may be beneficial as new therapy in very high-risk patients. Echocardiography should be obtained only when valvular disease, left ventricle dysfunction or pulmonary hypertension is suspected, but should not be done systematically. Another significant result is the under-use of cardiac indexes. Cardiac risk for lung resection can be stratified through validated indexes based on simple items, such as the patient's history, physical examination and electrocardiogram [4–6]. The British Thoracic Society (BTS) and the American College of Chest Physicians (ACCP) [1, 2] recommend the use of ACC/AHA guidelines [5] and the ERS/ESTS task force recommend the revised cardiac risk index (RCRI) index [3]. However, two-thirds of participants do not use these indexes, which also define when the patient should be referred to the cardiologist. Eventually, high-technology exercise tests are prescribed by most participants (75% of surgeons and 57% of physicians) to assess concomitantly the cardiac and the pulmonary status of their patients, additional cardiologic tests being prescribed only if a coronary disease is detected. A lower proportion of surgeons (17%) and physicians (36%) always prescribe additional cardiologic tests to patients undergoing cardiopulmonary exercise test (CPET).

Lung function tests

Despite results of recent studies demonstrating that diffusing capacity is important in predicting postoperative complications, even in patients with a normal forced expiratory volume in one second (FEV_1) [7, 8], DLCO is assessed in all patients only by one-third of respondents (Table 3). Most physicians (57%) assess DLCO only in patients with compromised lung. This seems somewhat inconsistent with the subsequent responses showing that 74% of participants think DLCO is a strong predictor of outcomes. Consequently, the position of DLCO needs to be clearly defined in the future guidelines.

The use of split function studies is well established in current practice. However, two points of interpretation are less known: segment counting is recommended rather than scintigraphic techniques before lobectomy, and ventilation and perfusion scintigraphy are equivalent in predicting predicted postoperative (ppo) lung function [9, 10].

Exercise tests

Unsurprisingly, for 77% of respondents, the main role of exercise tests is to avoid lung resection in patients who perform below a specific cut-value (Table 4). This clearly underlines the weight of this test in the decision to operate or not. Physicians also use this test in less 'validated' indications: to discriminate a high-risk population who will be sent to the ICU after the procedure (49%) or to whom preoperative rehabilitation will be proposed (28%). Exercise tests are prescribed by 24% of physicians in all patients before lung cancer surgery.

Most respondents prescribe integrated cardiopulmonary assessment (CPET) after calculation of ppo values, following BTS or ACCP guidelines. Only a quarter of them use high-tech exercise tests before split function studies, following recommendations by Bolliger and Perruchoud [11]. However, cut-off values used by physicians differ from those recommended by Bolliger and Perruchoud, since only 20% of respondents perform exercise tests if FEV_1 and DLCO are lower than 80%. Exercise tests appear to be proposed to patients with severely compromised lung function, the most used cut-off values being around 40% of predicted for both

Table 2
Cardiologic evaluation

	Response count	Response percent
For preoperative cardiac risk stratification, is one of the following scoring systems currently used in your institution? (more than one answer allowed) (184 responses)		
Goldman	38	20.7
Lee	3	1.6
Revised cardiac	18	9.8
None	125	67.9
Other	9	4.9
In your practice, patients undergoing cyclergospirometry or treadmill with integrated cardiopulmonary assessment, are they also submitted to other cardiologic examinations? (225 responses)		
No never	20	8.9
Yes, but only in case CPET detected coronary artery disease	152	67.6
Yes always	53	23.6
Other than testing related to lung function, is any other preoperative cardiac testing routinely recommended for major pulmonary surgery at your institution? (more than one answer allowed) (198 responses)		
Echocardiography	109	55.1
Thallium/sestamibi scanning	5	2.5
Both	13	6.6
Neither	76	38.4
Is perioperative β-blockade to reduce cardiac complications recommended for major lung surgery patients with: (191 responses)		
Known coronary disease	56	29.3
Known or suspected coronary disease	60	31.4
Regardless of the presence or absence of coronary disease	8	4.2
Never	67	35.1

CPET, cardiopulmonary exercise test.

Table 3
Interpretation of DLCO and ppo values

	Response count	Response percent
Which statement do you believe is most accurate regarding the use of DLCO in predicting outcomes after major lung resection? (242 responses)		
DLCO is not related to adverse outcomes	2	0.8
DLCO may have a minor statistical relationship to outcomes	44	18.2
DLCO is a strong predictor of outcomes	179	74.0
DLCO is the strongest predictor of outcomes	17	7.0
Which statement most closely matches your clinical practice regarding the use of DLCO in evaluation of lung resection candidates? (246 responses)		
I don't assess it	13	5.3
The tests I get include it but I don't pay much attention to it	4	1.6
I think it's important to assess in patients with compromised lung function	141	57.3
I think it's important to assess in all patients	88	35.8
ppoFEV_1 after lobectomy was statistically significant correlated with: (246 responses)		
Postoperative lung function using the simple segment counting technique	94	38.2
Postoperative lung function using scintigraphic techniques	63	25.6
Scintigraphic technique significantly better than segment counting	55	22.4
Postoperative lung function, with similar results using V scintigram or Q scintigram	34	13.8
The following statements are true for predicting post-pneumonectomy FEV_1 (multiple answers allowed): (236 responses)		
The correlation between actual and predicted values was significant for FEV_1 in litre	78	33.1
The correlation between actual and predicted values was significant for FEV_1 percentage of predicted	116	49.2
Using ventilation scintigram or perfusion scintigram or combined scans offers similar result	63	26.7
Scintigraphic ppoFEV_1 was lower than the actual postoperative FEV_1	90	38.1

DLCO, diffusing capacity of the lung for carbon monoxide; ppo, predicted postoperative; FEV_1, force expiratory volume in one second.

Table 4
Indication of exercise tests and current practice of high-technology exercise tests

	Response count	Response percent
In your current practice, exercise tests before lung resection are aimed at (more than one answer allowed) (188 reponses)		
To contraindicate lung resection in patients under a specific cut-value	145	77.1
To discriminate a high-risk population (depending on a specific cut-value) who will be sent to the ICU after the procedure	92	48.9
To indicate preoperative rehabilitation	52	27.7
To select patients to indicate calculation of estimated postoperative values of FEV_1 and/or DLCO	50	26.6
To indicate more intensive physiotherapy during the postoperative period	43	22.9
Other purpose/s (please specify)	8	4.3
According to your criteria regarding evaluation for lung cancer resection, exercise tests are indicated (more than one answer allowed) (195 responses)		
In COPD patients with an estimated postoperative FEV_1 $<40\%$	96	49.2
In patients with an estimated postoperative DLCO $<40\%$	62	31.8
In patients with a preoperative DLCO $<60\%$	57	29.2
As a routine in all patients	47	24.1
In COPD patients with a preoperative FEV_1 $<80\%$	38	19.5
Other situation (please specify)	10	5.1
High-tech exercise test		
In your hospital is there a CPET lab readily available? (230 responses)		
Yes	172	74.8
No	58	25.2
In your current practice which proportion of candidates for lung resection perform a $V\dot{O}_{2\ max}$ measurement through a formal CPET? (224 responses)		
None	42	18.8
10%	86	38.4
30%	51	22.8
50%	18	8.0
80%	16	7.1
All patients	11	4.9
In your practice and in patients performing $V\dot{O}_{2\ max}$ assessment, which is your lower limit of operability? (196 responses)		
$V\dot{O}_{2\ max}$ <15 ml/kg/min ($+$ppoFEV_1 and ppoDLCO $<40\%$)	95	48.5
$V\dot{O}_{2\ max}$ <10 ml/kg/min	42	21.4
$V\dot{O}_{2\ max}$ <15 ml/kg/min regardless the PFTs values	27	13.8
$V\dot{O}_{2\ max}$ $<50\%$	11	5.6
ppo$V\dot{O}_{2\ max}$ <10 ml/kg/min	9	4.6
Other (please specify)	12	6.1

ICU, intensive care unit; FEV_1, force expiratory volume in one second; DLCO, diffusing capacity of the lung for carbon monoxide; COPD, chronic obstructive pulmonary disease; CPET, cardiopulmonary exercise test; $V\dot{O}_{2\ max}$, maximal oxygen consumption; ppo, predicted postoperative; PFT, pulmonary function tests.

FEV_1 and DLCO. This likely explains that only 10–30% of patients have a high-tech exercise test according to the majority of respondents, even though these tests are available in 75% of their centers. The high variability of practice in exercise tests may be partly due to a lack of availability of CPET in some centers, but also emphasizes the current debates about indications of high-technology tests.

Low-technology exercise tests usually are part of current practice, as demonstrated by the very low percentage of respondents who never perform them (6.5%) (Table 5). However, these tests are prescribed in very different situations, e.g. in patients with ppoFEV_1 or ppoDLCO values lower than 40% (33%), as a screening test in patients with FEV_1 or DLCO lower than 80% (28%), or as an alternative to CPET (20%). The 6-min walk and the stair climbing test are the most frequently prescribed low-technology tests, the shuttle walk test being used by only 6% of physicians. Interestingly, low-technology tests belong to the first stage screening for 24% of surgeons, but only for 9% of chest physicians. In addition, 42% of surgeons choose stair climbing, compared to 13% of chest physicians. Chest physicians prefer the 6-min walk test. This test is prescribed by 56% of chest physicians, but only by 24% of surgeons. It is worth noting that the 6-min walk test is widely used whereas its association with postoperative outcome after lung resection is highly controversial [12–14]. The recent literature on the stair climbing test [15] appears to be favorably received since 64% of respondents think this test could predict lung cancer outcome, despite standardization is regarded as insufficient by 75% of surgeons and 92% of chest physicians. Taken as a whole, these results underline the need to clarify both indications and limits of low-technology exercise performed before lung resection.

Patient's care management

Scoring systems

Several multifactorial scoring systems and predictive models have been published recently with the objective of providing a standardized risk assessment to compare outcomes across different hospitals. In this survey, almost 75% of physicians do not use them, either because they are too difficult to calculate (52%) or because they were felt not to add any information (18%) or being inaccurate and not useful (4%). The role and limitations of these systems for selection purposes still need to be clarified to limit their improper use in surgical lung cancer patients.

Aim and indication of physiotherapy and rehabilitation

Physiotherapy, as usually delivered in a multidisciplinary rehabilitation context, is not widely reported in literature [16]; nonetheless, 80% of respondents have declared to refer their patients to both pre- or post-surgery, in order to decrease the risk of postoperative atelectasis (75%), decrease the risk of postoperative respiratory insufficiency (72%), facilitate postoperative bronchial toilette (72%), improve functional exercise capacity (57%), improve long-term quality of life (47%), and improve immediate postoperative pulmonary volumes (40%). Hence, physicians assign substantial benefit to pulmonary rehabilitation, that is highly probable but not firmly established in surgical patients with lung cancer [17, 18]. In particular, specific characteristics of patients (i.e. underlying comorbidities and/or functional status) who are likely to benefit from rehabilitation course still need to be elucidated.

Admission to ICU after surgery

Patients with pneumonectomy necessitate admission to ICU according to 80% of respondents. Opinions differ regarding admission of patients with lobectomy or minor resection: most respondents (53%) said patients may be transferred to the surgical ward in stable cardiorespiratory condition after a short stay in a high dependency unit/intermediate care unit (HDU/IntCU); 37% of respondents said patients should be admitted in HDU/IntCU for at least 24 h, whereas 12% of respondents felt patients should be

Table 5
Current practice of low-technology exercise tests before lung cancer surgery

	Response count	Response percent
Which is in your view the position of low-tech exercise tests in a functional algorithm (223 responses)		
To be performed only in patients with ppoFEV_1 <40% or ppoDLCO <40%	74	33.2
First stage screening tests to patients with FEV_1 <80% or DLCO <80%	63	28.3
As an alternative to $V\dot{O}_{2\ max}$ measurement (cycling/treadmill) as a last step to decide operability	45	20.2
First stage screening tests to all patients	41	18.4
In your current practice, which of the following low-tech exercise tests are performed in at least 50% of patients (more than one answer allowed) (231 responses)		
The choice of the test depends on the patient characteristics and co-morbidities	80	34.6
6-min walking test	77	33.3
Stair climbing test	73	31.6
Shuttle walk test	13	5.6
One of the above, but only occasionally (<50% of patients)	71	30.7
Never performed in any patients	15	6.5
Other (please specify)	6	2.6
The following statements are true (more than one answer allowed) (231 responses)		
Distance covered during the shuttle walk test is correlated well with $V\dot{O}_{2\ max}$ in COPD as well as lung cancer patients. Interpretation of the distance walked in 6 min is well standardised	120	51.9
Stair climbing test is performed in a standardised manner	48	20.8
Stair climbing test could predict lung cancer surgical outcome	148	64.1

ppo, predicted postoperative; FEV_1, force expiratory volume in one second; DLCO, diffusing capacity of the lung for carbon monoxide; $V\dot{O}_{2\ max}$, maximal oxygen consumption; COPD, chronic obstructive pulmonary disease.

admitted in ICU for at least 24 h. Recently, published recommendations by the ERS/ESTS task force [3] are that in an emergency situation, patients requiring support for organ failure (i.e. ventilatory mechanical assistance) should be admitted to ICU. Patients undergoing complex pulmonary resection, those with marginal cardiopulmonary reserve and those with moderate to high risk should be admitted to HDU.

Future trends

Among the numerous outcomes proposed by the questionnaire and the physicians themselves, measurement of long-term impairment of quality of life was the highest priority for 89% of respondents. Indeed, the commonly used outcomes, especially pulmonary function assessment, are poorly correlated with symptoms and quality of life after lung resection [19, 20]. This interest in quality of life assessment should encourage initiation of research projects in this area. Other responses included the need of home care after discharge (55%), how hospital costs are influenced by a complicated postoperative period (33%), long-term psychological impairment after surgery (33%), and the expected period of inability to work for medical reasons after surgery (31%).

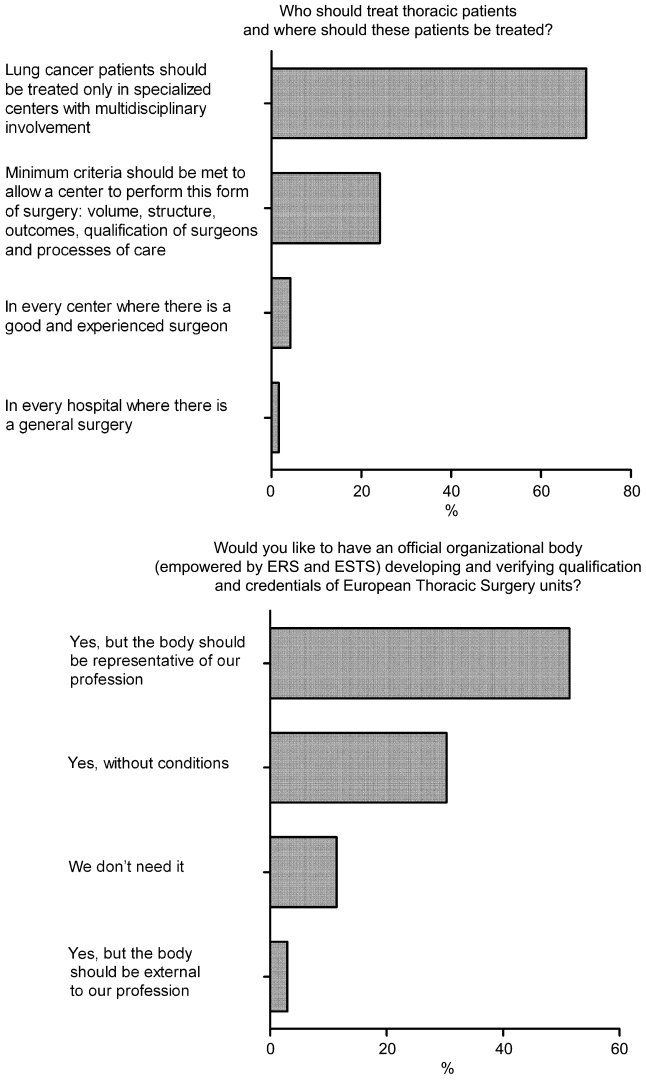

Fig. 2. Who should treat patients with lung cancer and where should these patients be treated?

Who should treat thoracic patients and where these patients should be treated?

There is a clear consensus asserting that lung cancer patients should be treated in specialized centers and that minimum criteria should be met to allow a hospital to permit lung cancer surgery. In addition, there is an agreement on the need of a European official organization to develop and verify credentials to guarantee the patients to be operated under high quality surgical standards. The only constraint emphasized by the respondents is that the official organizational body should be representative of the profession (Fig. 2).

Conclusion

This survey provides a snapshot of the opinions of 200 physicians with a great commitment to treating lung cancer, although it does not describe in detail the current practice of the preoperative assessment of lung cancer patients. The responses to the questionnaire help define the lack of consensus in some areas as well as difficulties in putting existing recommendations into practice. The results of this survey warrant the revision of published guidelines or the development of new ones to provide clinicians with clear, updated, and pragmatic recommendations [21, 22]. Indeed, information derived from this analysis was taken into consideration during preparation of the ERS-ESTS guidelines for evaluating fitness for radical treatment of lung cancer patients [3]. This questionnaire is planned to be repeated after the publication of the ERS/ESTS guidelines [3] to assess their impact on clinical practice.

Acknowledgments

The authors wish to thank Eveline Internullo, who implemented the questionnaire in the survey designer.

References

[1] BTS guidelines: guidelines on the selection of patients with lung cancer for surgery. Thorax 2001;56:89–108.
[2] Colice GL, Shafazand S, Griffin JP, Keenan R, Bolliger CT. Physiologic evaluation of the patient with lung cancer being considered for resectional surgery: ACCP evidenced-based clinical practice guidelines (2nd edition). Chest 2007;132(3 Suppl):161S–177S.
[3] Brunelli A, Charloux A, Bolliger CT, Rocco G, Sculier JP, Varela G, Licker MJ, Ferguson MK, Faivre-Finn C, Huber RM, Clini EM, Win T, De Ruysscher D, Goldman L, on behalf of the European Respiratory Society and European Society of Thoracic Surgeons Joint Task Force on Fitness for Radical Therapy. ERS-ESTS clinical guidelines on fitness for radical therapy in lung cancer patients (surgery and radiochemotherapy). Eur Respir J 2009;34:17–41.
[4] Auerbach A, Goldman L. Assessing and reducing the cardiac risk of noncardiac surgery. Circulation 2006;113:1361–1376.

[5] Fleisher LA, Beckman JA, Brown KA, Calkins H, Chaikof E, Fleischmann KE, Freeman WK, Froehlich JB, Kasper EK, Kersten JR, Riegel B, Robb JF, Smith SC Jr, Jacobs AK, Adams CD, Anderson JL, Antman EM, Buller CE, Creager MA, Ettinger SM, Faxon DP, Fuster V, Halperin JL, Hiratzka LF, Hunt SA, Lytle BW, Nishimura R, Ornato JP, Page RL, Tarkington LG, Yancy CW. ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery): developed in collaboration with the American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, and Society for Vascular Surgery. Circulation 2007;116:e418–e499.

[6] Lee TH, Marcantonio ER, Mangione CM, Thomas EJ, Polanczyk CA, Cook EF, Sugarbaker DJ, Donaldson MC, Poss R, Ho KK, Ludwig LE, Pedan A, Goldman L. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation 1999;100:1043–1049.

[7] Brunelli A, Refai MA, Salati M, Sabbatini A, Morgan-Hughes NJ, Rocco G. Carbon monoxide lung diffusion capacity improves risk stratification in patients without airflow limitation: evidence for systematic measurement before lung resection. Eur J Cardiothorac Surg 2006;29:567–570.

[8] Ferguson MK, Vigneswaran WT. Diffusing capacity predicts morbidity after lung resection in patients without obstructive lung disease. Ann Thorac Surg 2008;85:1158–1164; discussion 1164–1165.

[9] Win T, Laroche CM, Groves AM, White C, Wells FC, Ritchie AJ, Tasker AD. Use of quantitative lung scintigraphy to predict postoperative pulmonary function in lung cancer patients undergoing lobectomy. Ann Thorac Surg 2004;78:1215–1218.

[10] Win T, Tasker AD, Groves AM, White C, Ritchie AJ, Wells FC, Laroche CM. Ventilation-perfusion scintigraphy to predict postoperative pulmonary function in lung cancer patients undergoing pneumonectomy. AJR Am J Roentgenol 2006;187:1260–1265.

[11] Bolliger CT, Perruchoud AP. Functional evaluation of the lung resection candidate. Eur Respir J 1998;11:198–212.

[12] Holden DA, Rice TW, Stelmach K, Meeker DP. Exercise testing, 6-min walk, and stair climb in the evaluation of patients at high risk for pulmonary resection. Chest 1992;102:1774–1779.

[13] Markos J, Mullan BP, Hillman DR, Musk AW, Antico VF, Lovegrove FT, Carter MJ, Finucane KE. Preoperative assessment as a predictor of mortality and morbidity after lung resection. Am Rev Respir Dis 1989; 139:902–910.

[14] Pierce RJ, Copland JM, Sharpe K, Barter CE. Preoperative risk evaluation for lung cancer resection: predicted postoperative product as a predictor of surgical mortality. Am J Respir Crit Care Med 1994;150:947–955.

[15] Brunelli A, Refai M, Xiume F, Salati M, Sciarra V, Socci L, Sabbatini A. Performance at symptom-limited stair-climbing test is associated with increased cardiopulmonary complications, mortality, and costs after major lung resection. Ann Thorac Surg 2008;86:240–247; discussion 247–248.

[16] Varela G, Ballesteros E, Jimenez MF, Novoa N, Aranda JL. Cost-effectiveness analysis of prophylactic respiratory physiotherapy in pulmonary lobectomy. Eur J Cardiothorac Surg 2006;29:216–220.

[17] Nazarian J. Cardiopulmonary rehabilitation after treatment for lung cancer. Curr Treat Options Oncol 2004;5:75–82.

[18] Nici L. Preoperative and postoperative pulmonary rehabilitation in lung cancer patients. Thorac Surg Clin 2008;18:39–43.

[19] Larsen KR, Svendsen UG, Milman N, Brenoe J, Petersen BN. Cardiopulmonary function at rest and during exercise after resection for bronchial carcinoma. Ann Thorac Surg 1997;64:960–964.

[20] Sarna L, Padilla G, Holmes C, Tashkin D, Brecht ML, Evangelista L. Quality of life of long-term survivors of non-small-cell lung cancer. J Clin Oncol 2002;20:2920–2929.

[21] Bolliger CT. Functional reserves before lung resection: how low can we go? Respiration 2009;78:20–22 Epub 2009 Apr 30.

[22] Brunelli A. Algorithm for functional evaluation of the lung resection candidates: time for reappraisal? Respiration 2009;78:117–118 Epub 2009 Mar 27.