Thoracic surgery: risk factors for postoperative complications of lung resection

Eduardo Oliveira Fernandes[1], Cassiano Teixeira[2], Luis Carlos Correa da Silva[3]

[1] MD, Coordinator of the General Medicine Residency Program at Grupo Hospitalar Nossa Senhora da Conceição, Porto Alegre, RS
[2] MD, Intensive Care Medicine at Complexo Hospitalar da Santa Casa de Porto Alegre; Professor at Clínica Médica, Universidade Federal de Ciências da Saúde de Porto Alegre (UFCSPA), Porto Alegre, RS
[3] MD, Pneumologist at Pavilhão Pereira Filho da Santa Casa de Porto Alegre; Coordinator of the Pulmonary Function Test Laboratory at Pavilhão Pereira Filho and Professor of the Pneumology Department at UFCSPA, Porto Alegre, RS

Summary

Objective: To identify preoperative and transoperative risks factors for postoperative complications developed in lung resection surgery. **Methods:** During 14 months; 189 patients underwent pulmonary resection and were enrolled to the study. After a clinical interview, patients were evaluated by laboratory, pulmonary function tests and radiography, submitted to a surgical procedure, and were followed during their stay in the ICU and hospital, evaluating postoperatory complications and death. **Results**: The postoperative rate of complications was 52.9%: respiratory (34.3%), infectious (31%), and cardiovascular (21.4%). Respiratory complications were related to smoking ($p < 0.01$, RR 2.31), airway obstruction by spirometry ($p = 0.01$, RR 2.60), presence of anemia ($p < 0.01$, RR 2.13), and prolonged protrombine time [PT] ($p = 0.03$, RR 1.77). Infection complications were related to smoking ($p < 0.01$, RR 2.69), airway obstruction by spirometry ($p = 0.01$, RR 3.31), presence of anemia ($p < 0.01$, RR 2.10), and prolonged PT ($p = 0.03$, RR 2.29). Cardiovascular problems were related with older age ($p < 0.01$, RR 2.66), cigarette smoking ($p < 0.01$, RR 4.55), and hypoxemia ($p = 0.03$, RR 2.43). The postoperative mortality rate was 7.1%. **Conclusion:** A preoperative evaluation can provide a suitable and safe postoperative prediction of complications in patients submitted to lung resection. Patients with COPD, hypoxemic, older, and anemic patients must be classified as high-risk for developing these complications.

Keywords: Thoracic surgery; preoperative care; risk factors; prognosis hospital mortality.

Resumo

Cirurgia torácica: fatores de risco para complicações pós-operatórias na ressecção pulmonar

Objetivo: Identificar os fatores de risco pré e transoperatórios para o desenvolvimento de complicações pós-operatórias na cirurgia de ressecção pulmonar. **Introdução:** Os pacientes submetidos à cirurgia de ressecção pulmonar desenvolvem graves e frequentes complicações pós-operatórias. A identificação dos fatores de risco para o desenvolvimento das mesmas é fundamental na predição das complicações no pós-operatório. **Métodos:** Durante 14 meses, 189 pacientes foram submetidos à intervenção cirúrgica torácica e foram incluídos no estudo. Depois de uma entrevista clínica, os pacientes foram avaliados por exames laboratoriais, espirometria e exames de imagem. Os mesmos foram submetidos ao procedimento cirúrgico e foram seguidos durante a sua permanência na UTI e no hospital, avaliando as complicações pós-operatórias e o risco de morte. **Resultados:** A taxa de complicações pós-operatórias foi de 52,9%, principalmente respiratórias (34,3%), infecciosas (31%) e cardiovasculares (21,4%). As complicações respiratórias foram relacionadas ao tabagismo ($p < 0,01$, RR 2,31), obstrução das vias aéreas ($p = 0,01$, RR 2,60), presença de anemia ($p < 0,01$, RR 2.13), e prolongado tempo de protrombina [PT] ($p = 0,03$, RR 1,77). As complicações infecciosas estiveram relacionados ao tabagismo ($p < 0,01$, RR 2,69), obstrução de vias aéreas ($p = 0,01$, RR 3,31), presença de anemia ($p < 0,01$, RR 2.10) e TP prolongado ($p = 0,03$, RR 2,29). Os problemas cardiovasculares, especialmente a presença de arritmias, foram relacionados com idade mais avançada ($p < 0,01$, RR 2,66), tabagismo ($p < 0,01$, RR 4,55) e hipoxemia ($p = 0,03$, RR 2,43). A taxa de mortalidade pós-operatória foi de 7,1%. **Conclusão:** A identificação dos fatores de risco pode predizer complicações pós-operatórias nos pacientes submetidos a ressecção pulmonar. Pacientes com DPOC, hipoxêmicos, idosos e anêmicos devem ser classificados como de alto risco para o desenvolvimento de complicações.

Unitermos: Cirurgia torácica; cuidados pré-operatórios; fatores de risco; prognóstico; mortalidade hospitalar.

Study conducted at Pavilhão Pereira Filho da Santa Casa de Porto Alegre, Porto Alegre, RS

Submitted on: 11/27/2010
Approved on: 03/17/2011

Correspondence to:
Cassiano Teixeira
Rua Riveirat, 355/403
Porto Alegre – RS
CEP: 90670-160
Tel/Fax: +55 (51) 3312-2608
cassiano.rush@gmail.com

Conflict of interest: None.

Introduction

Benefits of pulmonary surgical treatment are well-established. Life expectation of patients with non-small cell lung cancer is increased to 48 months, compared to 17 months of survival of patients submitted only to medical treatment[1]. Furthermore, surgery for bronchiectasis increases the quality of life[2] and survival of these patients[3]. However, postoperative complications are a significant cause of morbidity and mortality in patients submitted to thoracic or abdominal surgeries[4].

Managing of these patients requires an understanding of the predictable changes in pulmonary physiology occurring with surgery and anesthesia as well as a knowledge of factors associated with development of postsurgical complications. The surgical procedure causes reduction of lung capacity (represented by forced vital capacity [FVC] and forced expiratory volume in one second [FEV_1]) diaphragm dysfunction, impairs gas exchange, and cough and mucociliary clearance leading to development of microatelectasis and postoperative hypoxemia[4,5]. These modifications are exacerbated in chronic obstructive pulmonary disease [COPD][6,7], as well as in older patients[8], survivors of recent myocardial infarction[9], in starvation[10] and smoking patients[11].

The patients submitted to pulmonary resection procedures developed severe and frequent postoperative complications, so these patients frequently are submitted to the preoperative risk evaluation[12]. Advances in surgical and anesthetic techniques, combined with a detailed preoperative and sophisticated perioperative assessment, have contributed to an increasing number of adults undergoing these procedures[12-14].

The objective of this study was to identify preoperative, and transoperative risks factors for developed postoperative complications in lung resection surgery.

Methods

Patient management

All patients submitted to lung surgery at a reference for clinical and surgical lung diseases hospital over a 14 month period were prospectively studied. All subjects enrolled underwent elective lung resection surgeries (lobectomy and pneumonectomy) with or without chest wall resection due to cancer, abscesses, or bronchiectasies. Exclusion criteria were: < 18 years of age, palliative resection, lung transplantation, thoracic trauma, thoracic surgery with no lung resection, thoracoscopy or thoracotomy for lung nodule biopsy, tracheostomy, emergency surgery, and informed consent declined. The study was approved by the Ethics in Research Committee of both hospitals and Informed Consent was obtained from all patients or next of kin.

The preoperative evaluation included a complete history, physical examination, blood cell count, biochemical profile, chest film, 12-lead ECG, and pulmonary function tests. When FEV_1 was < 60% of the predicted value, a differential lung perfusion scan was performed. Patients with borderline spirometric results or impaired exercise tolerance underwent a cardiopulmonary exercise test on a bicycle ergometer. Transthoracic echocardiography, thallium-dipyridamole myocardial scintigraphy, or coronary angiogram were performed in patients with risk factors for coronary artery disease [CAD] and in those patients with low functional capacity, according to guidelines published by the American College of Physicians [ACP][15,16]. Preoperatively, as routine a thoracic epidural catheter was inserted, except for patients who refused placement of the catheter, patients with coagulation disorders, acute neurologic problems, local or systemic infections, or technical failures (i.e., catheter malpositioning or malfunction). Prophylactic antibiotic therapy (i.e., cefuroxime, 1.5 g every 8 h for 24 h) was administered routinely. All patients were operated by one of three specialized surgeons in thoracic surgeries and were managed by the same team of anesthesiologists and chest critical care physicians.

After surgery, patients were monitored for at least 48 h in the postanesthesia care unit or intensive care unit [ICU] to provide intensive nursing and respiratory care with emphasis on pain control, diaphragmatic breathing, aggressive pulmonary toilet by aggressive postoperative physical therapy, as well as early mobilization, ambulation, and feeding. Intravenous [IV] fluid infusion was limited to compensate for volume of blood loss with 0.9% saline solution and to replace evaporation loss with 5% glucose in saline solution at a rate of 1 mL/kg/h. Postoperative pain was assessed at rest and during coughing with a visual analog scale. The analgesic regimen was titrated to keep the visual analog scale at < 4/10 using either IV (morphine sulfate and nonsteroidal anti-inflammatory drugs) or epidural catheter (morphine sulfate) from 2 to 4 days.

Data collection and extraction

The preoperative data registered during standard interview and physical exam included: age, gender, smoking history (positive when smoking more than 20 pack years), presence of concomitant diseases (diabetes, cardiovascular, renal, and pulmonary disease). Other preoperative data registered were: arterial blood gases on air, blood cell count, biochemical profile, pulmonary function test [PFT](FEV_1 and FVC as percentage of predicted), 12-lead ECG, type of malignancy, and informed consent. Diagnosis of chronic obstrutive pulmonary disease [COPD] was based on a history of myocardial infarction or angina, or typical Q waves seen on the ECG. Elevated blood pressure, arrhythmias, and *diabetes mellitus* requiring medication were considered significant comorbidities. Peripheral artery disease was defined by clinical evidence (i.e., claudication at exercise and past or current vascular surgery) or arteriography. Diagno-

sis of COPD was based on criteria of the American Thoracic Society [ATS] and on results of pulmonary functional tests (i.e., FEV1/FVC, ≤ 70% of predicted value)[17]. Specific cut-off points were selected to define risk factors: (a) advanced age: ≥ 65 years; (b) moderate to severe COPD: FVC or FEV_1 ≤ 60% of the predicted; (c) hypoxemia in room air: PaO_2 ≤ 60 mmHg; (d) hypercapnia: $PaCO_2$ ≥ 45 mmHg; (e) lymphocytopenia: lymphocyte count < 1500/μL; (f) increased hemorrhage risk: prothrombin time [PT] > 13 sec; and (g) anemia: hemoglobin ≤ 10 g/dL.

Intraoperative risk factors studied were perioperative estimated blood loss (3 or more packed red blood cells requirement), and occurrence of a hemodynamic instability defined as need for IV vasopressor or IV vasodilator during procedure. Experience of the surgeon and anesthetist were not recorded since all surgical procedures were performed by the same surgical and anesthesia team with more than 20 years of experience in management of lung diseases. The duration of the surgical procedure (from skin incision to closure) was not registered.

Patients were followed during ICU and hospital stay to evaluate postoperative complications and mortality. Complications were grouped as (a) respiratory: atelectasis, endotracheal reintubation, mechanical ventilation requirement > 24 h, and pleural air leak for more than 7 days; (b) cardiovascular: arrhythmias, hemodynamic instability with need for inotropic or vasodilators and coronary acute syndrome; (c) infectious: pneumonia (defined as new and persistent lung infiltrates at chest film, axillary temperature > 38.5°C, and macroscopically proven purulent tracheal secretions), wound infection and pleural empyema; (d) metabolic: hyperglycemia (need of continuous insulin), eletrolite disturbances, and acute renal insufficiency (need of dyalisis); and (e) prognosis (survival or death). Severe postoperative complications were considered: endotracheal reintubation, hemodynamic instability with need for inotropic or vasodilators, coronary acute syndrome, pneumonia, pleural empyema, acute renal insufficiency, and death. Each patient could have one or more complications therefore, the number of complications was greater than the number of patients. Operative mortality was defined as death until 30th day after procedure.

Data were classified as preoperative, and intraoperative, risk factors and as postoperative complications.

Statistical analysis

Data were analyzed using statistical software (Epi-Info version 6.0). Univariate analysis was carried out using the χ^2 test or Fisher's Exact Test for categorical variables and the Wilcoxon or Kruskal-Wallis test for continuous variables. Multivariate analysis (multiple logistic regression) was used to determine the relative risk (RR) and odds ratio (OR) and their 95% confidence intervals (95%CI) in variables with a p value <0.05 in univariate analysis for postoperative complications and death. All tests were two sided, and p values of < 0.05 were considered statistically significant.

Results

Study population

During the 14 months reference period, 532 thoracic surgeries were performed, and 189 patients were prospectively enrolled, and submitted to elective lung resection surgery (lung lobectomy and pneumonectomy). Sixty-nine point three percent were male, mean age of 62.2 ± 12.4 years, and 104 smokers (mean cigarette consumption was 49 pack years). More men than women were smoking (92.1% and 53%, respectively). Lung cancer was present in 75.5% of the cases. Preoperative clinical characteristics of patients, laboratory data and type of surgery as well as intraoperatory data are presented in Table 1.

Table 1 – Preoperative characteristics, type of surgery, transoperatory data, and postoperative complications

Characteristics	n (%)
Preoperative characteristics	
Clinical data	
Age ≥ 65 yr	49 (25.9)
Male gender	131 (69.3)
Cigarette smokers	132 (69.8)
Spirometry data	
FVC ≤ 60%	84 (44.4)
FEV1 ≤ 60%	98 (51.8)
Arterial blood gases	
PaO2 ≤ 60mmHg	93 (49.2)
PaCO2 ≥ 45mmHg	16 (8.4)
Laboratory analysis	
Lymphocytopenia	44 (22.2)
Prolonged prothrombin time	39 (20.6)
Anemia	82 (43.3)
Type of surgery	
Lobectomy	140 (74.1)
Pneumonectomy	49 (25.9)
Complications	
Respiratory	48 (34.3)
Atelectasis	16 (11.5)
Endotracheal reintubation*	13 (9.4)
Mechanical ventilation > 24 h	20 (14.2)
Pleural air leak > 7 days	11 (7.8)
Cardiovascular	30 (21.4)
Arrhythmias	24 (17.5)
Hemodynamic instability*	46 (34.5)
Acute coronary syndrome*	1 (0.7)
Infectious	42 (31)
Pneumonia*	41 (29.7)
Wound infection	15 (10.7)
Pleural empyema*	12 (8.6)
Metabolic	2 (1.4)

* Considered severe postoperatory complications

Postoperative complications

Postoperative complications are presented in Table 1. The postoperative rate of complications was 52.9%: respiratory (34.3%), infectious (31%), cardiovascular (21.4%), and metabolic (1.4%). The mortality rate was 13.7%, and mostly due to sepsis (52.9%) follow pneumonia (29.7%) or pleural empyema (8.6%).

Respiratory postoperative complications were related with smoking ($p < 0.01$, RR 2.31 [95% CI 1.92 - 2.95]), airway obstruction in spirometry ($p = 0.01$, RR 2.6 [95% CI 1.8 - 3.1]), presence of anemia ($p < 0.01$, RR 2.13 [95% CI 1.12 - 3.92]), and prolonged PT ($p = 0.03$, RR 1.77 [95% CI 0.94 - 4.16]). Delay in extubation was the only respiratory complication that correlated individually with the cigarette smoking risk factor ($p = 0.02$, RR 2.76 [95%CI 1.53 - 3.38]). Table 2 shows the relationship between postoperative complications and preoperative characteristics, type of surgery, and intraoperative data.

Infectious postoperative complications were related with smoking ($p < 0.01$, RR 2.69 [95% CI 1.28 - 3.54]), airway obstruction in spirometry ($p = 0.01$, RR 3.31 [95% CI 2.56 - 3.85]), presence of anemia ($p < 0.01$, RR 2.10 [95% CI 1.25 - 3.12]), and prolonged PT ($p = 0.03$, RR 2.29 [95% CI 1.82 - 3.17). Pneumonia was the only infectious complication correlated with smoking ($p < 0.01$, RR 2.69 [95% CI 2.42 - 2.98]), airway obstruction in spirometry ($p < 0.01$, RR 3.31 [95% CI 2.96 - 3.77]), presence of anemia ($p < 0.01$, RR 2.12 [95% CI 1.37 - 3.75]), and prolonged PT ($p < 0.01$, RR 2.26 [95% CI 0.76 - 5.78]). Pre and intraoperative risk factors were unable to predict occurrence of wound infection or pleural empyema.

Cardiovascular problems were related with older age ($p < 0.01$, RR 2.66 [95% CI 2.21 - 2.96]), cigarette smoking ($p < 0.01$, RR 4.55 [95% CI 3.65 - 5.95]), and hypoxemia ($p = 0.03$, RR 2.43 [95% CI 1.02 - 3.68]).

Metabolic postoperative problems were not predicted by the presence of pre or intraoperative risks. Pneumonectomies did not present more postsurgical complications when compared with lobectomies. When evaluating arterial blood gases, hypercapnia did not relate with complications. Detailed analysis of preoperative ECG did not predict risk of surgical complications. It is important to remember that patients could have one or more postsurgical complications.

Postoperative mortality

Smoking ($p = 0.01$, RR 3.76 [95% CI 2.54 - 5.02]) and hypoxemia ($p = 0.02$, RR 3.56 [95% CI 3.08 - 3.97]) were the preoperative risk factors that increased patient postoperative mortality. Although requirement for intraoperative blood transfusion did no increase postoperative complications individually, it increased postoperative mortality ($p = 0.01$, RR 4.53 [95% CI 1.72 - 7.65]), as well as the need of pneumonectomy ($p < 0.01$, RR 2.31 [95% CI 1.22 - 4.19]).

Table 3 shows the increase of mortality due to finding of postsurgical complications.

Discussion

Thoracic surgeries are procedures associated with relatively high rates of postsurgical complications[18]. Incidence of pulmonary complications is uncertain, due to the variability of definitions used by different authors[19]. Although physicians involved in preoperative evaluations can base surgical risk assessment on extensive research, their ability to do so correctly is limited by methodological problems in literature such as poor standardization and definition of postoperative complications, inadequate blinding of observers, selection bias, limitation by study size, and reporting of non-clinical significant complications (e.g., microatelectasis)[20].

Table 2 – Univariate analysis of potential risk factors for operative risk factors*

Risk factors	Postsurgical complications			
	Respiratory	Cardiovascular	Infectious	Metabolic
Age ≥ 65-years	ns	< 0.01	ns	ns
Male gender	ns	ns	ns	ns
Smoking	< 0.01	< 0.01	< 0.01	ns
COPD moderate-severe	0.01	ns	0.01	ns
$PaO_2 \leq 60mmHg$	ns	0.03	ns	ns
$PaCO_2 \geq 45mmHg$	ns	ns	ns	ns
Lymphocytopenia	ns	ns	ns	ns
Prolonged prothrombin time	0.03	ns	0.03	ns
Anemia	< 0.01	ns	< 0.01	ns
Pneumonectomy	ns	ns	ns	ns
Requirement of 3 packed red blood cells or more	ns	ns	ns	ns

*All data are represented with p value if statistically significant. ns, not significant (p value ≥ 0.05); COPD, chronic obstructive pulmonary disease

Table 3 – Multivariate analisys of the increase of mortality due to presence of postsurgical complications and type of surgery

Postsurgical complications	p value	OR (95% CI)
Pneumonia	< 0.01	5.20 (1.93-14.04)
Mechanical ventilation required > 24 h	< 0.01	13.85 (6.85-30.18)
Arrhythmias	< 0.01	7.85 (3.15-19.52)
Endotracheal reintubation need	< 0.01	18.45 (7.47-45.46)
Pleural empyema	< 0.01	7.06 (3.16-15.79)
Atelectasis	< 0.01	4.39 (1.75-11.03)
Pleural air leak for more than 7 days	< 0.01	5.02 (2.21-11.43)
Need of vasodilators	< 0.01	10.42 (4.70-22.74)
Need of vasopressor	< 0.01	14.67 (5.76-37.32)
≥ 3 packed red blood cells	< 0.01	4.53 (2.10-9.13)
Pneumonectomy	< 0.01	2.31 (1.22-4.19)

OR, odds ratio

Patient-related risk factors

Age. Some authors consider advanced age as a risk factor for mortality and perioperative complications[8,21-24], others disagree with it[25-30]. Ergina *et al.*[31] demonstrated that older patients have more respiratory or cardiovascular complications, and Tisi *et al.*[7] suggested that it was due to the physiological effect of aging (reduction of the vital capacity, peak-flow, elastic lung retraction, and increase of residual lung volume). Despite early suggestions of an increased risk of pulmonary complications with advanced age, this is not an independent risk factor for pulmonary complications. The healthy status of a patient, mainly cardiorespiratory seems to be much more important than age[26]. In our study, those older 65 years had no increase of postoperative mortality, and in agreement with Kroenke *et al.*[23], we observed an association with cardiovascular complications.

Smoking. The beneficial effects of smoking cessation, including improvement in ciliary and small airway function and a decrease in sputum production, occur gradually over several weeks. The risk is highest in patients who were smoking within the last 2 months, and patients who had quit smoking for more than 6 months, have a risk similar to those who do not smoke. Postoperative morbidity did not decrease in patients who had quit smoking for less than 4 weeks[32]. Our study showed increase of pulmonary and cardiovascular complications as well as increase of mortality rates.

Pulmonary function tests. Results of several retrospective studies of routine preoperative PFT disclosed only a marginal benefit in predicting postoperative complications in patients except in those undergoing lung resection. PFT could be used to identify high-risk patients for whom aggressive perioperative management is warranted. The ACP consensus statement[15,16,33] suggests the following indications for preoperative PFT: (a) patients undergoing cardiac or upper abdominal surgery with a history of smoking or dyspnea; (b) patients undergoing lower abdominal surgery if dyspnea or history of smoking indicates prolonged surgery; (c) patients undergoing orthopedic surgery with uncharacterized lung disease; (d) patients undergoing lung resection; (e) older than 60 years of age; (f) positive smoking history; (g) presence of pulmonary disease; and (h) presence of pulmonary symptoms. PFT results should not be the sole reason to change plans necessary for surgery.

PFT remain the standard screening tests performed before pulmonary resection. It is generally agreed that a minimum value of FEV_1 is required preoperatively (2 L before pneumonectomy and 1.5 L lobectomy, respectively) and that further cardiopulmonary testing is needed in patients with marginal lung function[34]. Variable cut-off values of FEV_1 (ranging from 35% to 80%) have been arbitrarily chosen to assess the severity of COPD and to predict the risk for pulmonary complications, but preoperative FEV_1 less than 60% is still a main predictor of perioperative mortality and respiratory morbidity[35].

COPD. Patients with severe COPD are 6 times more likely to have a major postoperative complication[35]. Elective surgery should be deferred in patients who are symptomatic, have poor exercise capacity, or have acute exacerbation. PFT results do not facilitate identification of the high-risk patients or of severity of dysfunction when risk of surgery is forbidding. Therefore, surgery should never be withheld based on PFT results[33]. Patients with severe COPD, classified as very high risk, may undergo surgery and will face a moderate risk of postoperative complications (29%)[23,35]. We use the Kroenke *et al.*[23] criteria and more than 40% of the patients presented with severe COPD based upon spirometric findings, and identifing an association between FEV_1 and respiratory, cardiovascular complications.

Arterial blood gases. A $PaCO_2$ of more than 45 mmHg often occurs in persons with severe COPD and indicates a high risk, although it is not necessarily prohibitive for surgery[7,36,37]. Hypoxemia is not a significant predictor of complications[36]. In our study, we verify that hypoxemia

was associated with cardiac complications, principally occurrence of arrhythmias. We did not find an association between hypercapnia and prognosis, perhaps due to the small number of patients with this alteration.

Anemia. Anemia is present in 10% of patients admitted to general hospitals[38]. Hemoglobin values above of 10 g/dL do not significantly reduce oxygen transport and treatment is not required before surgery, and almost 45% of our patients had anemia, based in this criteria. Our data showed that anemic patients had more respiratory and infectious complications, probably due to nutritional deficiencies not identified during the preoperative evaluation.

Lymphocytopenia. This is a malnutrition marker just as albumin level, and malnutrition is a risk of morbidity and mortality in critical care and surgical patients[39,40]. Moreover, patients submitted to thoracic surgery, frequently have cancer and are smokers; predisposing factors to malnutrition. Busch *et al.*[41], in 106 patients submitted to lung surgery due to bronchogenic cancer, did not correlate lymphocytopenia with higher postoperative complications, in agreement with our study data.

Prothrombin time. High values of PT are a contraindication for surgical procedures, due to an increase of hemorrhagic complications[42]. Our data showed increased respiratory complications, which in our opinion is due to PT being a marker of hepatic synthesis capacity and not because of coagulation defects[43].

Intraoperative risk factors

Perioperative blood transfusion. Whitson *et al.*[44] showed that perioperative blood transfusion was associated with increased postoperative complications (53.5% *vs.* 30.5%, $p < 0.001$). In our study, blood transfusion was associated with an increased operative mortality (3.4% *vs.* 1.7%, $p = 0.005$) and length of stay after surgery (median 6 *vs.* 5 days, $p < 0.001$).

Postoperative complications

Keagy *et al.*[45,46] reported on 369 patients, 244 had postoperative complications during follow-up of 30 days, mainly cardiovascular (41%) and pulmonary (21%). Wahi *et al.*[28], in 197 pneumonectomies followed-up during 30 days, showed 23% of arrhythmias and prolonged MV in 9.1% of the cases. Ferguson *et al.*[47], evaluating 271 patients, showed postoperative complications in 52% of the cases; and Asamura *et al.*[48], in 267 patients submitted to thoracotomy, found 23.6% of arrhythmias. Our study found respiratory complications in 34.3% of the cases, and pneumonia in 29.7% of the cases.

Postoperative mortality

Some authors[34,45-47,49] described variables postoperative mortality rates (2.8% - 12.6%), and the higher mortality rates found in patients submitted to pneumonectomies (7.1% - 27.4%)[28,47,49]. Ginsberg *et al.*[50], reviewed 2,220 patients submitted to thoracotomies in North-American and Canadian reference hospitals, and showed mortality post-segmentectomies of 1.4%, after lobectomies of 2.9%, and after pneumonectomies of 6.7%. Our data demonstrated global mortality of 7.1%, and pneumonectomy mortality of 19.4%.

Strengths and limitations: We believe that the strengths of this paper are: (a) large sample; (b) research developed in a hospital specialized in respiratory diseases; and (c) follow-up of all patients studied. We are mindful of several limitations related to: (a) design of the study (cohort study); (b) no evaluation of preoperative creatinine values (despite all patients have values lower than 1.5 mg/dL); (c) single center report; (d) no evaluation of intraoperative data (e.g. duration of the surgery or anesthesia, and intraoperative fluid balance); and (e) no evaluation of stairs climbing test in patients with preoperative $VEF_1 < 2$ L[51].

Conclusion

In an era of progressive cost containment and public scrutiny, the wisdom of aggressive preoperative evaluations for all surgical candidates have been questioned. Current data quantify the risks and morbidities associated with the care of seriously ill patients with coronary artery disease and demonstrate the need for professional and public discussions focusing on the association of a high preoperative risk status and the consumption of resources. A concise and standarized preoperative evaluation can provide a suitable and safe postoperative prediction of complications in patients submitted to lung resection, and patients with COPD, hypoxemic, older, anemic patients, and need of pneumonectomy must be classified as high-risk for develop postoperative complications.

References

1. Thomas SD, Berry PD, Russel GN. Is this patient fit for thoracotomy and resection of lung tissue? Postgrad Med J. 1995;71:331-5.
2. Ellis DA, Thornley PE, Wightamn AJ, Walker M, Chalmers J, Crofton JW. Present outlook in bronchiectasis: clinical and social study and review of factors influencing prognosis. Thorax 1981;36:659-64.
3. Sanderson JM, Kennedy MCS, Johnson MF, Manley DC. Bronchiectasis: results of surgical and conservative management. A review of 393 cases. Thorax 1974;29:407-16.
4. Wright CD, Gaissert HA, Grab JD, O´Brien SM, Peterson ED, Allen MS. Predictors of prolongated length of stay after lobectomy for lung cancer: a Society of Thoracic Surgeons General Thoracic Surgery Database risk-adjustment model. Ann Thorac Surg. 2008;85:1857-65.
5. Boffa DJ, Allen MS, Grab JD, Gaissert HA, Harpole DH, Wright CD. Data from The Society of Thoracic Surgeons General Thoracic Surgery database: the surgical management of primary lung tumors. J Thorac Cardiovasc Surg. 2009;138:295-9.
6. Stein M, Koota GM, Simon C, Frank HA. Pulmonary evaluation of surgical patients. JAMA 1962;181:765-70.
7. Tisi GM. Preoperative evaluation of pulmonary function. Am Rev Respir Dis. 1979;119:293-10.
8. Cole WH. Medical differences between the young and the aged. J Am Geriat Soc. 1970;18:589-614.
9. Tarhan S, Moffitt EA, Taylor WF, Giuliani ER. Myocardial infarction after general anesthesia. JAMA 1972;220:1451-1454.

10. Buzby GP. Prognostic nutritional index in gastrointestinal surgery. Am J Surg. 1980;139:160-7.
11. Morton HJV, Camb DA. Tobacco smoking and pulmonary complications after operation. Lancet 1944; 1:368-372.
12. Bryant AS, Cerfolio RJ.The influence of preoperative risk stratification on fast-tracking patients after pulmonary resection. Thorac Surg Clin. 2008;18:113-8.
13. Jordan S, Evans TW. Predicting the need for intensive care following lung resection. Thorac Surg Clin. 2008;18:61-9.
14. Cohn SL. Preoperative cardiac evaluation of lung resection candidates. Thorac Surg Clin. 2008;18:45-59.
15. Qaseem A, Snow V, Fitterman N, Hornabake ER, Lawrence VA, Smetana GW *et al.* Risk assessment for and strategies to reduce perioperative pulmonary complications for patients undergoing noncardiothoracic surgery: a guideline from the American College of Physicians. Ann Intern Med. 2006;144:575-80.
16. Bapoje SR, Whitaker JF, Schulz T, Chu ES, Albert RK. Preoperative evaluation of the patient with pulmonary disease. Chest 2007;132:1637-45.
17. Stocks J, Quanjer PH. Reference values for residual volume, functional residual capacity and total lung capacity. ATS Workshop on Lung Volume Measurements. Official Statement of European Respiratory Society. Eur Respir J. 1995;8:492-506.
18. Datta D, Lahiri B. Preoperative evaluation of patients undergoing lung resection surgery. Chest 2003;123:2096-103.
19. Agostini P, Singh S. Incentive Spirometry following thoracic surgery: what we are doing? Phisiotherapy 2009;95:76-82.
20. Dales RE, Dionne G, Leech JA, Lunau M, Schweitzer I. Preoperative prediction of pulmonary complications following thoracic surgery. Chest 1993;104:155-9.
21. Winter H, Meimarakis G, Pirker M, Spelsberg F, Kopp R, Rüttinger D *et al.* Predictors of general complications after video-assisted thoracoscopic surgical procedures. Surg Endosc. 2008;22:640-5.
22. Gerson MC, Hurst JM, Hertzberg VS, Baughman R, Rouan GW, Ellis K. Prediction of cardiac and pulmonary complications related to elective abdominal and noncardiac thoracic surgery in geriatric patients. Am J Med. 1990;88 101-7.
23. Kroenke K, Lawrence VA, Theroux JF, Tuley MR, Hilsenbeck S. Postoperative complications after thoracic and major abdominal surgery in patients with and without obstructive lung disease. Chest 1993;104:1445-51.
24. Harpole DH, Liptay MJ, DeCamp MM Jr, Mentzer SJ, Swanson SJ, Sugarbaker DJ. Prospective analysis of pneumonectomy: risk factors for major morbidity and cardiac dysrithmias. Ann Thorac Surg. 1996;61:977-82.
25. Jones LW, Peddle CJ, Eves ND, Haykowsky MJ, Courneya KS, Mackey JR *et al.* Effects of presurgical exercise training on cardiorespiratory fitness among patients undergoing thoracic surgery for malignant lung lesions. Cancer 2007;110:590-8.
26. Jesek V, Ouredník A, Lichtemberg J, Mostecký H. Cardiopulmonary function in the lung resection performed for bronchogenic cancer in patients above 65 years of age. Respiration 1970;27:42.
27. Didolkar MS, Moore RH, Takita H. Evaluation of the risk in pulmonary resection for bronchogenic carcinoma. Am Surg Surg. 1974;127:700-3.
28. Wahi R, McMurtrey MJ, DeCaro LF, Montain CF, Ali MK, Smith TL *et al.* Determinants of perioperative morbidity and mortality after pneumonectomy. Ann Thorac Surg. 1989;48:33-7.
29. Morandi U, Stefani A, Golinelli M, Ruggiero C, Brandi L, Chiapponi A *et al.* Results of surgical resection in patients over the age of 70 years with non small-cell lung cancer. Eur J Cadiothorac Surg. 1997;11:432-9.
30. Roxburgh JC, Thompson J, Goldstraw P. Hospital mortality and long term survival after pulmonary resection in the elderly. Ann Thorac Surg. 1991;51:800-3.
31. Ergina PL, Gold SL, Meakins JL. Perioperative care of the elderly patient. World J Surg. 1993;17:192-8.
32. Vaporciyan AA, Merriman KW, Ece F, Roth JA, Smythe WR, Swisher SG *et al.* Incidence of major pulmonary morbidity after pneumonectomy: association with timing of smoking cessation. Ann Thorac Surg. 2002;73:420-5.
33. Wyser C, Stulz P, Solèr M, Tamm M, Müller-Brand J, Habicht J *et al.* Prospective evaluation of an algorithm for the functional assessment of lung resection candidates. Am J Respir Crit Care Med. 1999;159:1450-6.
34. Zibrak JD, O´Donnel CR, Marton K. Indications for pulmonary function testing. Ann Intern Med. 1990;112:763-71.
35. Licker MJ, Widikker I, Robert J. Operative mortality and respiratory complications after lung resection for cancer: impact of chronic obstructive pulmonary disease and time trends. Ann Thorac Surg. 2006;81:1830-7.
36. Chen C, Ding JA, Gao W. Risk factors scoring system for predicting acute respiratory failure general thoracic surgery. Zhongguo Wei Zhong Bing Ji Jiu Yi Xue. 2004;16:274-6 (abstract).
37. Milledge JS, Nunn JF. Criteria of fitness for anesthesia in patients with chronic obstructive lung disease. Br Med J. 1975;3:670-3.
38. Harvey KB, Moldawer BS, Bistrian RB, Blackburn GL. Biological measures for the formulation of a hospital prognostic index. Am J Clin Nutr. 1981;34:2013-22.
39. Morice RC, Peters EJ, Ryan MB, Putnam JB, Ali MK, Roth JA. Exercise testing in the evaluation of patients at high risk for complications from lung resection. Chest. 1992;101:356-61.
40. Mullen JL. Consequences of malnutrition in surgical patients. Surg Clin North Am. 1981;61:465-87.
41. Busch E, Verazin G, Antkowiak JG, Driscoll D, Takita H. Pulmonary complications in patients undergoing thoracotomy for lung carcinoma. Chest. 1994;105:760-6.
42. Suchman AL, Griner PF. Diagnostic uses of the activated partial thromboplastin time and prothrombin time. Ann Intern Med. 1986;104:810-6.
43. Aghajanian A, Grimes DA. Routine prothrombin time determination before elective gynecologic operations. Obstet Gynecol. 1991;78:837-9.
44. Whitson BA, Huddleston SJ, Savik K, Shumway SJ. Bloodless cardiac surgery is associated with decreased morbidity and mortality. J Card Surg. 2007;22:373-8.
45. Keagy BA, Lores ME, Starek PJ, Murray GF, Lucas CL, Wilcox BR. Elective pulmonary lobectomy: factors associated with morbidity and operative mortality. Ann Thorac Surg. 1985;40:349-52.
46. Keagy BA, Schorlemmer GR, Murray GF, Starek PJ, Wilcox BR. Correlation of preoperative pulmonary function testing with clinical course in patients after pneumonectomy. Ann Thorac Surg. 1983;36:253-7.
47. Ferguson MK, Reeder LB, Mick R. Optimizing selection of patients for major lung resection. J Thorac Cardiovasc Surg. 1995;109:275-81.
48. Asamura H, Naruke T, Tsuciya R, Goya T, Kondo H, Suemasu K. What are the risk factors for arrhythmias after thoracic operations? J Thorac Cardiovasc Surg. 1993;106:1104-10.
49. Foster R, Toth S, Redmann K. A prospective risk analisys of contemporary thoracic surgery. Eur J Cardiothorac Surg. 1996;10:641-8.
50. Ginsberg RJ, Hill LD, Eagan RT, Thomas P, Mountain CF, Deslauriers J *et al.* Modern thirty day operative mortality for surgical resections in lung cancer. J Thorac Cardiovasc Surg. 1983;86:654-8.
51. Nikolić I, Majerić-Kogler V, Plavec D, Maloca I, Slobodnjak Z. Stairs climbing test with pulse oximetry as predictor of early postoperative complications in functionally impaired patients with lung cancer and elective lung surgery: prospective trial of consecutive series of patients. Croat Med J. 2008;40:50-7.