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Performance of the ARISCAT Score for predicting postoperative pulmonary complications in major abdominal surgery in elderly patients

Rendimiento del puntaje de ARISCAT para predicción de complicaciones pulmonares posoperatorias en cirugía abdominal mayor en pacientes ancianos

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What do we know about this problem?

Postoperative pulmonary complications contribute to postoperative morbidity and mortality after abdominal surgeries. Advanced age is associated with a higher risk of postoperative respiratory complications and worse outcomes. However, there are few studies describing this phenomenon in Colombia and Latin America, and the diagnostic performance of risk prediction tools like ARISCAT is not well established in our population.

What does this study contribute?

This study provides information on the frequency of PPC in Bogotá and Colombia, where statistical knowledge on the subject is scarce. The results of the study show that preoperative factors such as weight loss, altered sensorium in the perioperative period, diabetes mellitus, and acute kidney injury are associated with a high risk of PPC, while the ARISCAT score has adequate diagnostic performance for predicting pulmonary complications in elderly patients after major abdominal surgery.

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Abstract

Introduction: The ARISCAT score is one of the most widely used tools to predict the probability of postoperative pulmonary complications (PPC).

Objective: To determine the performance of the ARISCAT score for predicting PPC in elderly patients undergoing abdominal procedures.

Methods: Retrospective cohort study including patients over 70 years of age undergoing abdominal surgery. Logistic regression was performed to determine the association between clinical and operative characteristics and the occurrence of PPC.

Results: A total of 381 patients were included, with a PPC frequency of 37.5% (n=143). Mortality was 10.8% (n=41). The median ARISCAT score was 42 points (IQR 26-57), with 50.6% (n=161) classified as high risk. The most frequent PPC was respiratory failure with 56.6% (n=81). According to the adjusted logistic regression, ASA classification II and III (OR 2.49; 95% CI 1.25-4.90; p=0.009), weight loss (OR 4.16; 95% CI 1.56-11.09; p=0.004), altered sensorium (OR 5.27; 95% CI 2.46-11.32; p<0.001), diabetes mellitus (OR 2.73; 95% CI 1.33-5.55; p=0.006), atrial fibrillation (OR 5.38; 95% CI 1.27-22.76; p=0.022), and high-risk ARISCAT classification (OR 9.19; 95% CI 2.85-22.63; p<0.001) were significantly associated with the presence of PPC. In the high-risk category, the observed sensitivity was 77.1% (95% CI 68.94-83.94), and a specificity of 67.9% (95% CI 60.71-74.54). The area under the curve (AUC) for the ARISCAT score was calculated at 0.7867 (95% CI 0.737-0.834).

Conclusions: The ARISCAT score is a useful tool for predicting the frequency of PPC in elderly patients.

Keywords: Aged; General surgery; Postoperative complications; Respiratory failure; Anesthesia.

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Resumen

Introducción: El puntaje de ARISCAT es una de las herramientas más ampliamente utilizadas para predecir la probabilidad de presentación de complicaciones pulmonares posoperatorias (CPP).

Objetivo: Determinar el rendimiento del ARISCAT para la predicción de CPP en pacientes ancianos sometidos a procedimientos abdominales.

Métodos: Estudio de cohorte retrospectivo. Se incluyeron pacientes mayores de 70 años de edad sometidos a cirugía abdominal. Se realizó una regresión logística para determinar la asociación entre características clínicas y operatorias con la presentación de CPP.

Resultados: Se incluyeron 381 pacientes con una frecuencia de CPP del 37,5% (n=143). Se observó una mortalidad el 10,8% (n=41). La mediana del puntaje de ARISCAT fue de 42 puntos (RIC 26-57), con el 50,6% (n=161) clasificados como riesgo alto. La CPP más frecuente fue la insuficiencia respiratoria con 56,6% (n=81). En la regresión logística ajustada, clasificación ASA II y III (OR 2,49; IC 95% 1,25-4,90; p=0,009), pérdida de peso (OR 4,16; IC 95% 1,56-11,09; p=0,004), alteración del sensorio (OR 5,27; IC 95% 2,46-11,32; p<0,001), diabetes mellitus (OR 2,73; IC 95% 1,33-5,55; p=0,006), fibrilación auricular (OR 5,38; IC 95% 1,27-22,76; p=0,022) y la clasificación de ARISCAT para riesgo alto (OR 9,19; IC 95% 2,85-22,63; p<0,001) se asociaron significativamente con la presencia de CPP. Para la categoría de riesgo alto se observó una sensibilidad del 77,1% (IC 95% 68,94-83,94), una especificidad del 67,9% (IC 95% 60,71-74,54%). El área bajo la curva (AUC) del ARISCAT fue calculado en 0,7867 (IC 95% 0,737-0,834).

Conclusiones: El ARISCAT es una herramienta útil para predecir la frecuencia de CPP en pacientes ancianos.

Palabras clave: Anciano; Cirugía general; Complicaciones posoperatorias; Insuficiencia respiratoria; Anestesia.

INTRODUCTION

Postoperative pulmonary complications (PPC) are one of the main causes of postoperative morbidity and mortality. (1) Although definitions vary widely, their incidence ranges from 2% to 20%. (1-3) The European Society of Anaesthesiology (ESA) and the European Society of Intensive Care Medicine (ESICM) have established operational definitions for PPC that include: respiratory infection, respiratory failure, pleural effusion, atelectasis, pneumothorax, bronchospasm, and aspiration pneumonitis. (4) However, the international collaboration to determine standards for perioperative medicine defines PPC as the group of respiratory diagnoses that share common pathophysiological mechanisms, such as airway collapse and airway contamination, which include: identification of atelectasis by tomography (CT) or chest X-ray, pneumonia, acute respiratory distress syndrome—according to the Berlin Consensus criteria—and pulmonary aspiration—clear clinical history associated with radiological evidence. This consensus excludes other diagnoses that do not share pathophysiological mechanisms and therefore should be assessed separately, such as pulmonary embolism, pleural effusion, cardiogenic pulmonary edema, pneumothorax, and bronchospasm. (5)

The ARISCAT score (Assess Respiratory Risk in Surgical Patients in Catalonia) was developed in 2010 from a cohort of 2,464 patients from 59 hospitals in Spain (2); it is one of the main tools for predicting pulmonary complications in perioperative medicine with multiple external validation studies with adequate diagnostic prediction for different types of surgical procedures. (6,7) The most frequently assessed PPCs include: respiratory tract infection, acute respiratory failure, pleural effusion, atelectasis, pneumothorax, bronchospasm, and aspiration pneumonitis (2) (Table 1).

Most validation studies agree on the association of PPC with certain risk factors, which are also associated with early mortality, ICU admission, need for invasive mechanical ventilation, or prolonged length of stay (8). Among these factors, advanced age and abdominal surgery are the most frequently reported (9-11). The incidence of pulmonary complications after abdominal surgery can be as high as 60%(1). On the other hand, senescence is closely related to the presence of comorbidities, frailty, and functional dependency (1,2,9,12,13).

Table 1. Variables included in the ARISCAT score for predicting postoperative pulmonary complications.

Variables	Points
Age in years	≤50 years, 0 points 51-80 years, +3 points >80 years, +16 points
Preoperative oxygen saturation (%)	≥96%, 0 points 91-95%, +8 points <90%, +24 points
Respiratory infection in the last month	No, 0 points Yes, +17 points
Preoperative anemia (hemoglobin ≤10 g/dL)	No, 0 points Yes, +11 points
Surgical incision	Peripheral, 0 points Upper abdominal, +15 points Intrathoracic, +24 points
Duration of surgery	<2 hours, 0 points 2-3 hours, +16 points >3 hours, +23 points
Emergency procedure	No, 0 points Yes, +8 points
Interpretation	Low risk <26 points Intermediate risk 26-44 points High risk ≥45 points

Source: Authors.

In Colombia, the elderly population over 65 years old as of July 2019 represented 9.1% (14), with an estimated increase of 15% for 2024, corresponding to 7,891,331. An increase in the number of surgeries in this population is expected, with a subsequent increase in postoperative morbidity and its impact on public health. The objective of this study is to determine the diagnostic performance of the ARISCAT score for predicting pulmonary complications in patients over 70 years old who underwent open or laparoscopic abdominal procedures at a university hospital in Bogotá, Colombia.

METHODS

A retrospective cohort study was conducted. Patients over 70 years old undergoing major abdominal surgery (open or laparoscopic) between January 1, 2015, and December 31, 2019, at Hospital Universitario Clínica San Rafael were included. Patients who underwent endoscopic procedures or procedures that did not include entry into the abdominal cavity were excluded. Additionally, patients with ASA VI classification, perioperative long bone fracture, requirement for invasive mechanical ventilation within 30 days prior to the procedure, requirement for intrathoracic procedure, or history of major abdominal surgery within 30 days prior to the procedure were excluded.

The sample size was calculated considering an anticipated outcome frequency of 8%, a type I error of less than 5% ($p<0.05$), a type II error of less than 20%, and a 95% confidence interval for a minimum of 114 patients. The selected patients were included sequentially within the study period. This study was reviewed and approved by the Research and Bioethics Committee of Hospital San Rafael on December 4, 2020 (Minutes CEI-162-2020).

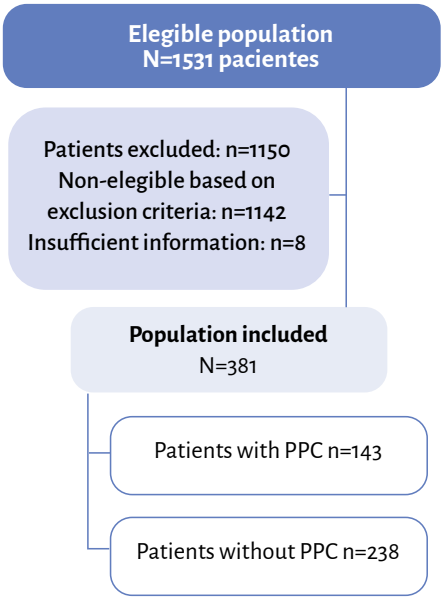
After reviewing the medical records, sociodemographic variables, clinical history, intraoperative variables, and postoperative complications were recorded (Complementary material 1). The following variables were included to calculate the ARISCAT score: preoperative hemoglobin, preoperative oxygen saturation, duration of the surgical procedure, history of respiratory infection in the last 30 days, type of incision (peripheral, upper abdominal, or intrathoracic; in this case, all patients included underwent intra-abdominal surgery), and emergency surgery. To determine PPC, the parameters defined in the derivation study by Canet et al. (2) were used, which include: respiratory infection, respiratory failure, bronchospasm, atelectasis, pleural effusion, pneumothorax, and aspiration pneumonitis occurring within the in-hospital period not exceeding 15 days after the surgical intervention (Complementary material 2). According to the ARISCAT score and based on the initial validation, patients were classified into three risk groups: low, intermediate, and high risk (Table 1). Additionally, the presence of perioperative adverse outcomes such as in-hospital mortality, reoperation, ICU admission in the perioperative period, and massive transfusion requirement was identified.

Qualitative variables were defined using relative and absolute frequencies. For quantitative variables, measures of central tendency and dispersion (median and interquartile ranges) were used. The composite outcome of the presence of PPC was used as the dependent variable. A bivariate analysis was performed to determine differences in the occurrence of pulmonary complications considering preoperative clinical and paraclinical variables. The Chi-square test was used for qualitative variables, and the Mann-Whitney test was used for quantitative variables. Additionally, a backward elimination logistic regression was performed, including variables with significant association in the bivariate analysis, retaining variables with a p-value ≤0.2. Variables that could present collinearity within the model, such as creatinine and blood urea nitrogen with chronic kidney disease, or hemoglobin <10 g/L with the ARISCAT score, were not included. The results of the logistic regression were reported in terms of Odds Ratio (OR) and their respective 95% confidence interval (95% CI). For the calculation of the diagnostic performance of the ARISCAT score, the area under the curve (AUC) was estimated, with their respective 95% confidence intervals. For each risk category, sensitivity (SE) (true positives / true positives + false negatives), specificity (ES) (true negatives / true negatives + false positives), positive predictive value (PPV) (true positives / true positives + false positives), negative predictive value (NPV) (true negatives / true negatives + false negatives), and the percentage of correctly classified patients were calculated, along with their confidence intervals. A p-value <0.05 was considered statistically significant. The statistical analysis was performed using Stata statistical software (Version 18.0).

RESULTS

The study included 381 patients, of whom 37.5% (n=143) presented postoperative pulmonary complications (Figure 1).

Figure 1. Diagram showing the inclusion of participants in the study.



Source: Authors.

Table 2. Preoperative and surgery-associated clinical characteristics.

Variable	Total (n = 381)	Without pulmonary complications (n = 238, 62.5%)	With pulmonary complications (n = 143, 37.5%)	p-value
Age, median (IQR)	75 (72-80)	75 (72-78)	77 (73-82)	<0.001
Sex				0.433
Female	174 (45.7)	105 (44.1)	69 (48.3)	
Male	207 (54.3)	133 (55.9)	74 (51.8)	
ASA				<0.001
I	2 (0.5)	2 (0.8)	0 (0.0)	
II	171 (44.9)	142 (59.7)	29 (20.3)	
III	189 (49.6)	93 (39.1)	96 (67.1)	
IV	17 (4.5)	1 (0.4)	16 (11.2)	
V	2 (0.5)	0 (0.0)	2 (1.4)	
Functionality				0.008
Independent	135 (35.4)	96 (40.3)	39 (27.3)	
Partial dependence	216 (56.7)	129 (54.2)	87 (60.8)	
Total dependence	30 (7.9)	13 (5.5)	17 (11.9)	
Dyspnea				<0.001
No dyspnea	183 (48.0)	134 (56.3)	49 (34.3)	
On exertion	149 (39.1)	77 (32.4)	72 (50.4)	
At rest	49 (12.9)	27 (11.3)	22 (15.4)	
Weight loss	40 (11.3)	7 (3.2)	33 (24.8)	<0.001
BMI, median (IQR)	26.1 (23.4-30.6)			0.054
Underweight	6 (1.6)	2 (0.8)	4 (2.8)	0.137
Normal	88 (23.1)	51 (21.4)	37 (25.9)	0.319
Overweight	83 (21.8)	53 (22.3)	30 (21.0)	0.768
Obesity	43 (15.9)	25 (15.5)	18 (16.5)	0.828
Current alcohol use	20 (5.3)	13 (5.5)	7 (4.9)	0.810
Smoking				0.784
No	226 (59.3)	138 (58.0)	88 (61.5)	
Ex-Smoker	146	94 (39,5)	52 (26,4)	
(38.3)	94 (39.5)	52 (26.4)		
Current smoker	9 (2.3)	6 (2.5)	3 (2.1)	
Biomass exposure	96 (25.2)	47 (19.8)	49 (34.3)	0.002
Use of oral steroids	5 (1.3)	2 (0.8)	3 (2.1)	0.296
Altered sensorium	75 (19.7)	14 (5.9)	61 (42.7)	<0.001
Infection/effusion	19 (5.0)	9 (3.8)	10 (7.0)	0.163
Suspicious active cancer	62 (16.3)	23 (9.7)	39 (27.3)	<0.001
Diabetes	99 (26.0)	49 (20.6)	50 (35.0)	0.002
Non-insulin dependent diabetes	86 (88.9)	45 (18.9)	41 (28.7)	0.027
Insulin-dependent diabetes	13 (13.1)	4 (1.7)	9 (6.3)	0.016
Coronary artery disease	39 (10.2)	20 (8.4)	19 (13.3)	0.128
Atrial fibrillation	28 (7.4)	6 (2.5)	22 (15.4)	<0.001
Heart failure	49 (12.9)	16 (6.7)	33 (23.1)	<0.001

Variable	Total (n = 381)	Without pulmonary complications (n = 238, 62.5%)	With pulmonary complications (n = 143, 37.5%)	p-value
Chronic kidney disease	62 (16.3)	32 (13.5)	30 (21.0)	0.054
OSA syndrome	19 (5.0)	12 (5.0)	7 (4.9)	0.949
Previous pulmonary disease	132 (34.7)	79 (33.2)	53 (37.1)	0.442
Polycythemia	52 (13.7)	36 (15.2)	16 (11.2)	0.272
Urea nitrogen (mg/dL), median (IQR)	20.2 (16-30.5)	19.5 (15.4-26.7)	23.9 (16.6-41)	<0.001
Creatinine (mg/dL), median (IQR)	0.92 (0.72-1.15)	0.92 (0.72-1.09)	1 (0.73-1.44)	0.055
Preoperative Ejection fraction (%) Median (IQR)	57 (50-60)	60 (54-60)	55 (49-60)	0.007
Type of anesthesia				<0.001
Neuraxial	71 (18.6)	65 (27.3)	6 (4.2)	
General	310 (81.4)	173 (73.7)	137 (95.8)	
Surgical approach				
Laparoscopic	121 (31.8)	94 (39.5)	27 (18.9)	
Open	260 (68.2)	144 (60.5)	116 (81.1)	

Source: Authors.

Table 2 describes the preoperative clinical characteristics and those related to the surgical procedure. The median age of the included patients was 75 years (IQR 72-80), and 54.3% (n=207) were men. 44.9% (n=171) and 49.6% (n=189) were classified as ASA II and III, respectively. 35.7% (n=135) of the patients were functionally independent, while 56.7% (n=216) reported partial dependence, and 7.9% (n=30) total dependence. The 48% (n=183) of the included patients did not report any type of dyspnea upon admission. A 11.3% (n=40) reported weight loss—≥10% of body weight in the last six months—prior to the surgical procedure. BMI was available in 70.8% (n=270) of the included patients, with a median BMI of 26.1 kg/m2 (IQR 23.4-30.6). Among toxicological antecedents, the most frequent was smoker — ex-smoker, 38.3% (n=146), smoking, 2.3% (n=9). Additionally, 25.2% (n=96) of the included patients reported a history of biomass exposure. The 19.7% (n=75) of the included patients had preoperative cognitive impairment. Among the pathological antecedents, the most frequent were pulmonary disease (34.7%, n=132), diabetes mellitus (26%, n=99), pulmonary hypertension (20.2%, n=77), suspected active cancer (16.3%, n=62), heart failure (12.9%, n=49), and coronary artery disease (10.2%, n=39).

In terms of preoperative laboratory variables, the median hemoglobin was 14.2 g/dL (IQR 12.9-15.6); the median blood urea nitrogen was 20.2 mg/dL (IQR 16-30.5); the median creatinine was 0.92 mg/dL (0.72-1.15); left ventricle ejection fraction was available in only 43.8% (n=167) of the included patients, with a median of 57% (IQR 50-60). Finally, 81.4% (n=310) of the patients underwent general anesthesia, with 18.4% (n=71) undergoing neuraxial anesthesia. 68.2% (n=260) were open procedures, 78.7% (n=300) had a duration of less than 210 minutes, and 33.3% (n=127) were emergency procedures.

The bivariate analysis, comparing the characteristics of patients with and without PPC, showed that patients with pulmonary complications were older, had a higher ASA classification, a higher percentage of dependence, a higher frequency of antecedents such as dyspnea, weight loss, biomass exposure, and sensorium alterations. Regarding comorbidities, patients with PPC had a higher frequency of suspected or active cancer, diabetes mellitus, atrial fibrillation, heart failure, pulmonary hypertension, and acute kidney injury. According to the preoperative laboratories, patients with PPC had a lower median hemoglobin, a higher frequency of anemia, a higher median blood urea nitrogen, and a lower ejection fraction. Additionally, a higher proportion of patients with PPC underwent general anesthesia and open surgical approach, the duration of the procedure was more than 210 minutes, and required emergency procedures.

Table 3 lists the variables of the ARISCAT score for the patients included. The median ARISCAT score was 42 points (IQR 26-57), with 18.2% (n=58) classified as low risk, 31.1% (n=99) as intermediate risk, and 50.6% (n=161) as high risk. The median ARISCAT score was higher in patients with pulmonary complications (55 (IQR 42-66) vs. 28 (26-43) points, p<0.001) with a higher proportion of patients classified as high risk (77.1% vs. 60%, p<0.001).

Table 4 shows the frequency of pulmonary complications observed in the patients. The most frequent PPC was respiratory failure representing 56.6% (n=81); In-hospital mortality was 10.8% (n=41); The median hospital stay for patients included in the study was 7 days (IQR 2-15) with a longer hospital stay for patients who had PPC (18 days (IQR 9-28 days) vs. 3 days (IQR 1-7 days), p<0.001).

Table 5 shows the results of the logistic regression analysis conducted to determine the factors associated with the presence of PPC. Prior to the backward elimination process, the following variables were included: ASA classification, functional dependence, weight loss, preoperative dyspnea, altered mental status, suspected or active cancer, biomass exposure, diabetes mellitus, atrial fibrillation, heart failure, pulmonary hypertension, and ARISCAT score classification. Using the backward elimination method, the following variables were maintained: ASA classification (OR 2.49; 95% CI 1.25-4.90; p=0.009), weight loss (OR 4.16; 95% CI 1.56-11.09; p=0.004), altered mental status (OR 5.27; 95% CI 2.46-11.32; p<0.001), diabetes mellitus (OR 2.73; 95% CI 1.33-5.55; p=0.006), atrial fibrillation (OR 5.38; 95% CI 1.27-22.76; p=0.022), and ARISCAT score classification for intermediate risk (OR 2.71; 95% CI 0.79-9.32; p=0.114) and high risk (OR 9.19; 95% CI 2.85-22.63; p<0.001).

Finally, the diagnostic performance of the ARISCAT score for predicting adverse pulmonary outcomes was determined. For the high-risk category, sensitivity was 77.1% (95% CI 68.94-83.94), specificity was 67.9% (95% CI 60.71-74.54), positive predictive value (PPV) was 62.7% (95% CI 54.77-70.21), and negative predictive value (NPV) was 81% (95% CI 73.9-86.7), with 77.1 of patients classified correctly. The AUC of the score was calculated at 0.7867 (95% CI 0.737-0.834), while the AUC for ASA was 0.702 (95% CI 0.657-0.747) (p<0.001) (Figure 2).

Table 3. Variables assessed in the ARISCAT score.

Variable	Total n = 381	Without pulmonary complications (n = 238, 62.5%)	With pulmonary complications (n = 143, 37.5%)	p-value
Preoperative hemoglobin (g/dL), median (IQR)	14.2 (12.9-15.6)	14.5 (13.5-15.8)	13.2 (11.9-15)	<0.001
Preoperative hemoglobin <10.0 g/dL	32 (8.4)	8 (3.4)	24 (16.8)	<0.001
Preoperative oxygen saturation				<0.001
≥96%	14 (3.7)	11 (4.6)	3 (2.1)	
91-95%	282 (74.0)	191 (80.3)	91 (63.6)	
<95%	85 (22.3)	36 (15.1)	49 (34)	
Surgical time				<0.001
<210 minutes	300 (78.7)	220 (92.4)	80 (55.9)	
≥210 minutes	81 (21.3)	18 (7.6)	63 (44.1)	
Emergency surgery	127 (33.3)	51 (21.4)	76 (53.2)	<0.001
ARISCAT, median (IQR)	42 (26-57)	28 (26-43)	55 (42-66)	<0.001
Low risk	58 (18.2)	54 (28.9)	4 (3.1)	
Intermediate risk	99 (31.1)	73 (39.0)	26 (18.9)	
High risk	161 (50.6)	60 (32.1)	101 (77.1)	

Source: Authors.

Table 4. Pulmonary complications experienced and other adverse postoperative outcomes.

Type of complication	N (%)
Respiratory tract infection	21 (14.7)
Respiratory failure	81 (56.6)
Ventilatory failure	53 (37.1)
Pleural effusion	45 (31.5)
Atelectasis	40 (28.0)
Pneumothorax	3 (2.1)
Aspiration pneumonitis	5 (3.5)
Bronchospasm	23 (16.1)
Adverse postoperative outcomes	N (%)
In-hospital mortality	41 (10.8)
Abdominal reoperation	66 (17.3)
Lavage and/or drainage	44 (66.7)
Intervention on intra-abdominal organs	22 (33.3)
Massive transfusion	41 (10.8)
ICU admission	119 (31.2)

Source: Authors.

DISCUSSION

The results of this study show a high frequency of PPC in elderly patients undergoing abdominal procedures. Additional preoperative factors included in the ARISCAT score, such as ASA classification (III-V), diabetes mellitus, atrial fibrillation, preoperative weight loss and altered sensorium, as well as other factors included in the score, such as preoperative anemia, were independent risk factors for the development of PPC. The ARISCAT score showed a moderate diagnostic performance in the high-risk category.

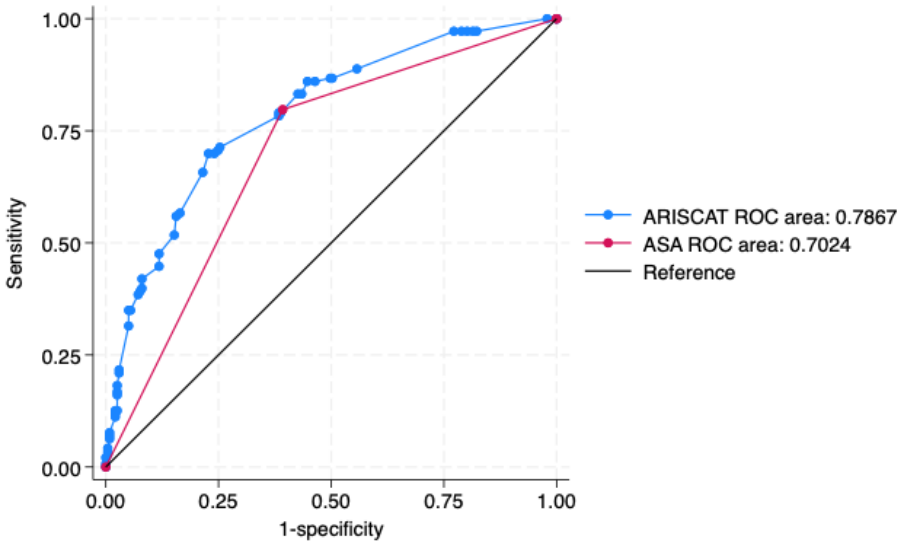
The ARISCAT score was developed from a cohort of 2,464 patients undergoing a range of surgical procedures, considering pulmonary complications as the outcome, with diagnostic performance in the validation cohort for an AUC of 0.8. (2) Following its publication, the results have been corroborated through a number of studies: Mazo et al. found an AUC of 0.8 (95% CI 0.78-0.82), sensitivity of 69.31%, specificity of 75.25% (cut-off score of ≥26) (6). Similarly, Kokotovic et al. conducted an external validation of the score with data from a national cohort including only patients undergoing emergency abdominal surgery, 585 Danish patients with an AUC of 0.83 (95% CI 0.79-0.86). (7) In the referred study, the median age of the patients was 70 years, but patients undergoing elective procedures were excluded, in contrast to this study which included any type of abdominal intervention. There are some studies that have assessed the value of ARISCAT in elderly populations, including high-risk abdominal procedures (Whipple surgery, liver resections, liver transplants, open and laparoscopic cholecystectomies, biliary tract resections, pancreatectomies, adrenalectomies, splenectomies, gas-

Table 5. Logistic regression for the development of postoperative pulmonary complications.

Variable	Crude OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
ASA				
I or II	Reference	-	Reference	-
III or IV	6.02 (3.71-9.77)	<0.001	2.49 (1.25-4.90)	0.009
Weight loss	10.04 (4.29-23.48)	<0.001	4.16 (1.56-11.09)	0.004
Altered sensorium	11.90 (6.31-22.42)	<0.001	5.27 (2.46-11.32)	<0.001
Diabetes mellitus	2.07 (1.30-3.30)	0.002	2.73 (1.33-5.55)	0.006
Atrial fibrillation	7.03 (2.78-17.80)	<0.001	5.38 (1.27-22.76)	0.022
ARISCAT				
Low risk	-	-	Reference	-
Intermediate risk	4.80 (1.60-14.59)	0.006	2.71 (0.79-9.32)	0.114
High risk	22.72 (7.83-65.90)	<0.001	9.19 (2.85-22.63)	<0.001

Source: Authors.

Figure 2. ROC curve Comparison for predicting postoperative pulmonary complications for ARISCAT and ASA classification.



Source: Authors.

trectomies, and hyperthermic intraperitoneal chemotherapies) which found a slightly lower AUC compared to those previously mentioned (AUC 0.72; 95% CI 0.665-0.774). (15) Other studies such as the one published by Fernández-Bustamante et al. (1) have explored the presence of factors associated with PPC in the general population. Although this study failed to assess the ARISCAT score, it did include patients undergoing different surgical procedures, such as abdominal and/or pelvic (45.3%), in patients with a mean age of 62.1 years (SD 13.8). This particular study found a similar frequency of PPC (33.4%, versus 37.5% in our study) with similar associated factors such as emergency surgery, old age, preoperative oxygen saturation, duration of the procedure, and other factors such as blood loss, colloid administration, and tidal volume administered to patients undergoing invasive mechanical ventilation. (1) Unfortunately, this study did not include similar variables such as the type of fluids administered, or variables associated with mechanical ventilation during the procedure.

Other risk factors, in addition to those included in the ARISCAT score, have been identified as predictors of PPC. Preoperative factors such as age (>70 years), history of pulmonary diseases (i.e. COPD), toxic habits such as smoking, BMI (>30 kg/m2 or <21 kg/m2) have been associated with an increased frequency of PPC. (16,17) Among the studies that have evaluated the frequency of PPC in abdominal surgery, an open approach or an emergent/urgent surgery have also been identified as risk factors. (1,13,16) Other risk factors relating to laboratory parameters, such as hemoglobin, are also associated with a higher probability of PPC. Similar to this study, other authors have found that a hemoglobin value <10 g/dL increases the risk of PPC. (17,18)

Routine evaluation of ARISCAT has proven to be a useful and cost-effective tool for reducing postoperative complications in the Latin American context. In the study published by Mares-Gutiérrez et al., a strategy combining preoperative risk assessment with the ARISCAT score in addition to preoperative spirometry proved to be cost-effective in moderate risk patients, and showed a cost reduction in high-risk patients. (19)

Compared to other scales, the ARISCAT score has adequate diagnostic performance to determine the probability of PPC. As compared against the ASA classification, the ARISCAT score exhibits better diagnostic performance. (18,20) Although other risk prediction tools have been explored, such as the LAS VEGAS score which assesses similar preoperative variables (ASA classification, preoperative anemia, preoperative oxygen saturation, active cancer, obstructive sleep apnea), that relate to the surgical procedure (urgent or elective, duration ≥1 hour) in addition to intraoperative variables such as the type of airway device, type of anesthesia (balanced vs. total intravenous), high levels of end-expiratory pressure (≥3 cmH2O) and vasopressor requirement, the diagnostic performance of this scale was even lower compared to that described in the original ARISCAT score cohort (AUC 0.78; 95% CI 0.76-0.80). (21) Although other promising parameters for predicting PPC such as functional variables like VO2 quantification exist, (22) the ARISCAT score remains the most widely used strategy to determine the preoperative risk of PPC. Other scales, such as SPORC (Score for Prediction Of Postoperative Respiratory Complications), also derived from large cohorts of surgical patients, have considered more specific outcomes, such as the composite outcome of reintubation requirement and perioperative mortality, with good diagnostic performance, both in the original derivation cohort (AUC 0.79; 95% CI 0.75-0.84) (23) and in other external validation studies (AUC 0.84; 95% CI 0.82-0.85). (24) However, these scores have not been compared in the context of abdominal surgery in elderly patients, but in the context of thoracic surgery, with results showing low discriminatory power for predicting PPC (ARISCAT: AUC 0.60; 95% CI 0.55-0.65; LAS VEGAS: AUC 0.68; 95% CI 0.63-0.73; SPORC: AUC 0.63; 95% CI 0.59-0.68). (25)

According to the authors' review, this study is one of the first to determine the value of PPC prediction scales in elderly patients in the region. (26) The results of this study will enable the identification of additional risk factors that allow for the optimization and monitoring of perioperative factors to reduce the frequency of postoperative complications in susceptible populations such as elderly patients. Some of the limitations of the study include its retrospective nature, which hindered the assessment of other factors associated with the development of pulmonary complications specifically related to anesthesia (ventilatory parameters, type of anesthesia administered, preoperative pulmonary evaluation), as well as the identification of other complications, such as adult respiratory distress syndrome in the immediate postoperative period. However, the study design included a rigorous definition of PPC, as well as a strict protocol for collecting variables to limit information biases related to the retrospective nature of the study. Additionally, with regards to the evaluation of ARISCAT as the only scale, no comparison was made with other tools such as SPORC or LAS VEGAS, neither was a calibration analysis conducted (through other methods such as LOESS (Locally Estimated Scatterplot-Smoothed Curves)). Likewise, the inclusion of patients over 70 years old is a limitation to be able to generalize the results to the general population; however, the results clearly portray the performance of ARISCAT and the frequency of PPC in this group of patients, who present this type of complications more frequently and are at higher risk of general perioperative morbidity and mortality. However, further similar studies will provide the foundation for evaluating and comparing the diagnostic performance with other scales, such as LAS VEGAS and SPORC, in other populations and different types of surgical procedures.

CONCLUSIONS

The ARISCAT score is a useful tool for predicting the frequency of PPC in elderly patients undergoing abdominal surgery. Further studies are required to establish the role of other factors such as functional tests, cardiopulmonary prehabilitation, and variables related to anesthesia in the development of PPC.

ETHICAL DISCLOSURES

Approval by ethics committee

Approval was obtained from the Research and Bioethics Committee of the Hospital Universitario Clínica San Rafael de Bogotá, Colombia through act CEI-162-2020 on December 4, 2020.

Protection of people and animals

The authors declare that no experiments were conducted on humans or animals for this research. The authors declare that the procedures followed complied with the ethical standards of the responsible human experimentation committee and in accordance with the World Medical Association and the Declaration of Helsinki.

Data confidentiality

The authors declare that they followed confidentiality standards for data management. Sensitive data were not recorded in the data collection instrument. Coding ensured patient and data confidentiality.

Right to privacy and informed consent

The authors declare that no patient data are disclosed in this article. Patients did not undergo any tests or interventions, so informed consent from the research subjects was not considered mandatory. This document is the possession of the corresponding author.

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Contributions by the authors

CDRM and JPPS: Study planning, data collection, interpretation of the results, and manuscript writing.
SCA: data analysis, manuscript writing.

All authors participated and approved the final version of the manuscript for publication.

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Disclosures

The authors declare that they have no conflict of interest to disclose.

Presentations

None declared.

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COMPLEMENTARY MATERIAL

Complementary material 1 Definition of Variables and Data Collection Instrument

For qualitative variables, choose only one option for each variable.

1. Age: Number of completed years.

2. Sex: 0. Male; 1. Female

3. American Society of Anesthesiologists Classification: 2. ASA II; 3. ASA III; 4. ASA IV.

4. Functionality: 0. Independent: performs self-care activities autonomously, moves on their own, does not require supplemental oxygen, and performs household tasks independently; 1. Partial dependence: performs self-care activities autonomously and meets at least one of the following: a) Requires orthotics or third-party assistance to move; b) Requires supplemental oxygen; c) Requires help with household tasks; 2. Total dependence: requires third-party assistance to perform self-care activities, requires orthotics or third-party assistance to move, with or without the need for supplemental oxygen. Also includes if the patient is bedridden.

5. Dyspnea: 0. No Dyspnea: Patient does not present dyspnea. NYHA class I classification. mMRC grade 0 or grade 1 classification; 1. Effort dyspnea: Patient presents dyspnea with moderate or minimal efforts. NYHA class II or class III classification. mMRC grade 2 or grade 3 classification; 2. Rest dyspnea: Patient presents dyspnea at rest and/or requires supplemental oxygen. NYHA class IV classification. mMRC grade 4 classification.

6. Weight loss ≥ 10% of usual body weight in the last six months: 0. No; 1. Yes.

7. Body Mass Index: BMI value in kilograms/meters squared (kg/m²).

8. Current alcohol consumption: 0. Does not consume alcohol or consumes sporadically (<1 time per week in the last 2 weeks); 1. Consumption ≥1 time per week in the last 2 weeks.

9. Smoking history: 0. Never; 1. Former smoker: consumed tobacco, cigarettes, and/or smoked psychoactive substances at some point in their life; 2. Active or recent smoker: the last cigarette was smoked ≤60 days before surgery.

10. History of exposure to biomass and/or particulate matter: 0. Never exposed to biomass or particulate matter in the occupational setting; 1. Exposed at some point in their life to biomass and/or occupational particulate matter.

11. Oral glucocorticoid use for ≥ 7 days before surgery: 0. No; 1. Yes.

12. Acute kidney injury: Patient meets the criterion and/or has the diagnosis in the medical history: 0. No; 1. Yes.

13. Altered state of consciousness: 0. No; 1. Yes: patient presented one or more of the following in the 15 days before surgery or in the 15 days after surgery: disorientation, incoherent speech, drowsiness, delirium.

14. Preoperative respiratory infection and/or pleural effusion: 0. No; 1. Yes: diagnosis in the 15 days before surgery of one or more of the following: pneumonia, acute bronchitis, exacerbation of chronic lung disease with infection, exacerbation of chronic lung disease Anthonisen type I, II, or III, upper respiratory tract infection, pleural effusion.

15. Comorbidity with obesity: 0. No; 1. Yes: diagnosis of obesity and/or BMI ≥30 kg/m² before surgery.

16. Comorbidity with active cancer: 0. No cancer: without this history or with a history of cancer that has been cured; 1. Neoplasia under study: without established diagnosis but with high suspicion of malignant neoplasia pending diagnostic confirmation; 2. Active cancer: with established diagnosis of active cancer before surgery.

17. Comorbidity with diabetes mellitus: 0. No diabetes mellitus; 1. Non-insulin-dependent diabetes mellitus: diagnosis of diabetes mellitus before surgery treated with diet and/or oral antidiabetics. Includes patients diagnosed in the first 15 days after surgery; 2. Insulin-dependent diabetes mellitus: diagnosis of diabetes mellitus before surgery treated with some type of insulin.

18. Comorbidity with coronary artery disease: 0. No; 1. Yes: diagnosis of known epicardial and/or microvascular coronary artery disease before surgery or in the first 15 days after surgery.

19. Comorbidity with atrial fibrillation: 0. No; 1. Yes: diagnosis of atrial fibrillation before surgery or in the first 15 days after surgery.

20. Comorbidity with acute or chronic heart failure: 0. No; 1. Yes: diagnosis of acute heart failure, exacerbation of heart failure, and/or chronic heart failure before surgery or in the first 15 days after surgery.

21. Comorbidity with possible or probable pulmonary hypertension: 0. No: without diagnosis of pulmonary hypertension or with echocardiogram not indicating pulmonary hypertension nor a maximum tricuspid regurgitation velocity ≤2.8 m/sec or a PASP ≤35 mmHg; 1. Yes: with diagnosis of pulmonary hypertension before surgery and/or in the first 15 days after surgery or with echocardiogram indicating possible or probable pulmonary hypertension and/or maximum tricuspid regurgitation velocity ≥2.9 m/sec or a PASP ≥ 35 mmHg.

22. Comorbidity with chronic kidney disease (CKD): 0. No CKD; 1. CKD without renal replacement therapy (RRT): diagnosis of CKD before surgery or in the first 15 days after surgery not requiring RRT; 2. CKD with RRT: diagnosis of CKD before surgery or in the first 15 days after surgery requiring RRT.

23. Comorbidity with chronic neurological diseases or sequelae: 0. No; 1. Yes: diagnosis of a neurological disease and/or

with a neurological sequela before surgery or in the first 15 days after surgery.

24. Comorbidity with obstructive sleep apnea-hypopnea syndrome (OSAHS): 0. No OSAHS; 1. Confirmed OSAHS: established diagnosis of OSAHS in the medical history.

25. Comorbidity with chronic lung disease: 0. No chronic lung disease: patient without diagnosis of any chronic lung disease, no history of exposure to any form of smoking, particulate elements, or biomass. Includes patients with history of exposure but with non-pathological pulmonary function test results; 1. Probable lung disease: diagnosis in the medical history of "Unspecified chronic lung disease" or "Unspecified exposure lung disease" or "Lung disease without pulmonary function tests," but without a clear diagnosis and with history of exposure to some form of smoking, particulate elements, and/or biomass; 2. Chronic lung disease: established diagnosis of one or more of the following entities: chronic obstructive pulmonary disease (COPD), bronchial asthma, diffuse parenchymal lung disease (DPLD), pneumoconiosis, silicosis, interstitial pneumonia, interstitial lung disease, restrictive lung disease, or any of the different forms of chronic parenchymal lung disease other than primary or secondary cancer. Includes patients with pathological pulmonary function test results: FEV1/FVC ≤ 70%, FVC ≤ 70%, TLC ≤ 70%.

26. Preoperative hemoglobin ≤ 11 g/dL: 0. No; 1. Yes.

27. Hemoglobin decrease: 0. No; 1. Yes: decrease ≥ 2 grams of hemoglobin in the first 15 days after surgery.

28. Preoperative polycythemia: 0. No; Yes: male patients with a hemoglobin value ≥ 17.5 g/dL and/or hematocrit ≥ 52% or female patients with a hemoglobin value ≥ 15.5 g/dL and/or hematocrit ≥ 47%.

29. Preoperative hemoglobin: Blood hemoglobin concentration expressed in grams per deciliter (g/dL).

30. Blood urea nitrogen (BUN): BUN concentration expressed in milligrams per deciliter (mg/dL).

31. Blood creatinine: Blood creatinine concentration expressed in milligrams per deciliter (mg/dL).

32. Preoperative left ventricular ejection fraction (LVEF): LVEF value expressed as a percentage (%), measured by one of the following techniques: transthoracic echocardiogram, transesophageal echocardiogram, myocardial perfusion, or ventriculogram in the six months before surgery.

33. Preoperative capillary oxygen saturation (SpO2): 0. SpO2 ≥96%; 1. SpO2 between 91 and 95%; 2. SpO2 ≤90% or requiring supplemental oxygen before surgery.

34. ARISCAT scale score: ARISCAT score value calculated before surgery, based on data obtained from the medical history.

35. Type of anesthesia: 0. Neuraxial anesthesia: includes spinal anesthesia and epidural anesthesia with or without peripheral blocks that have not been converted; 1. General anesthesia: general anesthesia with or without peripheral blocks. Includes combined anesthesia and neuraxial anesthesia converted to general anesthesia.

36. Surgical approach: 0. Laparoscopic; 1. Open with non-midline incision: surgery performed by open technique, with the main incision made in places other than the midline of the anterolateral abdominal wall. Includes laparoscopic surgeries that required an additional open approach and/or were converted to an open technique, with the main incision made in places other than the midline. Includes lumbotomy incisions; 2. Open with midline incision: surgery performed by open technique, with the main incision made in the midline of the anterolateral abdominal wall. Includes laparoscopic surgeries converted to laparotomy with the main incision made in the midline of the anterolateral abdominal wall.

37. Duration of reference surgery: 0. Less than or equal to 210 minutes; 1. Greater than 210 minutes.

38. Emergency or urgent surgery: 0. Non-urgent or emergency surgery: includes time-sensitive and elective surgery; 1. Includes one of the two categories: a) Emergency surgery: must be performed in less than 6 hours; b) Urgent surgery: must be performed in less than 24 to 30 hours.

39. Category of reference surgery: 1. Upper gastrointestinal tract surgery: stomach, esophagus (abdominal approach), spleen; 2. Hepatobiliary, pancreatic, and duodenal surgery: liver, bile ducts, pancreas, portal vessels, and duodenum; 3. Gallbladder surgery: procedures performed only on the gallbladder; 4. Intestinal surgery: jejunum, ileum, cecal appendix, cecum, ascending colon, transverse colon, descending colon, sigmoid colon, and rectum (abdominal approach); 5. Vascular surgery: surgery of the abdominal aorta, inferior vena cava, common iliac vessels, internal or external iliac vessels, renal vessels, and other intra-abdominal vessels; 6. Urological surgery: kidneys, ureters, bladder (male and female), prostate (abdominal approach); 7. Gynecological surgery: ovaries, fallopian tubes, uterus, uterine cervix (abdominal approach). 8. Diagnostic laparotomy/laparoscopy: procedures involving only abdominal cavity review with or without peritoneal fluid drainage and/or peritoneal lavage without any type of resection, correction, and/or suture of any intra-abdominal organ. 9. Multiple intra-abdominal: procedures involving some type of resection, correction, ligation, and/or suture of several intra-abdominal organs included in two or more of the previous categories; 10. Abdominal wall surgery: hernia reduction surgeries (inguinal, epigastric, and umbilical), without resection of any segment of the intestine, stomach, or duodenum. If resection of any segment of the intestine was required, they will be included in the category of "Intestinal surgery" or "Upper gastrointestinal tract surgery" as appropriate; 11. Minor

abdominal procedures: surgeries involving only the placement of peritoneal dialysis catheters or peritoneal drains.

40. Abdominal reoperations (excluding reference surgery): 0. None; 1. One reoperation; 2. Two reoperations; 3. Three reoperations; 4. Four or more reoperations.

41. Type of abdominal reoperations: 0. Peritoneal drainage or lavage: no reoperation involves resection, correction, ligation, and/or suture of any intra-abdominal organ; 1. Intra-abdominal organ operation: at least one of the reoperations involves resection, correction, ligation, and/or suture of any intra-abdominal organ.

42. Massive transfusion of blood products: 0. No: does not meet any of the criteria or was transfused with 3 units of packed red blood cells (PRBC) or less; 1. Yes: meets one or more of the criteria: a) transfusion of ≥4 units of PRBC; b) ≥1 unit of platelets; c) ≥1 unit of fresh frozen plasma.

43. Admission to intensive care unit (ICU): 0. No; 1. Yes: admitted to ICU before surgery or in the 15 days after surgery or in any of the readmissions occurring in the 15 days following the reference surgery.

44. Postoperative pulmonary complication: 0. No; 1. Yes: meets at least one of the operational definitions of postoperative pulmonary complication.

45. Postoperative respiratory infection (applies only to cases): 0. No; 1. Yes: meets the case definition for postoperative respiratory infection.

46. Postoperative ventilatory failure (applies only to cases): 0. No; 1. Yes: meets the case definition for postoperative ventilatory failure.

47. Postoperative respiratory failure (applies only to cases): 0. No; 1. Yes: meets the case definition for postoperative respiratory failure.

48. Pleural effusion (applies only to cases): 0. No; 1. Yes: meets the case definition for postoperative pleural effusion.

49. Atelectasis (applies only to cases): 0. No; 1. Yes: meets the case definition for postoperative atelectasis.

50. Pneumothorax (applies only to cases): 0. No; 1. Yes: meets the case definition for postoperative pneumothorax.

51. Bronchospasm (applies only to cases): 0. No; 1. Yes: meets the case definition for postoperative bronchospasm.

52. Aspiration pneumonitis (applies only to cases): 0. No; 1. Yes: meets the case definition for postoperative aspiration pneumonitis.

53. In-hospital death: 0. No; 1. Yes: dies during the hospitalization in which the surgical procedure was performed or in the hospitalization of any of the readmissions occurring in the 15 days following the surgery.

54. Hospital stay: Days of hospitalization in the institution during the admission in which the reference surgery was performed, including the days of hospitalization due to readmissions occurring in the 15 days following the surgery.

Source: Authors.

Complementary material 2

Definition of Postoperative Pulmonary Complications

- The definition of each pulmonary complication is outlined under "Definition of Postoperative Pulmonary Complications" in the text of the article.

- Patients without a diagnosis in the 15 days prior to surgery of any of the following: pneumonia, acute bronchitis, exacerbation of chronic lung disease with infection, upper respiratory tract infection, and/or pleural effusion; who in the 15 days following surgery (including readmissions) meet the definition of "postoperative respiratory infection."

- Patients who in the 15 days following surgery (including readmissions) meet the definition of "postoperative ventilatory failure."

- Patients who in the 15 days following surgery (including readmissions) meet the definition of "postoperative respiratory failure."

- Patients who in the 15 days following surgery (including readmissions) meet the definition of "postoperative atelectasis."

- Patients without a diagnosis in the 15 days prior to surgery of any of the following: pneumonia, acute bronchitis, exacerbation of chronic lung disease with infection, upper respiratory tract infection, and/or pleural effusion; who in the 15 days following surgery (including readmissions) meet the definition of "pleural effusion."

- Patients who in the 15 days following surgery (including readmissions) meet the definition of "pneumothorax" and whose cause is not attributed to an open or closed trauma occurring outside the hospital.

- Patients who in the 15 days following surgery (including readmissions) meet the definition of "bronchospasm."

- Patients who in the 15 days following surgery (including readmissions) meet the definition of "aspiration pneumonitis."

- Patients with a diagnosis in the 15 days prior to surgery of any of the following: pneumonia, acute bronchitis, exacerbation of chronic lung disease with infection, upper respiratory tract infection, and/or pleural effusion; who in the 15 days following surgery (including readmissions) meet the definition of any of the following entities. Signs or symptoms compatible with the definition of postoperative respiratory infection and/or pleural effusion in patients diagnosed with any of the entities mentioned in the 15 days prior to surgery are attributed to the preoperative pathology and not to a direct complication

of surgery and/or anesthesia, except if they meet the definition of any of the other described complications (The signs or symptoms compatible with the definition of postoperative respiratory infection and/or pleural effusion in patients who were previously diagnosed with any of the above-mentioned entities during the 15 days prior to surgery are attributed to the preoperative diagnosed pathology and not to a direct complication of the surgery and/or anesthesia, except when these meet the definition of any of the other described complications):

- Postoperative respiratory failure.
- Postoperative ventilatory failure.
- Atelectasis.
- Pneumothorax.
- Bronchospasm.
- Aspiration pneumonitis.

Source: Authors.