Superiority of respiratory failure risk index in prediction of postoperative pulmonary complications after digestive surgery in Japanese patients

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ABSTRACT

Background: Several multifactorial risk indexes have been proposed by Western countries for identifying patients at a high risk of developing postoperative pulmonary complications (PPC). However, there is no consensus on how to evaluate the risk of PPC and what multifactorial risk index should be adapted for Japanese patients. This study aimed at clarifying the utility of risk indexes to predict PPC following digestive surgeries in Japanese patients.

Methods: We retrospectively analyzed 892 patients who underwent digestive surgeries under general anesthesia in Niigata University Medical and Dental Hospital between January 2009 and March 2011. PPC was defined as postoperative respiratory failure and postoperative pneumonia. We calculated three risk indexes; respiratory failure risk index (RFRI), postoperative pneumonia risk index, and PPC risk score, and compared them between the PPC and the non-PPC group. A receiver operating characteristic (ROC) curve analysis was employed to compare the usefulness of each index.

Results: PPC developed in 55 patients (6.2%). All risk indexes were significantly higher in the PPC group than the non-PPC group. The category classification of the risk scores demonstrated a significant tendency to increase the incidence rate of PPC. In the ROC analysis, the area under the curve for RFRI was 0.762 (95% CI 0.697-0.826), which was the highest value observed among these indexes.

Conclusions: Multifactorial risk indexes are useful tools for identifying Japanese patients at a high risk of developing PPC following digestive surgeries. Of the risk indexes evaluated in this study, RFRI is potentially the most accurate in predicting PPC.

Keywords: postoperative pulmonary complications; postoperative respiratory failure; postoperative pneumonia; respiratory failure risk index

Abbreviations: BUN, blood urea nitrogen; COPD, chronic obstructive pulmonary disease; CVD, cerebrovascular disease; FEV_1, forced expiratory volume in 1 second; %$FEV_{1.0}$, forced expiratory volume in 1 second as a percentage of that predicted; FVC, forced vital capacity; PFT, pulmonary function test; PPC, postoperative pulmonary complications; PPRI, postoperative pneumonia risk index; PR, pulmonary rehabilitation; PRF, postoperative respiratory failure; RFRI, respiratory failure risk index; ROC, receiver operating characteristic; SpO_2, oxyhemoglobin saturation by pulse oximetry; %VC, vital capacity as a percentage of that predicted.

1. Introduction

Postoperative pulmonary complications (PPC) are associated with postoperative morbidity, mortality, longer hospital stays, and higher medical costs following a variety of surgeries [1-4]. Therefore, the prevention of PPC is one of the most important issues in perioperative management. Although it has previously been reported that pulmonary rehabilitation (PR) such as preoperative exercise therapy or lung physiotherapy has a beneficial effect on preventing PPC in lung resection [5] and coronary artery bypass graft surgery [6], there is little evidence to support the usefulness of PR and its use is not routinely recommended in noncardiothoracic surgery [7, 8]. The identification of high-risk patients is therefore needed in order to achieve efficient perioperative intervention [9].

The incidence of PPC is known to be affected by multiple factors. The risk factors of PPC include patient-related factors such as age, functional status, and history of chronic obstructive pulmonary disease (COPD), and surgery-related factors such as surgical site and time [10, 11]. Several multifactorial risk indexes, based on prospective large cohort studies, have been proposed almost exclusively from Western countries in order to identify high-risk patients [12-14]. In Japan, the scoring system for evaluating cardiac complications after noncardiac surgeries has already been developed [15], along with guidelines for perioperative cardiovascular management [16]. However, there is no guideline available on how to evaluate the risks for PPC and no available comparison between multifactorial risk indexes. In addition, since race and health-care settings differ between Caucasian countries and the Japanese, it is still unknown whether these scores are applicable to Japanese patients or not.

There are few studies in which comparisons of usefulness among multifactorial risk indexes are reported. Arozullah et al. proposed two indices, respiratory failure risk index (RFRI) and postoperative pulmonary risk index (PPRI), on the basis of a multivariable analysis of a large cohort of male veterans undergoing major noncardiac surgery [13, 14]. RFRI included seven factors: type of surgery, emergency surgery, albumin level less than 30 g/L, blood urea nitrogen level greater than 30 mg/dL, partially or fully dependent functional status, COPD, and age, in which surgery-related factors were dominant (see Table S1 in the supplement material). On the other hand, PPRI factors included weight loss, general anesthesia, impaired sensorium, history of cerebrovascular accident, transfusion of more than 4 units, steroid use for chronic condition, current smoker within 1 year, and alcohol intake of more than 2 drinks per day in the past 2 weeks in addition to some of the values of RFRI (see Table S2 in the supplement material). Recently, Canet et al. reported a PPC risk score by a prospective, multicenter study in a large, heterogeneous population [12]. This score consisted of seven factors: low preoperative arterial oxygen saturation, acute respiratory infection during the previous month, age, preoperative anemia, surgical incision, surgical duration of at least 2 h, and emergency surgery (see Table S3 in the supplement material). We previously reported that RFRI was useful for predicting PPC in a small number of patients with respiratory impairment [17]. Ideally, the validity of RFRI should be examined in a larger, population-based Japanese cohort.

The present study was designed to investigate the utility of multifactorial risk indexes as a predictor of PPC following digestive surgeries, including cases with normal preoperative pulmonary function. We also compared the predictive power in these indexes.

2. Material and methods

2.1. Study design and patient population

Adult patients (aged 18 years and older) who underwent digestive surgery under general anesthesia at Niigata University Medical and Dental Hospital from January 2009 to March 2011 were included in this retrospective cohort study. The patients who were ventilator dependent before surgery, performed PR for prevention of PPC, or had preoperative pneumonia, were excluded from the analysis. The patients who underwent multiple surgeries during their hospitalization were also excluded. Owing to the invasiveness of the procedure, those who underwent organ transplantations were also exempt from the analysis.

Ethical considerations concerning this study were reviewed and approved by the Ethical Committee at Niigata University (No. 1891, April 28, 2014). We obtained consent from attending physicians for this analysis and took attention to the anonymity of patient data.

2.2. Definition of terms

We defined PPC as postoperative respiratory failure (PRF) and postoperative pneumonia. In a previous report by Arozullah et al. [14], PRF was defined as the need for mechanical ventilation more than 48 hours after surgery, or reintubation followed by mechanical ventilation after postoperative extubation. Postoperative pneumonia was defined as a disease that required antibiotic treatment for a suspected respiratory infection, accompanied by the development of a fever and the appearance of new opacities on a chest X-ray. PRF and postoperative pneumonia that occurred within 30 days after surgery were considered as PPC.

2.3. Data collection

Patient data were retrospectively collected from medical records. For the patients' backgrounds, data on age, gender, body mass index, functional status, cognitive function, medical history, medications, and smoking status were collected. Data on surgical site, surgical method, surgical time, transfusion during surgery, clinical setting (emergency or not), length of hospital stay after surgery, development of PPC, and postoperative death were also collected. We furthermore obtained information on preoperative hematological data (hemoglobin, albumin, and blood urea nitrogen), oxygen saturation, arterial blood gas analysis, and pulmonary function test (PFT), if available.

2.4. Multifactorial risk indexes

According to the medical records, we calculated three multifactorial risk indexes; RFRI [14], PPRI [13], and PPC risk score [12]. The patients with obstructive ventilatory defects on preoperative PFT were regarded as having a history of COPD. Based on the original studies, patients were classified into three or four categories with regard to each risk score. We divided them into four categories of RFRI (≤11, 11-19, 20-27, ≥28) or PPRI (≤15, 16-25, 26-40, ≥41), and three categories of PPC risk score (≤25, 26-44, ≥45).

2.5. Statistical analysis

Data were expressed as mean ± SD. We used the chi-square test for categorical variables and the Student's *t*-test for continuous variables. The incidence of PPC in each category of risk scores was examined for trends using the Cochran-Armitage test. The receiver operating characteristic (ROC) analysis for predicting incidence of PPC was performed in multivariable risk score indexes. Values of $p < 0.05$ were considered significant. All statistical analyses were performed using GraphPad Prism 5 software (GraphPad Software Inc., San Diego, CA, USA).

3. Results

3.1. Patient characteristics and outcomes

Of the 1,019 patients who underwent digestive surgery during the study period, 127 (12.5%) were excluded for the following reasons; seven were ventilator dependent, 15 had PR performed on them, eight experienced preoperative pneumonia, 67 had multiple surgeries done, and 30 had organ transplant procedures. We eventually analyzed a total of 892 cases. Table 1 shows the baseline characteristics of the patients.

A total of 55 patients (6.2%) experienced episodes of PPC. Of these complications, 21 were PRF and 34 were postoperative pneumonia.

3.2. Comparison between PPC and non-PPC group

Table 2 displays the characteristics and test findings of the patients with and without PPC. In comparison to the non-PPC group, the mean age was significantly higher in the PPC group. With respect to surgery-related factors, PPC occurred frequently in those who underwent esophagus operations and thoracic incision, whereas those who underwent colon operations less frequently experienced PPC. The duration of surgery was longer in the PPC group. With regards to laboratory data, baseline serum albumin, blood urea nitrogen, and preoperative oxygen saturation were significantly different between the two groups. A total of 760 patients took a preoperative PFT. In these patients, both vital capacity as a percentage of that predicted (%VC), and forced expiratory volume in 1 second as a percentage of that predicted (%$FEV_{1.0}$) were significantly lower in the PPC group. However, there was no significant difference in the incidence of obstructive ventilator impairment between the groups. The duration of postoperative hospital stay was significantly longer in the PPC group. Postoperative hospital mortality tended to be higher in the PPC group. Concerning multifactorial risk scores, every score was significantly higher in the PPC group than the non-PPC group (Table 3).

3.3. Analysis of multifactorial risk indexes

Table 4 shows the incidence of PPC by the risk category groups of each index. The incidence rate of PPC had a significant tendency to increase along with an increase in the risk category groups in each risk score. There were only five patients who corresponded to the highest risk category of PPRI. Figure 1 shows the result of the ROC analysis for predicting incidence of PPC in three multivariable risk score indexes. The areas under the ROC curves for RFRI, PPRI, and PPC risk score were 0.762 (95% CI 0.697-0.826), 0.692 (95% CI 0.624-0.761), and 0.646 (95% CI 0.571-0.721), respectively. RFRI was the most accurate in identifying the patients with high risk for PPC.

4. Discussion

The results of the present study revealed that the multifactorial risk indexes were useful for identifying groups of Japanese patients at a high risk of developing PPC following digestive surgeries. In three multifactorial risk indexes, RFRI was the most effective in identifying high-risk patients.

In this study, the subjects were limited to the patients with digestive surgeries. Those with cardiopulmonary surgeries, which had high risk for PPC [18], were not included. However, the incidence of PPC in this study was similar to previous reports [19]. Furthermore, as our data demonstrated that the patients with PPC had significantly longer postoperative hospital stay than those without PPC, PPC had a high impact on postoperative clinical course. These findings suggest that respiratory care may be important in determining the duration of perioperative periods of digestive surgeries.

Compared to the non-PPC group, the patients in the PPC group had higher scores on three multifactorial risk indexes. Additionally, we observed a significant trend for the incidence of PPC to increase according to the risk category groups in each index.

These results suggest that all of the risk scores can be applied in order to identify patients at a high risk of developing PPC after digestive surgeries in Japan as well as in Western countries, despite differences in the patient background such as lower body mass index and longer postoperative hospital stay in Japan. In contrast to cardiopulmonary surgeries, the influence of digestive surgeries on postoperative respiratory functions depends on the surgical site [10]. There is not enough evidence to recommend the routine use of perioperative PR to prevent PPC [20]. Therefore, it is necessary to determine the criteria for patient recruitment into PR, especially in digestive surgeries. Multifactorial risk indexes have the potential for preoperatively identifying high-risk patients in the Japanese population.

To date, PFT has been widely used in Japan to identify patients at a high risk of developing PPC. However, in contrast to pulmonary resections [21], the value of PFT has not become evident in digestive surgeries. In this study, although %VC and $\%FEV_{1.0}$ were lower in the PPC group, there was no significant difference in the presence of ventilatory defects between the groups. Moreover, we found no relation between the incidence of PPC and the values of PFT in the patients with impaired respiratory function in the previous report [17]. It is considered that the PFT data is one of the risk factors of PPC and is less suitable for perioperative evaluation than multifactorial risk indexes. Nevertheless, because COPD is underdiagnosed in Japan [22], preoperative PFT may contribute to early diagnosis and treatment of COPD.

This study demonstrated that RFRI had the highest prediction power out of three risk indexes. Additionally, RFRI has the smaller number of entries, all of which are relatively simple and easy to evaluate, even in presurgical periods. The reason why RFRI had the highest sensitivity in spite of the smaller number of entries may be that more patients fell into the entries of RFRI, which were very different between the PPC and the non-PPC group than those of other scores. The entries of PPRI and PPC risk score include perioperative transfusion and duration of surgery, respectively, which cannot be evaluated before surgeries, whereas RFRI has the advantage of being applicable in the preoperative period. Thus, we believe that RFRI is much more useful in the setting of preoperative consultation or screening compared with PPRI or PPC risk score. However, it should be noted that some known risk factors for PPC, for example smoking status or obstructive sleep apnea, are not included in RFRI [23, 24].

Johnson et al. proposed a risk score system which consisted of 28 predictors [25]. Although the system is possibly more useful for a detailed stratification of high-risk patients than RFRI, the number of predictors that it has is too large to apply to Japanese outpatients. Moreover, because the evaluation system requires multiple experts and more laboratory findings, applying the system to all preoperative patients would be less cost effective.

Our study differs from previous reports in a number of respects [12-15]. While we enrolled patients who underwent digestive surgeries under general anesthesia, previous reports studied subjects who underwent other types of surgery, including those that were performed under local anesthesia. Both the duration of surgery and the postoperative length of hospital stay are much longer in our data [12]. Therefore, it is suspected that the subjects in previous studies might include those who underwent minimally invasive procedures that had a lower risk for PPC. Furthermore, the incidence of PPC was relatively low in two studies [12, 13]. Multifactorial risk indexes other than RFRI are possibly more useful in the less severe patients.

This study has certain limitations. First, the data were collected retrospectively from a single center. Second, concerning the patient population, surgeons are likely to recognize the patients with poor performance status as inappropriate candidates, especially for an elective surgery, so there may be a selection bias in our study. Additionally, since we retrospectively detected occurrences of PPC from medical records, PPC may be underdiagnosed due to lack of examinations such as chest X-rays. Prospective, multicenter, and larger scale observational studies are required to confirm our findings.

In conclusion, the results of the present study suggest that multifactorial risk indexes are useful tools for screening for Japanese patients who are at a high risk of developing PPC following digestive surgeries. Among the risk indexes, RFRI is the most accurate in identifying the high-risk patients. The findings of this study help to clarify the criteria for adapting respiratory care during the perioperative period. The present analysis is expected to outline the foundation for future research and lead to a spread of accurate perioperative intervention for improved surgical outcomes.

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Conflict of interest

The authors have no conflicts of interest.

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Table 1. Characteristics of patients

Characteristics	n = 892
Gender, male/female	557/335
Age, years	62.6 ± 15
Body mass index, kg/m^2	22.1 ± 3.9
Current smokers, n (%)	164 (18.3)
Site of Surgery, n (%)	
Esophagus	36 (4.0)
Stomach	158 (17.7)
Liver	128 (14.3)
Pancreas	53 (5.9)
Colon	285 (32.0)
Small intestine	108 (12.1)
Others	124(13.9)
Major comorbidity, n (%)	
Cerebrovascular disease	79 (8.9)
Ischemic heart disease	60 (6.7)
Heart failure	21 (2.4)
Chronic kidney disease	22 (2.5)
Postoperative hospital stay, days	23.3 ± 26
In-hospital death, n (%)	15 (1.7)

Table 2. Comparison of patient characteristics and test findings between PPC and non-PPC group

	PPC group n = 55	Non-PPC group n = 837	p Value
Gender, male/female	38/17	519/318	0.293[a]
Age, years	67.3 ± 13	62.2 ± 15	0.015[b,]*
Body mass index, kg/m^2	21.8 ± 4.3	22.1 ± 3.8	0.532[b]
Current smokers, n (%)	8 (14.5)	156 (18.6)	0.213[a]
Site of surgery, n (%)			
Esophagus	13 (23.6)	23 (2.7)	<0.001[a,]**
Stomach	7 (12.7)	151 (18.0)	0.317[a]
Liver	8 (14.5)	120 (14.3)	0.966[a]
Pancreas	2 (3.6)	51 (6.1)	0.651[a]
Colon	9 (16.4)	276 (33.0)	0.011[a,]*
Small intestine	8 (14.5)	100 (11.9)	0.567[a]
Others	8 (14.5)	116 (13.9)	0.887[a]
Duration of surgery, minutes	301.8 ± 181	246.1 ± 150	0.009[b,]**
Pulmonary function test (n = 760)			
FVC, L	2.94 ± 0.76	3.21 ± 0.86	0.063[b]
FVC % predicted, %	93.2 ± 19	101 ± 17	0.008[b,]**
FEV_1, L	2.23 ± 0.63	2.47 ± 0.70	0.047[b,]*
FEV_1 % predicted, %	87.0 ± 18	95.2 ± 17	0.005[b,]**
FEV_1/FVC < 70%, n (%)	8 (22.2)	114 (15.8)	0.303[a]
Preoperative SpO_2, %	96.9 ± 1.9	97.6 ± 1.4	<0.001[b,]**
Hemoglobin, g/dL	12.3 ± 2.2	12.3 ± 2.1	0.938[b]
Serum albumin, g/dL	3.5 ± 0.8	3.9 ± 0.6	<0.001[b,]**
Blood urea nitrogen, mg/dL	23.4 ± 20	15.7 ± 9.6	<0.001[b,]**
Postoperative hospital stay, days	41.8 ± 35	22.1 ± 25	<0.001[b,]**
In-hospital death, n (%)	3 (5.5)	12 (1.4)	0.088[a]

FEV_1: forced expiratory volume in 1 second, FVC: forced vital capacity, PPC: postoperative pulmonary complications, SpO_2: oxyhemoglobin saturation by pulse oximetry.

[a] χ^2-test. [b] t-test. * $p < 0.05$. ** $p < 0.01$.

Table 3. Comparison of multifactorial indexes between PPC and non-PPC group

	PPC group n = 55	Non-PPC group n = 837	*p* Value
Respiratory failure risk index			
Type of surgery: thoracic, n (%)	8 (14.5)	17 (2.0)	<0.001[a],**
Type of surgery: upper abdominal, n (%)	27 (49.1)	406 (48.5)	0.933[a]
Emergency surgery, n (%)	19 (34.5)	104 (12.4)	<0.001[a],**
Albumin (30 g/L), n (%)	13 (23.6)	74 (8.8)	<0.001[a],**
BUN (> 30 g/L), n (%)	12 (21.8)	33 (3.9)	<0.001[a],**
Dependent functional status, n (%)	7 (12.7)	17 (2.0)	<0.001[a],**
History of COPD, n (%)	11 (20.0)	129 (15.4)	0.365[a]
Age ≥ 70 years, n (%)	26 (47.3)	314 (37.5)	0.149[a]
Age 60-69 years, n (%)	16 (29.1)	241 (28.8)	0.962[a]
Total points	23.5 ± 9.0	14.2 ± 9.0	<0.001[b],**
Postoperative pneumonia risk index			
Age ≥ 80 years, n (%)	8 (14.5)	71 (8.5)	0.172[a]
Age 70-79 years, n (%)	18 (32.7)	243 (29.0)	0.560[a]
Age 60-69 years, n (%)	16 (29.1)	241 (28.8)	0.962[a]
Age 50-59 years, n (%)	8 (14.5)	133 (15.9)	0.791[a]
Functional status: totally dependent, n (%)	3 (5.5)	7 (0.8)	0.002[a],**
Functional status: partially dependent, n (%)	4 (7.3)	10 (1.2)	<0.001[a],**
Weight loss > 10% in past 6 months, n (%)	1 (1.8)	48 (5.7)	0.217[a]
Impaired sensorium, n (%)	1 (1.8)	0 (0)	<0.001[a],**
History of CVD, n (%)	7 (12.7)	72 (8.6)	0.297[a]

BUN < 8 mg/dL, n (%)	2 (3.6)	35 (4.2)	0.844[a]
BUN 22-30 mg/dL, n (%)	5 (9.1)	59 (7.0)	0.570[a]
BUN ≥ 30mg/dL, n (%)	12 (21.8)	36 (4.3)	<0.001[a],**
Transfusion > 4 units, n (%)	11 (20.0)	51 (6.1)	<0.001[a],**
Steroid use for chronic condition, n (%)	4 (7.3)	48 (5.7)	0.637[a]
Current smoker within 1 year, n (%)	8 (14.5)	157 (18.8)	0.436[a]
Alcohol intake > 2 drinks/day, n (%)	6 (10.9)	102 (12.2)	0.779[a]
Total points	27.3 ± 7.4	21.4 ± 8.5	<0.001[b],**
PPC risk score			
Age 51-80 years, n (%)	43 (78.2)	626 (74.8)	0.574[a]
Age > 80 years, n (%)	5 (1.8)	50 (6.0)	0.352[a]
Preoperative SpO_2 91-95 %, n (%)	10 (18.2)	57 (6.8)	0.002[a],**
Preoperative SpO_2 ≤ 90 %, n (%)	1 (1.8)	0 (0)	<0.001[a],**
Respiratory infection in the last month, n (%)	2 (3.6)	20 (2.4)	0.564[a]
Preoperative anemia (≤ 10 g/dL), n (%)	10 (18.2)	124 (14.8)	0.498[a]
Duration of surgery > 2 to 3 hours, n (%)	7 (12.7)	142 (17.0)	0.414[a]
Duration of surgery > 3 hours, n (%)	36 (65.5)	515 (61.5)	0.562[a]
Total scores	39.0 ± 14	31.4 ± 14	<0.001[b],**

BUN: blood urea nitrogen, COPD: chronic obstructive pulmonary disease, CVD: cerebrovascular disease, PPC: postoperative pulmonary complications, SpO_2: oxyhemoglobin saturation by pulse oximetry.

[a] χ^2-test. [b] t-test. * $p < 0.05$. ** $p < 0.01$.

Table 4. Incidence of postoperative pulmonary complications by risk category of each index

Risk category groups		Patients, n (%)	Number of PPC	Incidence of PPC (%)	*p* Value[a]
RFRI	≤ 10	281 (31.5)	4	1.4	< 0.001
	11-19	289 (32.4)	13	4.5	
	20-27	265 (29.7)	21	7.9	
	≥ 28	57 (6.4)	17	29.8	
PPRI	≤ 15	216 (24.2)	4	1.9	<0.001
	16-25	346 (38.8)	17	4.9	
	26-40	325 (36.4)	33	10.2	
	≥ 41	5 (0.6)	1	20.0	
PPC risk score	≤ 25	249 (27.9)	8	3.2	0.0015
	26-44	527 (59.1)	33	6.3	
	≥ 45	116 (13.0)	14	12.1	

[a] Cochran-Armitage test.

PPC: postoperative pulmonary complications, PPRI: postoperative pneumonia risk index, RFRI: respiratory failure risk index.

Figure 1

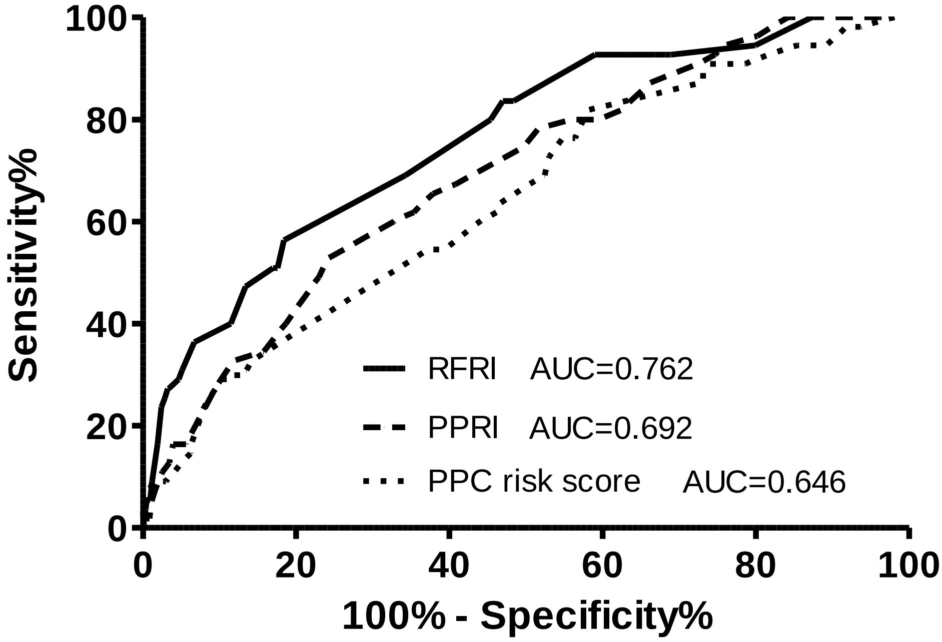
100
80
60
40
20
0
Sensitivity%
0
20
40
60
80
100
100% - Specificity%
RFRI AUC=0.762
PPRI AUC=0.692
PPC risk score AUC=0.646

Figure Legends

Figure 1. Receiver operating characteristic (ROC) curves of three multivariable risk score indexes

An ROC analysis for predicting incidence of postoperative pulmonary complications (PPC) was performed in three different multivariable risk score indexes. The areas under the ROC curves for respiratory failure risk index (RFRI), postoperative pneumonia risk index (PPRI), and PPC risk score were 0.762 (95% CI 0.697-0.826), 0.692 (95% CI 0.624-0.761), and 0.646 (95% CI 0.571-0.721), respectively. RFRI was the most accurate in identifying the patients at a high risk for developing PPC.

Supporting Information

Table S1. Respiratory failure risk index [14]

Preoperative Predictor	Point Value
Type of surgery	
Abdominal aortic aneurysm	27
Thoracic	21
Neurosurgery, upper abdominal, or peripheral vascular	14
Neck	11
Emergency surgery	11
Albumin (< 30 g/L)	9
Blood urea nitrogen (> 30 mg/dL)	8
Partially or fully dependent functional status	7
History of chronic obstructive pulmonary disease	6
Age (years)	
≥70	6
60-69	4

Table S2. Postoperative pneumonia risk index [13]

Preoperative Predictor	Point Value
Type of surgery	
Abdominal aortic aneurysm	15
Thoracic	14
Upper abdominal	10
Neck	8
Neurosurgery	8
Vascular	3
Age (years)	
≥80	17
70-79	13
60-69	9
50-59	4
Functional status	
Totally dependent	10
Partially dependent	6
Weight loss > 10% in past 6 months	7
History of chronic obstructive pulmonary disease	5
General anesthesia	4
Impaired sensorium	4
History of cerebrovascular accident	4
Blood urea nitrogen level	
< 8 mg/dL	4
22-30 mg/dL	2
≥ 30mg/dL	3
Transfusion > 4 units	3
Emergency surgery	3
Steroid use for chronic condition	3
Current smoker within 1 year	3
Alcohol intake > 2 drinks/d in past 2 weeks	2

Table S3. Postoperative pulmonary complications risk score [12]

Independent Predictor	Risk Score
Age (years)	
51-80	3
> 80	16
Preoperative SpO_2 (%)	
91-95	8
≤ 90	24
Respiratory infection in the last month	17
Preoperative anemia (≤ 10 g/dL)	11
Surgical incision	
Upper abdominal	15
Intrathoracic	24
Duration of surgery (hours)	
> 2 to 3	16
> 3	23
Emergency procedure	8

SpO_2, oxyhemoglobin saturation by pulse oximetry.