Original Article

MERIT OF PREOPERATIVE CLINICAL FINDINGS AND FUNCTIONAL PULMONARY EVALUATION AS PREDICTORS OF POSTOPERATIVE PULMONARY COMPLICATIONS

Denise Rossato Silva[1*], Marcelo Basso Gazzana[2], Marli Maria Knorst[3]

Study conducted at the Hospital de Clínicas de Porto Alegre, Pulmonology/respiratory medicine department, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil

ABSTRACT

Objective. To assess the relationship of clinical data and the results of preoperative pulmonary functional evaluation with postoperative pulmonary complications.

Methods. We conducted a retrospective cohort study with patients who underwent pulmonary functional evaluation over a period of 5 years. We analyzed clinical, demographic and spirometric data, surgical procedures performed and postoperative pulmonary complications.

Results. We analyzed the medical records of 521 patients. Mean age was 59.5 ± 14 years, 65.8% were male, and 93.4% were white. Mean FEV1 was 76.6 ± 24.6% of predicted. There were clinical comorbidities in 73.5% of all cases (COPD in 29.8%). The most common surgical sites were thorax (n = 122; 23.4%) and upper abdomen (n = 117; 22.5%). Postoperative pulmonary complications occurred in 99 patients (19.0%), with respiratory failure being the most common (4.6%). Forty-three (8.3%) patients died. Rates of pulmonary complications were higher after thoracic (28.9%), cardiac (28%) and upper abdomen surgery (24.3%) ($p \leq 0.0001$). Most patients (66.7%) with pulmonary complications were classified as ASA III or IV ($p < 0.01$), and in 70.2% of operations, time on anesthesia was > 3.5 hours ($p \leq 0.0001$). The difference in median length of hospital stay between patients with and without pulmonary complications was statistically significant (23.5 [15.8-34] days vs. 10 [6-18] days; $p < 0.001$). Patients who had never smoked had fewer complications than those with current or past smoking history ($p = 0.04$). We did not detect significant associations between postoperative pulmonary complications and presence of COPD, FEV1 or body mass index ($p > 0.05$).

Conclusion. The most important factors associated with postoperative pulmonary complications were surgical site, time of anesthesia, and ASA classification.

Key words: General surgery. Postoperative complications. Risk factors. Respiratory function tests.

***Correspondence:**
Rua São Manoel, 1584 – Apto. 606
Porto Alegre – RS, Brazil
CEP: 90620-110

Introduction

Postoperative pulmonary complications (POPC) occur after 25% to 50% of major surgical procedures[1]. Postoperative pulmonary complications are as prevalent as cardiac complications and have a similar effect on morbidity, mortality and length of hospital stay. They may even predict mortality over the long term better than cardiac complications[2].

The definition of a POPC is a second, unexpected, disease that appears up to 30 days after surgery, changing the patient's clinical status and making therapeutic intervention necessary. The following are considered POPC: pneumonia, tracheobronchial infection, atelectasis with clinical repercussions, bronchospasm, acute respiratory failure, prolonged tracheal intubation or mechanical ventilation (more than 48 hours). Several authors also consider fever with no definite cause, pulmonary embolism, pleural hemorrhage and bronchopleural fistula to belong to this group[3-8].

There are links between POPC and preoperative risk factors. Risk factors described in the literature include: advanced age (> 60 years), prior lung disease such as chronic obstructive pulmonary disease (COPD) or other comorbidities, an American Society of Anesthesiologists (ASA) classification greater than or equal to II, active smoking, obesity, malnutrition, type of anesthesia, length of surgery (> 3 hours), type of surgery, abnormal spirometry results, reduced capacity for exercise and prolonged preoperative hospital stay[2,4,7-9].

The objective of this study was to identify clinical factors and preoperative pulmonary function variables that are predictive of

1. Mestrado em Ciências Pneumológicas; médica pneumologista pelo Hospital de Clínicas de Porto Alegre, RS
2. Mestrado em Pneumologia; médico pneumologista pelo Hospital de Clínicas de Porto Alegre, RS
3. Pós-doutorado em Pneumologia; professora associada da Faculdade de Medicina da Universidade Federal do Rio Grande do Sul, Porto Alegre, RS

POPC in patients subjected to a variety of types of surgery at a tertiary University Hospital.

Methods

This was a retrospective study that reviewed the medical records of a 5-year cohort of patients who had preoperative pulmonary function assessments at the Pulmonary Physiology Department of a University Hospital and who went on to have a surgical operation. All of the pulmonary function tests were requested as part of these patients' routine preoperative workup, in addition to any other tests for which there were clinical indications. The study was approved by the institutional research ethics committee. The authors signed a data usage declaration committing them to preserve the anonymity of the patients studied.

Patients were excluded from the study if they already had any of the conditions defined as POPC for the purposes of this study during the perioperative period: pneumonia, tracheobronchitis, atelectasis with clinical repercussions, acute respiratory failure, tracheal intubation, bronchospasm, pulmonary embolism, pulmonary edema, pleural hemorrhage and/or pneumothorax needing drainage.

The researchers reviewed the medical records and filled out a standardized questionnaire for each patient covering the following items: demographic data, comorbidities, smoking, alcohol consumption, spirometric variables after bronchodilator administration (forced vital capacity [FVC], forced expiratory volume in 1 second [FEV1],) FEV1/FVC ratio), single breath carbon monoxide diffusing capacity (DCO), chest X-ray, arterial blood gas analysis, ASA classification, surgical site, time on anesthesia, length of hospital stay and POPC.

We defined POPC as new clinical conditions that appear after surgery. For the purposes of this study, specific POPC were defined as follows:

1. Pneumonia: recent pulmonary infiltrate visible on chest X-ray, combined with at least two of the following: purulent tracheobronchial secretion, increase in body temperature above 38.3oC or increase in the number of white blood cells in the circulation by more than 25% of the baseline figure.

2. Tracheobronchitis: increase in the quantity or changes in the color or purulent appearance of tracheobronchial secretions, with a normal chest X-ray.

3. Atelectasis with clinical repercussions: evidence of pulmonary atelectasis on chest X-ray combined with acute respiratory symptoms.

4. Acute respiratory failure: clinical status caused by acutely deficient pulmonary gaseous exchange with a need for mechanical ventilation.

5. Prolonged tracheal intubation: oral endotracheal intubation for more than 48 hours; either because mechanical ventilation was maintained to treat acute respiratory failure or for aspiration of tracheobronchial secretions in patients unable to eliminate them spontaneously.

6. Prolonged mechanical ventilation: mechanical ventilation for more than 48 hours to treat acute respiratory failure.

7. Bronchospasm: wheezing detected by pulmonary auscultation combined with acute respiratory symptoms requiring medication, with or without prior history compatible with bronchial hyperresponsiveness, asthma or chronic obstructive pulmonary disease (COPD).

8. Pulmonary embolism: detected by positive pulmonary computed tomographic angiography or high probability pulmonary perfusion scintigraphy.

9. Pulmonary edema: crepitant rales associated with altered cardiac output and capillary wedge pressure.

10. Pneumothorax or pleural hemorrhage observed on chest X-ray and requiring drainage.

11. Death from respiratory complications.

Data were input on Microsoft Excel XP® and processed and analyzed using the Statistical Package for the Social Sciences (SPSS) version 14.0. A descriptive analysis of the study variables was conducted. Quantitative data are shown as mean ± standard deviation or median and interquartile range (IQR). Qualitative data are expressed as absolute totals (% of total number of cases) and were analyzed using the chi-square test, with Yates' correction or Fisher's exact test where necessary. Quantitative variables were compared between patients with and without POPC using the t test for unpaired samples or the Mann-Whitney test, depending on the distribution. Multivariate logistic regression analysis was run in order to identify independent associations between the variables studied and presence or absence of POPC and death due to any cause using the forward stepwise method. Predictive factors identified through univariate analysis with p values below 0.2 were included sequentially in ascending p value order, recalculating the discriminatory function for variables already included at each step. As new variables were added, previously included variables were removed if their power to explain differences between groups was already provided by some other combination of variables already analyzed. The results were expressed as odds ratios. All statistical tests used were two-tailed. Results where $p < 0.05$ were considered statistically significant. The sample size calculated for a significance level of 5% and 80% power with an estimated POPC rate of 50% of major surgical procedures was 384 patients.

Results

A total of 521 patient records were analyzed from patients who underwent preoperative pulmonary function assessment during the study period. The principal characteristics of these patients are given in Table 1. The mean age of patients was 59.5 ± 14 (range: 16 to 90 years). Sixty-five point eight percent (65.8%, n = 343) of the patients were male and 93.4% (n = 487) were white. Forty-one percent (41%, n = 214) were active smokers, 34.7% (n = 181) had smoked previously and 23.6% (n = 123) had never smoked. With regard to body mass index (BMI), 13.6% (n = 71) of our patients had a BMI > 30 kg/m^2, 38.8% (n = 202) were overweight (BMI of 25 to 30 kg/m^2), 41.8% (n = 218) had healthy weights (18.5 kg/m^2) and just 5.8% (n = 30) had BMI < 18.5 kg/m^2. Means FVC and FEV_1 were 82.3 ± 20% and 76.6 ± 24.6% of predicted, respectively. Clinical comorbidities were present in 73.5% (n = 383) of the patients; 29.8% (n = 138) of the patients had a history of COPD. Three point two percent (3.2%, n = 16), 42.4% (n = 211), 47.8% (n = 238) and 6.6% (n = 33) of the patients were classified as ASA I, II, III and IV, respectively. The most common surgical sites were the thorax (23.4%, n = 122) and the upper abdomen (22.5%, n =

117) followed by other sites (19.6%, n = 102). General anesthetic was given to 227 (44.5%) patients, 208 (40.8%) received combined anesthesia and 74 (14.5%) were given local anesthetic. Median anesthesia duration was 3.5 hours (IQR: 2.25-5.25). Median length of hospital stay was 12 days [range: 6 to 22 days].

Postoperative pulmonary complications were observed in 95 patients (18.2%), with respiratory failure being the most common, affecting 4.6% (n = 24) of the patients. Pleural hemorrhage requiring drainage, pneumonia, oral endotracheal intubation and atelectasis were observed in 20 (3.8%), 13 (2.5%), 11 (2.1%) and 11 (2.1%) cases, respectively. Other complications, such as tracheobronchitis (0.8%, n = 4), bronchospasm (0.8%, n = 4), pulmonary embolism (0.4%, n = 2) and pneumothorax (1.2%, n = 6) were less common.

Postoperative pulmonary complication rates for patients who underwent thoracic surgery, heart surgery, upper abdominal surgery, lower abdominal surgery and surgery at all other sites were 28.9% (n = 43), 28.0% (n = 14), 24.3% (n = 36), 12.6% (n = 13) and 3.1% (n = 3), respectively. Both thoracic and upper abdominal surgery was significantly associated with POPC ($p<0.001$ and $p=0.042$, respectively) (Table 2). The majority of patients with POPC (n = 64; 66.7%) were classified as ASA III or IV ($p<0.01$) and 70.2% (66) were on anesthetic for more than 3.5 hours ($p\leq0.0001$). Patients given combined anesthesia suffered more POPC than those given other types of anesthesia ($p<0.001$). Patients given local anesthetic had fewer POPC ($p< 0.001$) than patients given general or combined anesthetic. Length of hospital stay was statistically different between patients with and without POPC (23.5 [range: 15.8-34] days vs. 10 [range: 6-18] days; $p<0.001$). Patients who had never smoked had fewer POPC than patients with a history of smoking ($p=0.04$). Significantly more patients with heart failure suffered POPC than patients without heart failure ($p=0.005$), in particular pneumonia (12.8% vs. 1.7%; $p=0.002$) and pulmonary edema (15.4% vs. 1.0%; $p< 0.0001$). Forced vital capacity as a percentage of predicted was statistically different between patients with and without POPC (82.8 ± 19.8 % vs. 87.6 ± 19.6 %; $p=0.034$). However, patients with FVC < 50% did not have more POPC than those with FVC > 50%. There was no significant association between POPC and sex; age (even after stratification into > 65 and < 65); COPD; VEF_1, VEF_1/CVF < 0,70, BMI < 18,5 kg/m^2 ou > 30 kg/m^2 or general anesthetic ($p>0.05$).

According to the multivariate analysis, the variables that increased the chance of POPC were: thoracic surgery (OR=2.83), combined anesthesia (OR=2.21), duration of anesthesia > 3.5 hours (OR=2.03), heart failure (OR=3.04) and ASA ≥ III (OR=2.46).

Forty-three patients (8.3%) died from all causes combined and 23 (4.4%) died from respiratory complications. Male patients ($p=0.025$), patients with ASA ≥ III ($p=0.001$), patients subjected to upper abdominal surgery ($p=0.001$), patients given combined anesthesia ($p=0.026$), patients with renal failure ($p=0.004$) and patients on anesthesia for more than 3.5 hours ($p=0.001$) were more likely to die from all causes (Table 3). Patients who died were significantly older than those who survived (65.8 ± 10.4 years vs. 58.9 ± 14.2 years; $p < 0.0001$). Univariate analysis of the patients who died from respiratory complications indicated that associated variables were upper abdominal surgery ($p=0.019$) and FVC (in % of predicted, $p=0.005$).

According to the multivariate analysis, variables associated with death from all causes were upper abdominal surgery (OR=3.45),

Table 1 - Characteristics of the 521 patients who underwent preoperative pulmonary function assessment

Characteristic	n (%) or mean ± SD or median (IQR)
Age (years)	59.5 ± 14
Male sex	343 (65.8)
Smoking history	
Current	214 (41)
Previous	181 (34.7)
Never smoked	123 (23.6)
BMI (kg/m2)	25.5 ± 5.3
FVC (% of predicted)	82.3 ± 20.0
FEV_1 (% of predicted)	76.6 ± 24.6
COPD	138 (29.8)
SAH	226 (43.3)
Ischemic heart disease	95 (18.2)
Diabetes mellitus	62 (11.9)
Heart failure	39 (7.5)
Renal insufficiency	20 (3.8)
ASA Classification	
I	16 (3.2)
II	211 (42.4)
III	238 (47.8)
IV	33 (6.6)
Surgery site	
Thorax	122 (23.4)
Upper abdomen	117 (22.5)
Other sites	102 (19.6)
Type of anesthesia	
General	227 (44.5)
Combined	208 (40.8)
Local	74 (14.5)
Time on anesthesia (h)	3.5 (2.25-5.25)
Length of hospital stay (days)	12 (6-22)

SD: standard deviation. IQR: interquartile range. BMI: body mass index. FVC: forced vital capacity. FEV_1: forced expiratory volume in 1 second. COPD: chronic obstructive pulmonary disease. SAH: systemic arterial hypertension. ASA: American Society of Anesthesiologists

Table 2 - Characteristics of patients with and without postoperative pulmonary complications (POPC)

Characteristic	With POPC	Without POPC	p
Age (years)	61.7 ± 13.1	59.1 ± 14.2	0.092
Sex male/female	65 (66.3) / 33 (33.7)	278 (65.7) / 145 (34.3)	0.909
History of smoking	76 (77.6)	319 (75.4)	0.04
COPD	27 (27.6)	111 (26.4)	0.821
SAH	40 (40.8)	186 (44.0)	0.570
Ischemic heart disease	24 (24.5)	71 (16.8)	0.075
Diabetes mellitus	17 (17.3)	45 (10.6)	0.065
Heart failure	14 (14.3)	25 (5.9)	0.005
Renal insufficiency	2 (2.0)	18 (4.3)	0.394
FVC (% of predicted)	82.8 ± 19.8	87.6 ± 19.6	0.034
FEV^1 (% of predicted)	77.7 ± 24.7	81.6 ± 24.3	0.170
ASA classification ≥ III	64 (66.7)	207 (51.5)	0.007
Thoracic surgery	43 (45.7)	106 (26.1)	< 0.0001
Upper abdominal surgery	36 (36.7)	112 (26.5)	0.042
General anesthetic	36 (36.7)	191 (45.2)	0.130
Combined anesthetic	55 (56.1)	153 (36.2)	< 0.0001
Local anesthetic	3 (3.1)	71 (16.8)	< 0.0001
Time on anesthesia > 3.5 hours	66 (70.2)	202 (48.1)	< 0.0001
Length of hospital stay (days)	23.5 (15.8-34)	10 (6.18)	< 0.0001

** Figures given as n (%) or mean ± standard deviation or median (interquartile range)*
POPC: postoperative pulmonary complications. COPD: chronic obstructive pulmonary disease. SAH: systemic arterial hypertension. FVC: forced vital capacity. FEV1: forced expiratory volume in 1 second. ASA: American Society of Anesthesiologists

time on anesthesia > 3.5 hours (OR=3.74), renal failure (OR=4.62) and ASA ≥ III (OR=4.31).

Discussion

Postoperative pulmonary complications are common and are an important cause of perioperative morbidity and mortality[7]. Pulmonary complications are reported in 12 to 70% of patients who undergo upper abdominal and thoracic surgery, in comparison with a 4% incidence after urological or orthopedic surgery[10-12]. The prevalence of POPC observed in our sample was 18.2%.

The majority of POPC were caused by changes to pulmonary volumes in response to respiratory muscle dysfunction or other mechanical changes to the chest wall. Surgery involving incisions close to the diaphragm, such as thoracic or upper abdominal surgery, is associated with increased risk of complications. Even when correct analgesia is given, diaphragm dysfunction may occur, with major reductions in vital capacity (VC) and small, but significant, reductions in functional residual capacity (FRC). After

Table 3 - Characteristics of patients who died or survived after surgery

Characteristic	Death	Survival	p
Age	65.8 ± 10.4	58.9 ± 14.2	< 0.0001
Male sex	35 (81.4)	308 (64.4)	0.025
History of smoking	8 (18.6)	115 (24.2)	0.408
COPD	15 (34.9)	123 (25.9)	0.202
SAH	21 (48.8)	205 (42.9)	0.451
Ischemic heart disease	7 (16.3)	88 (18.4)	0.729
Diabetes mellitus	8 (18.6)	54 (11.3)	0.156
Heart failure	4 (9.3)	35 (7.3)	0.551
Renal insufficiency	6 (14.0)	14 (2.9)	0.004
FVC (% of predicted)	82.0 ± 21.9	87.1 ± 19.5	0.107
FEV_1 (% of predicted)	77.4 ± 26.9	81.2 ± 24.2	0.335
ASA classification ≥ III	32 (80.0)	239 (52.2)	0.001
Thoracic surgery	11 (29.7)	138 (29.8)	0.992
Upper abdominal surgery	22 (51.2)	126 (26.4)	0.001
General anesthetic	15 (34.9)	212 (44.4)	0.230
Combined anesthetic	24 (55.8)	184 (38.5)	0.026
Local anesthetic	3 (7.0)	71 (14.9)	0.156
Time on anesthesia > 3.5 hours	32 (78.0)	236 (49.9)	0.001
Length of hospital stay (days)	20 (10.5-28)	11 (6.21)	0.260

** Figures given as n (%) or mean ± standard deviation or median (interquartile range)*
ASA: American Society of Anesthesiologists. FVC: forced vital capacity. FEV1: forced expiratory volume in 1 second. COPD: chronic obstructive pulmonary disease. SAH: systemic arterial hypertension.

major surgery, VC reduced by around 50% to 60% and FRC by around 30% during the first 16 to 24 hours, returning to normal values around the fifth day after surgery. When FRC is reduced, parts of the lungs undergo premature airway closure and atelectasis, causing a ventilation-perfusion imbalance, hypoxemia, retention of secretions, pneumonia and respiratory failure[1,13-16].

The objective of the preoperative assessment is to identify patients at risk of developing complications during or after surgery[10]. One study identified the following preoperative risk factors which increase the likelihood of POPC after thoracic and abdominal surgery: productive cough with yellow expectoration, thoracic surgery, BMI, smoking and duration of surgery[13]. In our study, patients who underwent thoracic and upper abdominal surgery also suffered a greater number of POPC.

One prospective study performed preoperative assessments on 408 patients prior to elective upper abdominal surgery. Of the clinical variables analyzed, the following determined increased POPC incidence: existing lung disease, respiratory symptoms, duration of surgery greater than 210 minutes, age greater than 50 years, related clinical diseases and active smoking. The only

spirometric variable that correlated with POPC was an FEV1/FVC ratio of less than 70%[3]. We did detect an association between FVC (in terms of % of predicted) and POPC in our univariate analysis, although this may be due to selection bias. All of the patients in our sample underwent spirometry on medical advice and not because of the study. It is likely that this test was requested as part of workup for patients known to have lung disease or in whom lung disease was suspected because of their clinical history. However, we did not detect any associations between FEV_1 or FEV_1/FVC and POPC.

The most frequently identified risk factor for POPC is COPD, with a rate of postoperative complications that varies from 26% to 78%[2,10,17]. There was no significant association between POPC and COPD in the patient sample that we investigated. Two other studies[4,13] also failed to identify this association. It is known that patients with acute respiratory symptoms or asthmatics exhibit the same incidence of POPC as the general population if they are treated and controlled clinically[4,13]. Since all of our patient sample underwent preoperative spirometry, it is possible that they were managed better.

An association between pre-existing clinical disease (SAH, heart disease or diabetes mellitus) and increased number of POPC has been described before[3]. In our study, patients with heart failure suffered more POPC and patients with renal failure suffered a greater number of deaths from all causes combined. We also observed a tendency towards an increased number of POPC among patients with diabetes mellitus and ischemic heart disease, although this was not a statistically significant association. A study that compiled an index of the risk of postoperative respiratory failure observed that a history of heart failure (OR=1.25) or renal failure (OR=1.67) were both risk factors[18].

Patients classified as ASA ≥ II are at increased risk of complications[2]. In our cohort, the majority of patients with POPC (66.7%) and also the majority of those who died from all causes combined (80%) had been classified as ASA III or IV.

Surgery lasting longer than 210 minutes is considered a risk factor for complications[13]. Postoperative pneumonia is more common after procedures that last longer than 4 hours, irrespective of surgical site[10]. The majority of patients with POPC (70.2%) in our study were under anesthesia for longer than 3.5 hours, as were patients who died from all causes combined (78%). However, this parameter can only be estimated during preoperative assessments.

In our study, patients given combined anesthesia suffered more complications than patients given either general anesthetic or local anesthetic. Although the majority of evidence suggests that combined anesthesia reduces the number of deaths[19-22], one previous study has demonstrated increased mortality among patients given this type of anesthesia[23].

Obese patients are susceptible to ineffective coughing, basal atelectasis and progressive hypoxia, facilitating infection[13]. Despite this, there is no evidence of increased risk of complications related with obesity, even among patients who are morbidly obese[2]. at the other end of the scale, malnutrition leads to a reduction in pulmonary defenses due to a fall in the levels of secretory IgA, reduced ventilatory response to hypoxemia and reduced muscle mass[13]. Patients who have lost more than 10% of their weight during the 6 months prior to surgery are at increased risk of respiratory failure and pneumonia[14]. In our study, we did not detect any association between BMI and pulmonary complications. Another study also failed to detect this association[3], This may be due to the fact that the majority of our patient sample were either healthy weight or overweight, which may have contributed to the negative result. Furthermore, we did not collect data on recent weight loss or serum albumin levels, considered an independent risk factor for POPC.

It is known that chest X-ray and spirometry should not be routinely used to predict the risk of POPC. These tests may be appropriate for patients with diagnosed or suspected COPD or asthma[2]. but their use with asymptomatic patients remains controversial[12]. While spirometry does provide a certain level of risk stratification, the majority of patients identified as high risk by a test would also be identified by clinical assessment[7]. Current evidence does not support this test as capable of predicting POPC for surgery outside of the thorax[1]. However, for patients with diagnosed or suspected lung disease, while pulmonary function tests cannot be considered prognostic tools, they may be capable of reducing the risk by promoting better medical management of the disease[10]. This, in turn, may explain why the percentage of POPC in our sample was not particularly high, since these patients' treatment could have been optimized.

Conclusions

In conclusion, the most important risk factors associated with POPC in our study were thoracic surgery, combined anesthesia, anesthesia lasting > 3.5 hours, heart failure and ASA classification ≥ III. Factors related to deaths from all causes combined were upper abdominal surgery, anesthesia duration > 3.5 hours, renal failure and ASA classification ≥ III.

Conflicts of interest: none

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