INTERSOCIETY CONSENSUS STATEMENT OF PREOPERATIVE EVALUATION FOR ELECTIVE LUNG RESECTION SURGERY.

G. DELLA ROCCA¹, C. COCCIA², F. PIERCONTI³, R. BADAGLIACCA³, CD VIZZA³, V. CILENTI¹, M. PAPALE⁴, E. MELIS⁵, F. FACCIOLÒ⁵

¹ Della Rocca Giorgio, Department of Anesthesia and Intensive Care Medicine, University of Udine. Udine, Italy
² Coccia Cecilia, Pierconti Federico, Department of Anesthesia, “Regina Elena” National Cancer Institute. Rome, Italy.
³ Badagliacca Roberto, Vizza Carmine Dario, Department of Cardiology. “Sapienza” University of Rome. Rome, Italy
⁴ V. Cilenti, Maria Papale, Department of Respiratory Physiology, Regina Elena National Cancer Institute. Rome, Italy.
⁵ Melis Enrico, Facciolo Francesco: Thoracic Surgery Unit, Department of Surgical Oncology, “Regina Elena” National Cancer Institute of Rome

G. Della Rocca, C. Coccia and F. Pierconti —on behalf of Società Italiana di Anestesia, Analgesia, Rianimazione e Terapia Intensiva (SIAARTI).

R. Badagliacca, CD Vizza —on behalf of Società Italiana di Cardiologia (SIC)

V. Cilenti, M. Papale —on behalf of Associazione Italiana Pneumologi Ospedalieri (AIPO)

E. Melis, F. Facciolo —on behalf of Società Italiana di Chirurgia Toracica (SICT)

Address for correspondence:
G. Della Rocca
Clinica Anestesia e Rianimazione
Padiglione Petracco
AOU Udine
P.le S. M. Misericordia, 15
33100 Udine, Italy
E-Mail: giorgio.dellarocca@uniud.it
Tel. +39 0432 559500-1
Fax. +39 0432 559512
ABSTRACT

Different guidelines are available in the literature, with quite different recommendations. None of them is a multidisciplinary effort as the one presented. The Italian Society of Anesthesia, Analgesia, Resuscitation, and Intensive Care (SIAARTI), the Italian Society of Thoracic Surgery (SICT), the Italian Society of Cardiology (SIC), the Association of Italian Pulmonologists (AIPO) have set down easy suggestions for preoperative evaluation of patients scheduled for “elective” lung resection surgery. This inter-society consensus statement aims at simplifying the grading system reported in the literature, and its goal is to benefit its clinical application.

Lung resection surgery has a degree of well-known morbidity and mortality. Special focus is given to the pulmonologist and the cardiologist point of view.

Cardiac evaluation follows the actual international guidelines and if metabolic equivalent (METs) is superior or equal than 4 the patient do not need any additional test. In case of METs ≤ 4 the cardiologist has to discriminate if it make sense to evaluate with non invasive/invasive tests that specific patient.

In addition to the arterial blood gas sample and percutaneous oxygen saturation, to discriminate lung resection limitations, physicians have to consider predicted postoperative FEV1 and DLCO to evaluate risks and benefits.

All the preexisting diseases, such as renal disease, obesity, systemic and pulmonary hypertension, diabetes represent additional risk factors. The preoperative risk evaluation, to stratify the global risk for each patient should be assessed by all the team together (surgeon, anesthesiologist and when required cardiologist and pulmonologist) but only of involved and familiar in the pre- intra- and post-operative management of these patients.

Finally, dividing all pts from those at high risk it will be easy also to trace a strategy for all patients, with at least with one preoperative organ dysfunction, who need a predicted postoperative admittance in ICU.

KEY WORDS
Preoperative evaluation, thoracic surgery, cardiac risk, spirometry, risk factors,

Purpose

Four purposes have been identified:

1. Keeping patients as safe as possible concerning the possibility of a preoperative evaluation and risk stratification in case of lung resection surgery in adults.
2. Reducing the possible complications linked principally to respiratory or cardiovascular systems and other risk factors.
3. Providing all specialists involved with unequivocal indications on the types of lung surgical resection in keeping with data reported in the national and international literature as well as with the laws in force in our country.
4. Supplying useful suggestions on clinical practice in all those situations in which no clear evidence is reported.

The creation of a **personalised, shared folder for preoperative evaluation** in patients scheduled for elective lung resection surgery to assess the risk stratification and or initiation of adequate therapy is suggested **in all hospital settings**. Furthermore, we recommend that the creation of this document be suggested by all administrations involved (hospital directorate, local health authority, regional administration, etc.).
INTRODUCTION
The thoracic surgery has the peculiar characteristic that the management and the function of the lung resected may interfere(with the pulmonary system in toto) with the cardiovascular system and are both able to change the outcome, in terms of morbidity and mortality.

The surgical guidelines for the preoperative evaluation of patients undergone pulmonary resection take into consideration only the stratification of the respiratory risk based on the type of surgery (1).

The cardiac assessment and the evaluation to reduce pulmonary complications are described in guidelines aimed at all types of non-cardiac surgery and often are difficult to be applied to specific thoracic problems.

The need for a Consensus with a position paper to share the different aspects among the physicians, such as surgeon, cardiologist, pulmonologist and anesthetist, involved in the preoperative evaluation of patients is asked through the position of the respective scientific societies.

This intersociety consensus aims at being a simplification in the grading system reported in the literature, and its purpose is that of favouring its clinical application. For this reason, we believed that there was no need to define the strength of recommendations provided, since few national and international dedicated guidelines already exist. (1-8). This statement is therefore addressed to the Italian scientific community and institutions with the aim of attaining good clinical practice in the profession.

The present statement will be published in the Journals of the Societies participating in this consensus.

Surgical evaluation for pulmonary resections and morbidity and mortality.

Lobar resections.
Lobar resections include resection of one lobe, two lobes and sleeve lobar resections. Mediastinal lymph node dissection, in surgical treatment of lung cancer, is essential to achieve accurate staging and together with lung resection improves survival (9,10).

Lobectomy and Bilobectomy.
In patients without risk factors and also in selected old patients, standard lobectomy and bilobectomy are the choice treatment in the management of lung cancer. It is also performed in case of lobe involvement secondary to chronic infections or bronchiectasis. Mortality after pulmonary lobectomy varies between 0 and 4.4% (11-14); nevertheless, morbidity rate may be as high as in pneumonectomy (23.8 % versus 25.7%) (15).

Sleeve lobectomy, consists with the removal of a portion of a main bronchus in conjunction with the involved lobar bronchus and associated lung tissue; indicated in case of invasion of the origin of the lobar bronchus, are valid alternative to a pneumonectomy. When compared with pneumonectomy, sleeve lobectomy offers comparable long-term results, decreased mortality and morbidity, and improved quality of life(16-18).
Indications for sleeve lobectomy are patients over the age of 70 and patients with compromised cardiopulmonary function; a postoperative predicted forced expiratory volume in 1 second (FEV1) of less than 50% indicates a likelihood of complications following pneumonectomy. Artery sleeve lobectomies are also now performed in case of main artery involvement. (16-18).

Mortality varies from 1.0% to 12% but it can be higher in patients undergoing combined angioplasty and bronchial sleeve procedures. Mortality is also higher in patients over the age of 70 and in patients who are functionally compromised (19-21).

**Pneumonectomy.**

As the right lung compromises 60% of the total lung volume, right pneumonectomy is more physiologically taxing than a left pneumonectomy and is associated with a higher morbidity and mortality. In patients undergoing standard pneumonectomy for NSCLC, mortality rates vary widely, from 3% to 12%. Morbidity is also higher after pneumonectomy compared to lesser pulmonary resections; overall complications rates range from 15% to as high as 75% (22-25).

**Lesser lung resections.**

- **Segmentectomy.** As an anatomic resection, segmentectomy obeys the principles of cancer surgery, and removing the associated lymph nodes provides excellent results; this is especially the case of patients with early stage NSCLC (T1N0) and poor pulmonary function. The nonfatal complications are similar to those occurring after a lobectomy; the major ones are prolonged air-leak, either peripheral alveolar pleural fistula or a bronchopleural fistula, empyema, and persistent pleural air space. Segmentectomy is essentially a benign procedure, and the mortality should be about 1%; it may, however, be as high as 4% to 6% in patients with poor pulmonary function or in those with previous pulmonary resection (26-28).

- **Non-anatomic resections.** Patients who also may benefit from such an approach are those with marginal function who have an early stage I or stage II lung cancer or patients with pulmonary metastatic lesions (29-31). The morbidity after a non-anatomic parenchymal sparing resection is minimal. When present, complications are most often the result of either retention of secretions or pleural problems. The mortality rate after non-anatomic parenchymal sparing resection is near zero in patients with benign inflammatory disease, and no more than 0.5% in those with malignant disease or pulmonary tuberculosis (32).

- **Bullectomy.** The operative mortality rate for bullous emphysema treated by bullectomy ranges between 1% and 5%; it depends on age, surgical approach, presence or absence of cor pulmonale and severity of emphysema (33). Most of the problems in bullectomy operations are related to the delayed expansion of the remaining lung, prolonged air leaks, or pleuro-pulmonary infections; usually better functional results are observed in selected patients with large compressive bullae and in those with only moderate signs of chronic obstructive pulmonary disease.
The pulmonologist point of view.

Spirometry, DLCO, arterial blood gas analysis and eventually exercise tests are the right way to evaluate patients subjected to pulmonary resections.

The majority of data are based on the preoperative FEV$_1$ value that is equal to 2 L to perform a pneumonectomy and 1.5 L for the lobectomy (34) but the absolute value are not in consideration of the changes in pulmonary functional values related to age, height, weight and gender of patient. It is recommended using percentage of predicted values instead of the absolute values.

DLCO is an important predictor of postoperative complications even in patients with normal FEV1 or without COPD; therefore it should be routinely measured during pre-operative evaluation of lung resection candidates, regardless of whether the spirometric evaluation is abnormal (3). There is a general consensus to not conduct other tests when FEV$_1$ and DLCO is $>80\%$ predicted (normal pulmonary function) while in patients with borderline pulmonary function and a predicted postoperative FEV$_1$ (ppoFEV1) and/or predicted postoperative DLCO (ppoDLCO) $<40\%$, calculated on quantitative CT scan or scintigraphy, exercise tests are recommended (Fig. 1) (1,34). Even if we have few data that provide guidance on a lower limit of lung function, the recent strong improvement in perioperative management and surgical techniques suggests a lower cut-off point of postoperative predicted FEV1 and DLCO of 30$\%$ for patients undergoing lung resection. The simple calculation using lung segment counting can predict post-operative FEV1 and DLCO accurately as ventilation/perfusion scintigraphy for lobectomy (3).

In patients with pulmonary emphysema, the resection of hyperinflated lung often leads to an improved pulmonary functionality (35), then the role of ppoFEV1 in assessing patients with airflow limitation and obstructive pulmonary disease is limited (3).

With physical effort, the ventilation, the O2 consumption, blood flow and the CO2 production increase in a similar way as observed after lung resection; patients who are not able to adequately respond to the effort could have the same status after the surgical stress (1). Performance on the exercise testing is correlated to surgical outcome (3) (Fig. 1).

Cardiopulmonary exercise tests (CPET) is the best predictor for post operative complications and is used to predict oxygen uptake as well as cardiopulmonary reserve. Patients with a preoperative VO2 max of 15 to 20 mL/kg/min can undergo lung cancer surgery with an acceptably low mortality rate. A VO2 max $>20$ mL/kg/min allows for a pneumonectomy. Values $<10$ mL/kg/min are generally associated with a high risk of complications (36). VO2 $>15$ mL/kg/min is a cut-off for good function (Baldwin Thorax 2010). Recently is found that VE/VCO2 slope was the only independent predictor of mortality while peak VO2 was instead the best predictor for the occurrence of severe cardiopulmonary postoperative complications. The presence of VO2 less than 10 mL/kg/min in association with postoperative predicted FEV1 and DLCO less than 30$\%$ are inoperability criteria. A shortcoming of the CPET is that there are no normal values for VO2 max available for a wide age range and body weight range. Consequently, the use of absolute CPET values may lead to the exclusion of patients who are actually fit enough to undergo curative surgery.
In absence of a CPET, the 6 minute walk test represents a peak oxygen uptake (VO$_2$) of about 15 mL/kg$^{-1}$/min when a 500 m walk is covered without stopping (37). A major limitation of the test is that the distance walked in minutes is not standardized. It is better tolerated in patients with COPD and in that sense superior to CPET in detecting exercise-induced hypoxemia.

*Stair climbing* is another method where the amount of stairs climbed is used to predict VO$_2$ and cardiopulmonary reserve and it represents an independent predictor of postoperative mortality but not of the morbidity (38).

Climbing two flights of stairs corresponds to a VO$_2$ max of about 12 mL/kg$^{-1}$/min$^{-1}$, whereas the VO$_2$ max exceeds 20 mL/kg$^{-1}$/min$^{-1}$ in those who are able to climb five flights of stairs.

The shuttle walking test (SWT) is an incremental based on an externally paced test, less influenced by the therapist encouragement, and it has been proposed as a more reproducible test to evaluate exercise tolerance. Other pulmonary functional tests need to be discussed and performed, and interpreted, by a specialist pulmonologist (3,35).

**Arterial blood gas analysis** should be done in all patients scheduled for an elective pulmonary resection. There is no consensus regarding a value for arterial oxygen tension that clearly indicates an increased risk for pulmonary resection. A value of PaCO$_2$>45 mmHg is associated with an increased risk of postoperative complication but is not considered to preclude pulmonary resection.

It is used to be considered of common sense that the presence of one of the three following conditions, FEV$_1$<30% of predicted, PaO$_2$<60mmHg and PaCO$_2$>50mmHg, increase the risk of postoperative complication and or respiratory failure.

According to other studies we assume that multidisciplinary management of patients undergoing lung resection is recommended, and the combination of different parameters is probably the best way to improve the assessment accuracy.

A 4-week preoperative physiotherapy/pulmonary rehabilitation program shows improvement in exercise tolerance in patients with moderate to severe chronic obstructive or restrictive pulmonary disease without changes in pulmonary function (39). It also preserves pulmonary function following surgery. Whether these benefits translate into a reduction in postoperative pulmonary complication is uncertain (40,41).

About 90% of patients affected by a lung cancer are smokers and 75% are often also affected by COPD (2,42). These patients should be treated for about 10 days to reduce hyperinflation, airway obstruction with: long-acting inhaled β2 agonists, eventually in association with anticholinergic and, if not enough, theophylline and inhaled/systemic corticosteroids, in addition to quitting smoking. O$_2$ therapy must be administered when PaO$_2$ is <55 mmHg or, in case of cardiac disease, <60 mmHg.

Patients with COPD had a decreased incidence of pulmonary complications when a pre-operative program of chest physiotherapy is initiated pre-operatively educating the patient to cough properly and deep breathing exercises (35). Eight weeks prior to surgery, smoking cessation, even for patients not...
afflicted with COPD, is recommended to decrease in sputum production, to improve ciliary action, macrophage activity and small airway functions (1,43). Smoking cessation at least 12/24 hours prior to surgery is anyway useful because carboxyl-hemoglobin has a half-life of about 12 hours. Patients suffering from bronchial asthma, even though some studies haven’t confirmed this condition as the cause of pulmonary complications postoperative, have to continue to assume inhaled β2 agonists and inhaled corticosteroids therapy to ensure freedom from symptoms and a peak expiratory flow of greater than 80% of predicted or their personal best value prior to surgery. Bronchial hyperactivity could cause bronchospasm during intubation. Inhaled β2 agonists and systemic corticosteroids therapy reduces the risk of bronchospasm if given for 5 days prior to operation (45).

Patients with interstitial lung diseases who have a reduced DLCO value or a FEV1 or a FVC < 60% of predicted value are not suitable candidates for surgery (46,47). The relationship between the PaCO2 and PaO2 if >0.72 is an index of high mortality rate (48).

The presence of OSAS (Obstructive Sleep Apnea Syndrome) (44) because of higher risk of mortality and morbidity post-surgery recovery in ICU is always recommended for patients afflicted with OSAS who are subjected to thoracic surgery. Patients subjected to chemotherapy usually show improvements in spirometry measurements and reductions in diffusing capacity (DLCO). A decrease in DLCO adjusted for alveolar volume (DLCO/VA) after chemotherapy was associated with increased risk of respiratory complications. A decrease >15% after chemotherapy should be considered an additional risk factor. After induction chemotherapy and/or radiotherapy a new functional evaluation (particularly of DLCO) before surgery are recommended (3).

The cardiologist point of view.

Since the '80s until today the prevalence of major cardiac events during non-cardiac elective surgery ranges on average from 0.5% to 3.5% (49-55). It is not possible to evaluate the influence of surgical technique innovations and risk assessment improvement on patients prognosis, since there are no systematically collected data about this topic.

With regard to the incidence of perioperative (within 30 days from surgical intervention) major cardiac events (deaths and myocardial infarction), surgical procedures can be divided into low-risk (<1%), intermediate-risk (1-5%), and high-risk (>5%) groups (51). Lung surgery is generally considered at intermediate-risk.
**Evaluation of functional capacity.** Functional capacity is usually expressed as METs (metabolic equivalents); 1 MET corresponds to baseline oxygen consumption, which is equal to 3.5 mL/kg/min. The patient is therefore set in a poor (<4 METs), moderate (4-6METs), good (7-10METs) and excellent (> 10 METs) functional capacity (56).

Relative risk of mortality in thoracic surgery is reported as 18.7 (95%, CI 5.9-59) (57). This type of patients needs further stratification of cardiac risk, while asymptomatic patients without a cardiac history and with good functional capacity can undergo surgical intervention without further evaluation (4,5).

An objective evaluation in METs is provided by exercise test, but it can also be estimated based on the patient's ability to perform activities of daily living. A simple diagram to identify a patient with poor functional capacity, and a more exhaustive scheme about METs required for different daily life activities has been previously reported (58,59).

**Evaluation of coronary artery disease risk factors.** The evaluation of acquired coronary artery disease risk factors gains importance in symptomatic patient (precordial pain, cardiogenic dyspnea, palpitations, syncope), whatever his functional capacity, and in asymptomatic patient with poor functional capacity (Fig. 2).

In the presence of symptoms related to coronary artery disease or poor functional capacity (< 4 METs) associated with multiple risk factors for coronary disease, cycloergometer or treadmill exercise stress test is mandatory(60).

The available data on dobutamine stress echocardiography are also mainly limited to patients undergoing vascular surgery, with NPV and PPV comparable to dipyridamole stress scintigraphy (61-63).

**Evaluation of patient with heart disease and comorbidity.**

The presence of heart disease significantly affects the value of Lee’s Revised Cardiac Risk Index (50). This index identifies 6 independent prognostic factors: high-risk type of surgery, history of ischemic heart disease, history of heart failure, history of cerebrovascular disease, preoperative treatment with insulin in patients with diabetes mellitus, preoperative serum creatinine > 2.0mg/dl. All factors contribute equally to the index (with 1 point each), and the incidence of major cardiac complications is estimated at 0.4, 0.9, 7, and 11% in patients with an index of 0, 1, 2, and ≥3 points, respectively (AUC 0.81). For this reason, the presence of heart disease highlights the need of medical therapy optimization before surgery. The presence of cardiac symptoms, especially if new-onset, makes an echocardiographic assessment necessary, in order to obtain a new definition of ventricular and /or
valvular function. In contrast, in case of stable and asymptomatic heart disease, an echocardiographic evaluation within the previous 12 months can be considered adequate. It is known that a left ventricular ejection fraction < 35% exposes patients to increased risk of major perioperative cardiac complications (61).

The presence of supraventricular or ventricular arrhythmias on baseline ECG, as well as symptoms like palpitations and/or syncope, requires a Holter-ECG evaluation.

**Indications for myocardial revascularization.**

There are two main important factors to consider: timing of lung surgical intervention and the type of cardiac risk for which myocardial revascularization should be indicated (Fig. 3).

The importance of knowing the correct timing is derived from the results of clinical studies that showed that discontinuation of antiplatelet therapy before surgery significantly increases mortality due to the high incidence of stent thrombosis in patients exposed to previous coronary stenting (64,65). For this reason, it is now recommended to discontinue antiplatelet therapy not earlier than 3 months in case of bare-metal stents (66) and 12 months for drug-eluting stents (67). On the other hand, coronary angioplasty without stenting allows surgery intervention after 2 weeks without increasing cardiac complications (68), but definitely increases the risk of long-term coronary re-stenosis.

As far as it regards patient’s cardiac condition, in case of acute coronary syndrome, most patients will undergo myocardial revascularization before lung surgery, according to the European guidelines (6,4), except for emergency surgery due to patient’s life-threatening risk (4). In case of chronic coronary disease and positive stress test for inducible myocardial ischemia, two randomized clinical trials (CARP trial (69) and DECREASE-V trial (70)) have shown that an interventional approach through coronary revascularization before non-cardiac surgery does not change patient’s perioperative risk of myocardial infarction and mortality, compared to a conservative strategy based on optimizing medical therapy.

It is known as coronary angioplasty is able to correct significant stenosis, but it cannot prevent rupture of hemodynamic non-significant vulnerable plaques, responsible for most of the fatal perioperative myocardial infarctions (71). This may also explain the lack of specificity of stress imaging techniques in predicting infarct-related coronary artery lesions (72). For this reason, myocardial revascularization is not currently recommended in clinically stable patients with a positive stress test for myocardial ischemia undergoing intermediate-risk surgery (such as lung surgery), while it can be evaluated in case of high-risk surgery (4,73).

**Hemodynamic evaluation of pulmonary circulation (and pulmonary hypertension).**
In case of intermediate and high-risk surgery, pulmonary hypertension exposes patients to high risk of perioperative cardiac complications (51).

Although systematic studies are not available, previously published literature suggests cardiac complications rate > 50% in case of moderate to severe pulmonary hypertension (mean pulmonary arterial pressure > 35mmHg) (7). Changes in right ventricular function after lung resection for cancer treatment have been investigated in recent years; however, small sample size and variable methodology has led to controversial results (74-78). In all patients after pneumonectomy pulmonary pressure and right ventricular diastolic diameter increases.

In the presence of symptoms referable to pulmonary hypertension or in case of strong clinical suspicion, an echocardiographic evaluation with pulmonary pressure estimation is recommended. It is suggested in patients undergoing pneumonectomy. In the presence of known lung disease an echocardiographic evaluation is not necessarily required, since the detection of pulmonary hypertension is quite uncommon (79,80). Echocardiography becomes mandatory when dyspnea is out of proportion in face of ventilatory impairment (80).

In case of medium to high probability of pulmonary hypertension (tricuspid regurgitation gradient > 2.9 m/s, that is > 36 mmHg), in case of strong clinical suspicion, patients should undergo right heart catheterization to assess pulmonary hemodynamics and its impact on right ventricular function (7), in order to evaluate therapeutic optimization.

**Atrial fibrillation and thoracic surgery.** Atrial fibrillation (AF) occurs in between 12% and 44% of patients after pulmonary and esophageal surgery. Its occurrence is associated with increased pulmonary complications, increased length of stay, and increased mortality. The incidence of AF increases with the extent of surgical procedure reaching the highest rates after pneumonectomies and extra pleural pneumonectomies (8). Pharmacological prophylaxis and management of postoperative AF are discussed, and not recommended, in the guidelines of the Society of Thoracic Surgery (8).

**Preoperative clinical risk factors**

**Renal disease.**

Preoperative reduced kidney function is an independent risk factor for adverse post-operative cardiovascular outcomes including myocardial infarction, stroke, and progression of heart failure (4,81).

Preoperative end stage renal disease and hemodialysis increase approximately fourfold the mortality rate after pulmonary resection (82-85).

In the Society of Thoracic Surgeons (STS) database, postoperative renal dysfunction after pulmonary resections, defined as doubling of plasma creatinine levels or requirement for renal replacement therapy, was reported to occur in 1.4% of surgery patients and has been identified as a strong predictor.
of mortality and composite major morbidity (82,86). But the true incidence of acute kidney injury (AKI) (87) in lung surgery seems to be underestimated because of the different definition criteria and the nonsystematic measurements of creatinine levels (2,88-92).

The development of AKI was associated with extensive lung resection with prolonged anesthetic and surgical times; and perioperative use of vasopressors (81,90,93).

**Diabetes.**

Even if Diabetes mellitus is a common co-morbidity in patients presenting to anesthetists for elective and emergency surgery (4,5), in lung surgery the diabetes in not a predictive factor of major morbidity and mortality (82,94).

**Obesity.**

The impairment of the central responses and the sleep-disordered breathing led to hypercapnia and hypoxia (95,96).

In the lung surgery series, the increase in body mass index (BMI) does not increase the risk of mortality (82,94,97).

An aggressive pain control, early mobilization, pulmonary toilet, physical therapy in all patients and the use of video-assisted thoracoscopic (VATS) procedure contribute to low rate morbidity (97). Anyway respiratory complications after standard pneumonectomy for lung cancer resulted fivefold more frequent in overweight and obese patients than in subjects with BMI < 25 kg m$^{-2}$ (98).

**Arterial Hypertension.**

In patients with mild, uncontrolled hypertension, antihypertensive medications should be continued during the perioperative period. In patients with systolic blood pressure ≥180 mmHg and/or diastolic blood pressure ≥ 110 mmHg, the potential benefits of delaying surgery to optimize the pharmacological therapy should be weighed against the risk of delaying the surgical procedure (4,5,82,86,99).

**Elderly.**

Age has been identified as an independent predictor of complications from lung resection (82,100,101) and it depends on the grade of surgery. The strongest predictors for postoperative mortality and morbidity are: MI; stroke; heart failure; renal failure (creatinine > 150mmol/L); peripheral arterial disease (99). The British Thoracic Society noted that pneumonectomy is associated with higher mortality risk in the elderly, and age should be a factor in deciding suitability for pneumonectomy (102).

However, with careful preoperative patient selection, patients older than 70 years of age, undergoing wedge resection, segmentectomy and lobectomy, with good exercise tolerance and adequate cardiopulmonary reserves have been shown to have the same morbidity and mortality risk (103,104). Postoperative death was not shown in patients with 80-89 years undergoing lesser pulmonary resection (105).
Most serious complications and operative deaths can be avoided by careful evaluation of cardiopulmonary function, careful selection of the surgical procedure, and meticulous postoperative management (100,101).

**Evaluation of the preoperative risk.**

In figure 4 the risk derived from cardiac, pulmonary and surgical evaluation is reported. Patients without cardiac disease and with normal respiratory function may be suitable for all types of surgery (level 1). Pneumonectomy should be evaluated in patients with cardiac disease (also if pulmonary hypertension or supraventricular arrhythmia are present), but with a negative stress test and a ppoFEV$_1$ or ppoDLCO> 40% (level 2). The presence of a positive stress test in patients with MET> 4 and a ppoFeV$_1$ or ppoDLCO<40% with negative CPECT make minor lung resections than pneumonectomies possible, but to be evaluated according to the patient and the type of intervention (point 3). A LVEF <35% with MET <4 and the presence of CPET positive indicates a very high risk for each type of resection which should thus be assessed individually (point 4). The contemporary presence of other pathologies increases the number of postoperative complications (Fig.5). In addition to the risk factors previously described, the presence of an index of LEE> 2 increases considerably the risk cardiology. It is described as the simultaneous presence of 2 or more factors among the following: high risk surgery (including pneumonectomy and lobectomy), ischaemic heart disease, heart failure, insulin-dependent diabetes, previous stroke or TIA, serum creatinine> 2mg/dL.

**Postoperative ICU (Intensive Care Unit) admission criteria**

Finally, dividing all pts from those at high risk it will be easy also to trace a strategy for all patients, with at least with one preoperative organ dysfunction, who need a predicted postoperative admittance in ICU.

After lung resection surgery, the patients are generally discharged to the ward after a short time in the PACU. If they achieve the intensive care unit (ICU) admission criteria they should be admitted to an ICU for early postoperative care.

As proposed by the Society of Critical Care Medicine (1999) the patients that will benefit from ICU admission are critically ill, unstable patients in need of intensive treatment and monitoring that cannot be provided outside of the ICU. Usually, these treatments include ventilator support and continuous vasoactive drug infusions. Examples may include postoperative or acute respiratory failure patients requiring mechanical ventilatory support and shock or hemodynamically unstable patients receiving invasive monitoring and/or vasoactive and/or cardiovascular drugs. These patients require intensive monitoring and may potentially need immediate intervention. Due to different chronic pre existing disease, in some selected cases, these patients can develop acute severe medical or surgical illness needing ICU admission and treatment.
Conclusion
This document represents a consensus among Italian experts, based on the scientific knowledge and on labels available during the winter of 2012, and it will be divulged by the 4 societies following different modalities (society journals, society websites, symposia organized within national congresses, etc.).
A periodical revision of this document is expected, which will be of particular use for the future according to the incoming literature.
The preoperative evaluation of patients undergoing lung resection should be performed by specialists who are familiar with all the perioperative aspects of thoracic surgery with pulmonary parenchymal resection.
In normal condition what to do is summarized in fig. 6.
The global risk assessment for each patient, particularly for all patients with one or more preoperative organ dysfunction and limited cardiopulmonary reserve, should be assessed by all the team together (surgeon, anesthesiologist and when required cardiologist and pulmonologist) only if involved in the pre- intra-and post-operative management.
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Fig 1. Pulmonary evaluation algorithm

FEV<sub>1</sub> > 80%, DLCO > 80% → SURGERY

FEV<sub>1</sub> < 60%, DLCO < 60% (associated with ▬ Mortality)

Quantitative Lung Scan → P<sub>po</sub>-FEV<sub>1</sub> < 40%

Exercise testing:
Cardiopulmonary Exercise test (CPET) VO<sub>2</sub>max > 15ml/kg/min

OR
Stair climbing test:
Shuttle walk test:
6 minute walk test:

Two flights stairs=VO<sub>2</sub> max 12
450 m
500m walk

Legend: DLCO: Diffusing Capacity of the Lung for Carbon Monoxide; P<sub>po</sub>DLCO= predicted postoper DLCO; FEV<sub>1</sub>: forced expiratory volume in the 1st sec; P<sub>po</sub>FEV<sub>1</sub>= predicted postoperative FEV<sub>1</sub>; CPET: cardiopulmonary functional tests
Fig. 2. Cardiac evaluation algorithm.

Legend: MET = metabolic equivalent; LVEF = left ventricle ejection fraction
Fig. 3. Myocardial revascularization indications.

Lung Surgery
Myocardial Revascularization Indications

Acute Coronary Syndrome

Urgent Surgery

YES

NO

Surgery after clinical stabilization

Myocardial Revascularization

HIGH Cardiac Risk

Coronary Heart Disease/
Coronary Risk factors

POSITIVE stress test

YES

NO

Surgery after clinical optimization

HIGH Cardiac Risk

Proceed to Surgery

INTERMEDIATE Cardiac Risk
Fig 4. Risk of pulmonary resections based on preoperative cardiac and respiratory evaluation and on type of surgery.

Legend. MET = metabolic equivalent; LVEF = left ventricle ejection fraction; FeV₁ = forced expiratory volume in 1 second; DLCO = diffusing capacity of the lung for carbon monoxide; ppo = predicted post-operative value; CPET = cardiopulmonary exercise test
Fig 5. Risk of lung resections based on preoperative cardio-pulmonary evaluation, type of surgery and on other clinical risk factors (grey triangle).

**Legend:**
- MET = metabolic equivalent
- LVEF = left ventricle ejection fraction
- DLCO = Diffusing Capacity of the Lung for Carbon Monoxide
- ppoDLCO = predicted postoper DLCO
- FEV₁ = forced expiratory volume in the 1st sec
- ppoFEV₁ = predicted postoperative FEV₁
- CPET = cardiopulmonary functional tests

**Risk factors:**
- Renal disease
- Diabetes
- Arterial hypertension
- Elderly
- Obesity

**LVE index ≥ 2:**
- High risk surgery (including pneumonectomy and lobectomy)
- Ischaemic heart disease
- Heart failure
- Insulin-dependent diabetes
- Previous stroke or TIA
- Creatinine ≥ 2 mg/dL

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Fig. 6

Standard Preoperative Evaluation in all patients undergoing lung resection surgery

Legend:
MET = Metabolic Equivalent
DLCO = Diffusing capacity of the lung for carbon monoxide
BGA = Arterial Blood gas analysis

If History = no risk factors with METS > 4
If spirometry (+DLCO) and BGA = normal
If ECG = normal with METs > 4

ALL PULMONARY RESECTIONS
(but not pneumonectomy)