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• *CLINICAL RESEARCH* •

Multivariate analysis of the risk for pulmonary complication after gastrointestinal surgery

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Abstract

AIM: To identify the risk factors for postoperative pulmonary complications (PPC) after gastrointestinal surgery.

METHODS: A total of 1 002 patients undergoing gastrointestinal surgery in the Second Affiliated Hospital, Sun Yat-Sen University, during December 1999 and December 2003, were retrospectively studied.

RESULTS: The overall incidence of PPC was 22.8% (228/1 002). Multivariate logistic analysis identified nine risk factors associated with PPC, including age odds ratio (OR = 1.040) history of respiratory diseases (OR = 2.976), serum albumin (OR = 0.954), chemotherapy 2 wk before operation (OR = 3.214), volume of preoperative erythrocyte transfusion (OR = 1.002), length of preoperative antibiotic therapy (OR = 1.072), intraoperative intratracheal intubation (OR = 1.002), nasogastric intubation (OR = 1.050) and postoperative mechanical ventilation (OR = 1.878). Logistic regression equation for predicting the risk of PPC was $P(1) = 1/[1+e^{-(-3.488+0.039\times Y+1.090\times Rd+0.001\times Rbc-0.047\times Alb+0.002\times Lii+0.049\times Lni+0.630\times Lmv+0.070\times Dat+1.168\times Ct)}]$.

CONCLUSION: Old patients are easier to develop PPC.

Key words: Postoperative pulmonary complications; Gastrointestinal surgery; Multivariate analysis

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INTRODUCTION

Postoperative pulmonary complications (PPC) following gastrointestinal surgery are frequent and closely associated with increased mortality and length of hospital stay[1,2]. Identifying the risk factors of PPC is very important for the prevention and treatment of PPC. The incidence of PPC following gastrointestinal surgery varies widely in the literatures, 20-69% for postoperative atelectasis and 9-69% for postoperative pneumonia, which is due to the difference in type of pulmonary complication included, clinical diagnostic criteria and the target population[2]. Many risk factors for PPC have been studied. The importance of some factors has been established, such as advanced age, obesity, smoking, history of respiratory disease, American Society of Anesthesiologists (ASA) classification and incision site[3-5]. However, the predictive value for PPC of some factors remains controversial, including preoperative pulmonary function, arterial blood gas analysis and postoperative analgesia[6-9]. And the role of some other factors receives little attention, such as preoperative serum albumin and globulin, preoperative lipidemia, chemical therapy, intratracheal intubation, volume of intraoperative fluid transfusion and blood transfusion, nasogastric intubation and antacids therapy. Thus, to determine the risk factors for PPC after gastrointestinal surgery, we retrospectively studied 1 002 cases undergoing gastrointestinal surgery in the Second Affiliated Hospital, Sun Yat-Sen University, during December 1999 and December 2003.

MATERIALS AND METHODS

Subjects

A total of 1 002 consecutive patients who received gastrointestinal surgery in the Second Affiliated Hospital, Sun Yat-Sen University, during December 1999 and December 2003, were enrolled in the study. Inclusion criteria were as follows: those who received gastrointestinal tract but not anal canal and appendix operation, those who received intra-abdominal but not laparoscope operations, those patients whose age was $\geqslant$ 18 years and those gastrointestinal tumor cases that had metastasis to lungs were excluded.

Among 1 002 patients who enrolled in our study, 649 were males and 353 were females. The average age was 56.69±15.26 years (ranging from 18 to 96 years).

Five hundred and eight patients received gastroduodenal surgery. Among them, 240 cases underwent surgery due to benign diseases, including 215 cases of gastric and duodenal ulcer, 7 cases of duodenal diverticulum, 7 cases of duodenal fistula, 4 cases of duodenal polyp, 3 cases of gastric stromal

tumor, 3 cases of gastric leiomyoma, and 1 case of duodenal leiomyoma. Among the patients with gastric and duodenal ulcer, 120 cases had gastric perforation, 19 cases had massive hemorrhage, and 7 cases had pyloric obstruction. Meanwhile, 268 cases underwent surgery due to malignant diseases. Among them, 255 cases had gastric carcinoma, including 1 case of gastric perforation, and 13 cases had gastroduodenal metastatic tumor. Radical gastrectomy was performed in 223 cases, subtotal gastrectomy in 202 cases, repair of peptic ulcer perforation in 77 cases, and gastrostomy in 6 cases.

Four hundred and ninety-four patients received intestinal surgery. Among them, 89 cases underwent surgery due to benign diseases, including 19 cases of intestinal obstruction (6 cases of complete intestinal obstruction), 16 cases of intestinal hemorrhage (2 cases of massive hemorrhage), 12 cases of intestinal diverticulum, 11 cases of splenic flexure syndrome, 6 cases of small intestinal leiomyoma, 6 cases of intestinal fistula, 6 cases of hernia, 4 cases of megacolon, 4 cases of Crohn's disease, 3 cases of intestinal polyp, and 2 cases of intestinal stromal tumor. Meanwhile, 405 cases underwent surgery due to malignant diseases, including 188 cases of colon cancer, 168 cases of rectal cancer, 16 cases of intestinal lymphoma, 9 cases of small bowel cancer, 1 case of intestinal sarcoma, and 23 cases of intestinal metastatic tumor. Radical colectomy was performed for colon cancer in 170 cases, radical rectectomy for rectal cancer in 170 cases, partial resection and anastomosis of small bowel in 74 cases, partial transverse colectomy in 69 cases, lysis of intestinal adhesions in 9 cases, and total colectomy in 2 cases.

Preoperative comorbid diseases included 80 cases of diabetes mellitus, 51 cases of heart disease (including 41 cases of angina pectoris, 8 cases of old myocardial infarction and 2 cases of rheumatic heart disease), 29 cases of cerebral disease (including 13 cases of cerebral hemorrhage, 11 cases of cerebral infarction and 5 cases of cerebral atrophy or others), 128 cases of hypertension, and 73 cases of respiratory disease (including 37 cases of chronic bronchitis, 5 cases of emphysema, 25 cases of old pulmonary tuberculosis, 5 cases of bronchial asthma and 1 case of bronchiectasis). Three hundred and seventy-six cases had abnormal electrocardiograph and 204 cases had abnormal chest radiograph in preoperative examinations.

Variables in logistic analysis

Dependent variable Y-Y_0 represented no PPC during 30 d after operation. On the contrary, Y_1 represented the occurrence of PPC during 30 d after operation. PPC was defined as pneumonia, tracheobronchitis, respiratory failure, pleural effusion, pneumothorax, atelectasis, acute respiratory distress syndrome or pulmonary infarction. The diagnosis of PPC was made by the same doctor, based on the clinical manifestations, radiologic examination, blood routine, arterial blood gas analysis and other laboratory tests.

Independent variable X-X_1 gender, X_2 age (year), X_3 body mass index (BMI, kg/m^2), X_4 smoking history (grades: 0-never smoking, 1-ex-smoker having quitted smoking more than 8 wk before operation, 2-current smoker <20/d×20 years, 3-current smoker ≥ 20/d×20 years), X_5 diabetes mellitus, X_6 heart diseases (including angina pectoris, old myocardial infarction and rheumatic heart disease), X_7 hypertension, X_8 cerebral diseases (including cerebral hemorrhage, infarction and atrophy, meningitis and sclerosis of cerebral vessels), X_9 respiratory diseases (including chronic bronchitis, obstructive emphysema, old pulmonary tuberculosis, bronchial asthma, and bronchiectasis), X_{10} abnormal electrocardiogram (including myocardium strain, hypovoltage of limb lead, chronic insufficiency of coronary artery, incomplete/complete right/left bundle branch block, left ventricular hypervoltage/ventricular hypertrophy, sinus bradycardia/tachycardia, atrioventricular block, paroxysmal supraventricular tachycardia, atrial/ventricular premature beats, pre-excitation syndrome, atrial fibrillation and old myocardial infarction), X_{11} abnormal chest radiograph (including chronic bronchitis, emphysema, pulmonary tuberculosis, lung cancer/lung metastatic tumor, and pleural thickening), X_{12} hemoglobin (g/L), X_{13} alanine aminotransferase (ALT, U/L), X_{14} serum albumin (g/L), X_{15} serum globulin (g/L), X_{16} blood urea nitrogen (BUN, mmol/L), X_{17} creatinine (μmol/L), X_{18} total cholesterol (TC, mmol/L), X_{19} high density lipoprotein cholesterol (HDL-C, mmol/L), X_{20} low density lipoprotein cholesterol (LDL-C, mmol/L), X_{21} triglyceride (mmol/L), X_{22} preoperative forced expiratory volume in 1 s (FEV_1, L), X_{23} preoperative forced vital capacity (FVC, L), X_{24} preoperative FEV_1 to FVC ratio (FEV_1/FVC%), X_{25} preoperative FVC percent of predicted value (FVC%), X_{26} preoperative maximum ventilatory volume percent of predicted value (MVV%), X_{27} volume of preoperative erythrocyte transfusion (mL), X_{28} volume of preoperative whole blood transfusion (mL), X_{29} volume of preoperative plasma transfusion (mL), X_{30} volume of preoperative platelet transfusion (U), X_{31} length of preoperative antibiotic therapy (days), X_{32} duration of preoperative antacids therapy (days), X_{33} chemotherapy in 2 wk before operation, X_{34} deep vein puncture, X_{35} length of preoperative stay (days), X_{36} history of respiratory infection in 2 wk before operation (cured), X_{37} type of diseases for operation (gastric and duodenal ulcer, duodenal diverticulum, gastric leiomyoma, gastric stromal tumor, duodenal fistula, duodenal polyp, duodenal leiomyoma, gastric carcinoma, gastroduodenal metastatic tumor, intestinal obstruction, intestinal diverticulum, small intestinal leiomyoma, intestinal fistula, splenic flexure syndrome, intestinal polyp, intestinal stromal tumor, hernia, megacolon, Crohn's disease, small bowel cancer, colon cancer, rectal cancer, intestinal sarcoma, intestinal lymphoma, intestinal metastatic tumor), X_{38} benign or malignant diseases, X_{39} ASA classification (class as 1-5), X_{40} site of surgical incision (upper abdominal incision, lower abdominal incision, combined upper and lower abdominal incision), X_{41} length of surgical incision (cm), X_{42} duration of operation (min), X_{43} type of operation (subtotal gastrectomy, radical gastrectomy for gastric cancer, gastrostomy, repair of peptic ulcer perforation, partial resection and anastomosis of small bowel, radical colectomy for colon cancer, radical rectectomy for rectal cancer, partial transverse colectomy, lysis of intestinal adhesions, total colectomy), X_{44} duration of anesthesia (min), X_{45} type of anesthesia (intravenous anesthesia combined with continuous epidural anesthesia, intravenous anesthesia combined with continuous epidural

anesthesia and endotracheal anesthesia, continuous epidural combined with endotracheal anesthesia, endotracheal anesthesia combined with intravenous anesthesia, continuous epidural anesthesia), X_{46} volume of blood loss during operation (mL), X_{47} total volume of intraoperative fluid transfusion (mL), X_{48} volume of intraoperative isotonic solution transfusion (mL), X_{49} volume of intraoperative colloid solution transfusion (mL), X_{50} volume of intraoperative glucose solution transfusion (mL), X_{51} total volume of intraoperative blood products transfusion (mL), X_{52} volume of intraoperative erythrocyte transfusion (mL), X_{53} volume of intraoperative whole blood transfusion (mL), X_{54} volume of intraoperative plasma transfusion (mL), X_{55} volume of intraoperative cryoprecipitate transfusion (u), X_{56} length of intraoperative intratracheal intubation (min), X_{57} pH of arterial blood after operation, X_{58} PaO_2 of postoperative blood gas analysis (kPa), X_{59} $PaCO_2$ of postoperative blood gas analysis (kPa), X_{60} length of postoperative ICU stay (h), X_{61} time of postoperative food intake (days), X_{62} postoperative analgesia, X_{63} length of nasogastric intubation (days), X_{64} duration of postoperative antacids therapy (days), X_{65} length of postoperative intratracheal intubation (h), X_{66} length of postoperative mechanical ventilation (h).

Statistical analysis

Numerical data were expressed as frequency and percentage (%). Measured data were expressed as mean±SD. Univariate and multivariate logistic regression were used to analyze each factor. The receiver operator characteristic (ROC) statistic was also calculated to evaluate predicting efficiency of the logistic regression equation. All statistical analyses were performed with SPSS 11.0 software package. $P<0.05$ was considered statistically significant.

RESULTS

Incidence and types of PPC following gastrointestinal surgery

Two hundred and twenty-eight among 1 002 patients developed PPC, the incidence was 22.8% (228/1 002). The types of PPC included pneumonia (101/228, 44.3%), tracheobronchitis (94/228, 41.2%), respiratory failure (5/228, 2.2%), pleural effusion (12/228, 5.3%), pneumothorax (3/228, 1.3%), atelectasis (1/228, 0.4%), acute respiratory distress syndrome (2/228, 0.9%). Nine cases (9/228, 3.9%) had two types of complications, one case (1/228, 0.4%) had three types of complications.

Comparisons of clinical data between PPC group and non-PPC group and results of univariate logistic regression (Table 1)

Thirty-one of sixty-six factors correlated with PPC that included age, smoking, heart disease, hypertension, cerebral disease, respiratory disease, abnormal preoperative chest radiograph, serum albumin, BUN, creatinine, HDL-C, respiratory infection 2 wk before operation (cured), chemotherapy 2 wk before operation, type of diseases for operation, ASA classification, site of surgical incision, volume of blood loss during operation, duration of operation and anesthesia, length of intraoperative intratracheal intubation, total volume of intraoperative blood transfusion and intraoperative erythrocyte transfusion, postoperative analgesia, PaO_2 of postoperative blood gas analysis, length of postoperative ICU stay, time of postoperative food intake, length of nasogastric intubation, duration of postoperative antacids use, length of postoperative intratracheal intubation and postoperative mechanical ventilation.

Results of multivariate logistic regression (Table 2)

The risk factors for PPC were screened out by multivariable logistic regression, including age odds ratio (OR = 1.040), respiratory disease (OR = 2.976), preoperative serum albumin (OR = 0.954), volume of preoperative erythrocyte transfusion (OR = 1.002), duration of preoperative antibiotic therapy (OR = 1.072), chemotherapy 2 wk before operation (OR = 3.214), length of intraoperative intratracheal intubation (OR = 1.002), nasogastric intubation (OR = 1.050), and postoperative mechanical ventilation (OR = 1.878).

Logistic regression equation for predicting the risk for PPC is $P(1) = 1/[1+e^{-(-3.488+0.039\times Y+1.090\times Rd+0.001\times Rbc-0.047\times Alb+0.002\times Lii+0.049\times Lni+0.630\times Lmv+0.070\times Dat+1.168\times Ct)}]$, where Y = age, Rd = history of respiratory disease, Rbc = volume of preoperative erythrocyte transfusion, Alb = preoperative serum albumin, Lii = length of intraoperative intratracheal intubation, Lni = length of nasogastric intubation, Lmv = length of postoperative mechanical ventilation, Dat = duration of preoperative antibiotic therapy, Ct = chemotherapy 2 wk before operation.

ROC curve: $c = 0.780$.

DISCUSSION

It was reported that age is associated with the incidence of PPC[2,3,10]. Hall *et al*[3], studied 1 000 patients undergoing abdominal surgery, and reported that the overall incidence of PPC is 23.2% and increases to 32.9% in patients over 59 years old. Brooks-Brunn[2] also identified that age ⩾ 60 years is a risk factor for PPC. In our study, the incidence of PPC was 22.8% (228 of 1 002). Age was proved to be associated with PPC by univariate and multivariate logistic regression, which is similar to the results from previous studies. Maybe it is due to the fact that elderly patients have a higher incidence of chronic heart disease and respiratory diseases. Wightman[11] found that chronic respiratory disease is significantly more common in patients over 70 years of age (27.2%) when compared with those under this age (7.8%).

One hundred and sixteen cases in our study had a record of BMI, 13 patients had a BMI over 25 kg/m^2, and 6 of them developed PPC (46.2%), 103 patients had a BMI equal or less than 25 kg/m^2, and 33 of them developed PPC (32%). No significant difference was observed between these two groups. However, obesity has been proved as a predisposing cause of PPC in previous studies[2,12,13], and is related to a decreased compliance and the elevated diaphragmatic position, leading to the decrease of vital capacity. It was reported that postoperative reduction in vital capacity is related to BMI[14]. Latimer *et al*[12], found that 42% of overweight patients had impairment of pulmonary function, and 95% developed PPC. Brooks-Brunn[2] reported that patients having a BMI ⩾ 27 kg/m^2 have 2.8-fold risk higher than those having a lower BMI.

Univariate logistic regression analysis revealed that the

Table 1 Comparisons of clinical data between PPC group and non-PPC group and results of univariate logistic regression (mean±SD)

X	PPC group *n* = 228	Non-PPC group *n* = 774	OR	*P*	95%CI
Age (yr)	64.10±13.95	54.51±14.95	1.048	0.000[a]	1.036-1.600
Sex male/female	152 (66.7)/76 (33.3)	497 (64.2)/277 (35.8)	0.897	0.495	0.657-1.226
BMI (kg/m^2)	20.54±3.64	20.60±3.03	0.995	0.935	0.883-1.122
Smoking	87 (38.2)	155 (20.0)	1.523	0.000[a]	1.450-1.600
Diabetes mellitus	20 (8.8)	60 (7.8)	1.144	0.618	0.674-1.942
Heart diseases	19 (8.3)	32 (4.1)	1.698	0.018[a]	1.097-2.630
Hypertension	39 (17.1)	89 (11.5)	1.588	0.027[a]	1.055-2.392
Cerebral diseases	13 (5.7)	16 (2.1)	1.555	0.008[a]	1.120-2.158
Respiratory diseases	38 (16.7)	35 (4.5)	1.663	0.000[a]	1.357-2.038
Abnormal electrocardiogram	98 (43.0)	278 (35.9)	1.039	0.090	0.994-1.087
Abnormal chest radiograph	62 (27.2)	142 (18.3)	1.211	0.015[a]	1.190-1.233
Hemoglobin (g/L)	114.90±23.52	117.20±25.73	0.996	0.228	0.991-1.002
ALT (U/L)	24.67±34.96	22.27±39.12	1.001	0.410	0.998-1.005
Serum albumin (g/L)	38.00±4.97	39.96±4.86	0.920	0.000[a]	0.899-0.953
Serum globulin (g/L)	25.46±6.61	26.42±6.66	0.978	0.058	0.957-1.001
BUN (mmol/L)	6.22±3.43	5.27±2.05	1.152	0.000[a]	1.086-1.221
Creatinine (μmol/L)	93.68±51.12	84.58±21.82	1.009	0.001[a]	1.003-1.014
TC (mmol/L)	4.00±1.24	4.18±1.28	0.893	0.067	0.791-1.008
HDL-C (mmol/L)	1.08±0.32	1.16±0.41	0.561	0.009[a]	0.365-0.864
LDL-C (mmol/L)	2.54±1.03	2.67±1.00	0.883	0.107	0.760-1.027
Triglyceride (mmol/L)	1.14±1.06	1.13±1.05	1.008	0.909	0.878-1.157
FEV_1 (L)	1.79±0.79	2.08±2.01	0.863	0.490	0.567-1.312
FVC (L)	2.37±0.87	2.25±0.76	1.211	0.531	0.665-2.206
FEV_1/FVC (%)	74.84±14.73	79.10±12.60	0.977	0.203	0.942-1.013
FVC%	80.05±22.05	79.95±21.91	1.000	0.985	0.978-1.023
MVV (%)	73.17±25.51	77.12±25.14	0.994	0.517	0.975-1.013
History of respiratory infection in 2 wk before operation (cured)	21 (9.2)	34 (4.4)	2.208	0.006[a]	1.254-3.886
Volume of preoperative erythrocyte transfusion (mL)	85.97±292.6	65.25±248.2	1.000	0.295	1.000-1.001
Volume of preoperative whole blood transfusion (mL)	23.25±140.6	16.67±115.1	1.000	0.476	0.999-1.002
Volume of preoperative plasma transfusion (mL)	28.07±148.7	23.06±227.7	1.000	0.755	0.999-1.001
Volume of preoperative platelet transfusion (U)	0.07±0.99	0.04±1.08	1.021	0.738	0.903-1.156
(To be continued)					
Duration of preoperative antibiotic therapy (d)	2.16±3.42	1.78±2.49	1.050	0.062	0.997-1.104
Duration of preoperative antacids therapy (d)	1.46±3.38	1.38±3.21	1.007	0.760	0.963-1.053
Chemotherapy 2 wk before operation	10 (4.4)	15 (1.9)	2.321	0.043[a]	1.028-5.240
Deep vein puncture	81 (35.5)	234 (30.2)	1.272	0.131	0.931-1.736
Length of preoperative stay (d)	6.43±7.12	5.73±6.39	1.015	0.162	0.994-1.036
Type of diseases for operation			0.934	0.040[a]	0.875-0.997
Benign or malignant diseases			0.992	0.938	0.812-1.212
ASA classification			2.310	0.000[a]	1.818-2.935
Site of surgical incision			1.606	0.004[a]	1.166-2.211
Duration of operation (min)	193.18±87.78	180.90±63.77	1.020	0.035[a]	1.015-1.025
Type of operation			1.013	0.312	0.988-1.039
Length of surgical incision (cm)	19.81±8.00	18.10±6.72	1.033	0.070	0.997-1.070
Duration of anesthesia (min)	263.71±96.55	246.53±85.82	1.027	0.026[a]	1.020-1.035
Type of anesthesia			1.293	0.000[a]	1.132-1.478
Volume of blood loss during operation (mL)	408.25±300.24	336.15±287.27	1.001	0.041[a]	1.001-1.002
Length of intraoperative intratracheal intubation (min)	139.10±148.10	83.79±128.71	1.003	0.000[a]	1.002-1.004
Total volume of intraoperative fluid transfusion (mL)	2 517.32±985.43	2 454.10±909.59	1.000	0.366	1.000-1.000
Volume of intraoperative isotonic solution transfusion (mL)	1 673.25±714.56	1 644.96±693.44	1.000	0.591	1.000-1.000
Volume of intraoperative colloid solution transfusion (mL)	763.16±423.49	733.66±383.33	1.000	0.319	1.000-1.001
Volume of intraoperative glucose solution transfusion (mL)	101.10±219.95	80.94±194.69	1.000	0.184	1.000-1.001
Total volume of intraoperative blood products transfusion (mL)	310.75±740.67	185.05±368.06	1.002	0.002[a]	1.001-1.002
Volume of intraoperative erythrocyte transfusion (mL)	164.04±366.82	112.92±217.27	1.002	0.015[a]	1.001-1.002
Volume of intraoperative whole blood transfusion (mL)	60.96±220.96	37.14±153.88	1.001	0.073	1.000-1.001
Volume of intraoperative plasma transfusion (mL)	76.32±259.13	41.41±135.75	1.001	0.051	1.000-1.002
Volume of intraoperative cryoprecipitate transfusion (U)	0.30±1.76	0.08±0.96	1.001	0.243	1.000-1.002
pH of arterial blood after operation	7.39±0.1	7.40±0.20	0.176	0.557	0.001-5.809
(To be continued)					
PaO_2 of postoperative blood gas analysis (kPa)	11.37±5.78	15.91±6.35	0.891	0.010[a]	0.816–0.973
$PaCO_2$ of postoperative blood gas analysis (kPa)	5.36±1.98	4.70±0.90	1.298	0.155	0.906–1.858
Length of postoperative ICU stay (h)	8.31±36.75	0.37±2.91	1.057	0.000[a]	1.027–1.087
Time of postoperative food intake (d)	5.17±4.09	4.92±3.08	1.065	0.012[a]	1.014–1.119
Postoperative analgesia	88 (38.6)	371 (47.9)	0.683	0.013[a]	0.505–0.923
Length of nasogastric intubation (d)	4.02±7.04	3.08±2.60	1.062	0.010[a]	1.014–1.112
Duration of postoperative antacids therapy (d)	11.86±11.10	7.66±3.78	1.455	0.015[a]	1.075–1.971
Length of postoperative intratracheal intubation (h)	8.11±38.00	0.10±1.54	1.157	0.000[a]	1.068–1.252
Length of postoperative mechanical ventilation (h)	3.53±19.88	2.32±0.46	1.339	0.002[a]	1.117–1.605

[a]$P<0.05$.

Table 2 Variables associated with PPC by multivariate logistic regression

Variable	Parameter estimate	SE	OR	95%CI	*P*
Age (yr)	0.039	0.007	1.040	1.027-1.054	0.000
History of respiratory diseases	1.090	0.278	2.976	1.724-5.135	0.000
Volume of preoperative erythrocyte transfusion	0.001	0.000	1.002	1.001-1.003	0.011
Serum albumin	-0.047	0.018	0.954	0.921-0.988	0.009
Length of intraoperative intratracheal intubation	0.002	0.001	1.002	1.001-1.004	0.000
Length of nasogastric intubation	0.049	0.022	1.050	1.007-1.096	0.023
Length of postoperative mechanical ventilation	0.630	0.232	1.878	1.193-2.957	0.007
Length of preoperative antibiotics therapy	0.070	0.033	1.072	1.005-1.145	0.037
Chemotherapy 2 wk before operation	1.168	0.445	3.214	1.345-7.684	0.009

risk of PPC in smokers was 1.5 times higher than that in non-smokers. Wightman[11] reported that PPC occurs more frequently in smokers (14.8%) than in non-smokers (6.3%). Recently, Bluman *et al*[15], found that the incidence of PPC in current smokers, past smokers and non-smokers was 22.0%, 12.8% and 4.9%, respectively; the OR of PPC was 5.5 in current smokers. A few days after stopping smoking, ciliary beating is greatly improved and sputum volume is significantly reduced after 1-2 wk. However, a period of 4-6 wk can greatly influence postoperative respiratory morbidity[16]. Jackson[13] reported that chronic obstructive pulmonary disease patients should stop smoking at least 8 wk before surgery.

Some patients with chronic respiratory disease have persistent airway inflammation with large amount of secretion. Because of postoperative pain, cough is weakened. Some receive preoperative corticosteroids treatment in order to relieve bronchial spasm, which impairs their immune system. COPD is more common in elderly patients with decreased immune function. A part of patients with COPD have potentially pathogenic micro-organisms in their sputum and usually show poorer health status[17]. All these factors make patients with chronic respiratory disease susceptible to PPC. Thirty-eight of seventy-three patients with a history of chronic respiratory disease in our study developed PPC. In 929 patients without history of chronic respiratory disease, 190 (20.5%) developed PPC. The difference was significant, which is consistent with previous studies[5-7,11]. Wightman[11] found that 33 of 402 patients without evidence of chronic respiratory disease developed PPC, while 14 of 53 patients with chronic respiratory disease developed PPC. Kroenke *et al*[6], reported that COPD patients with FVE_1 <50% and FVE_1/FVC <70% suffer more severe pulmonary complications and death, the incidence of serious pulmonary complications or death increases with the increasing severity of the disease. Fuso *et al*[7], found that patients with moderate to severe airway obstruction combined with hypoxemia have a significant higher risk for PPC in comparison with patients with a normal respiratory pattern.

In our study, there were 51 cases of heart disease, including 49 cases of ischemic heart disease. Univariate logistic analysis revealed that the risk for PPC in patients with heart disease was 1.7 times higher than that in patients without heart disease. Besides COPD, ischemic heart disease is identified as an independent predictor of PPC[7]. This relationship may be attributed to cigarette smoking associated with both COPD and ischemic heart disease. It was reported that symptoms of chronic bronchitis can predict the risk for coronary disease independently from the known major cardiovascular risk factors[18]. In a study on PPC, 33% patients have both pulmonary and cardiac complications[8]. Some investigators suggested that predicting and preventing postoperative cardiac morbidity is the best way to reduce postoperative pulmonary morbidity[9].

ASA classification reflects the basic conditions of patients, and provides a way to predict their anesthetic and surgical risks. Wolters *et al*[19], reported that ASA class is associated with intraoperative blood loss, duration of postoperative ventilation and intensive care stay, postoperative complications and mortality rate. Kocabas *et al*[20], found that PPC rate after selective upper abdominal surgery increases in patients with higher ASA class. Hall *et al*[3], also identified that ASA classification is an important factor for predicting PPC and found that combination of an ASA classification >1 and an age >59 years can identify 88% of the patients who subsequently develop PPC.

It was reported that patients receiving more than 4 units of blood before surgery have an OR of 1.35 for developing postoperative pneumonia[21]. In our study, we also found that preoperative erythrocyte transfusion was significantly associated with the risk of PPC. It may be due to the severe anemia resulting from acute or chronic blood loss, which would deteriorate their basic condition. Homologous blood transfusion is immunosuppressive and plays a role in the occurrence of PPC. Homologous blood transfusions have been shown to have a variety of immunomodulatory effects on tumor growth, recurrence and survival after operation[22-24]. Duke *et al*[25], found that blood transfusion significantly increases the risk for perioperative infection and respiratory complication.

In our study, we found that low serum albumin significantly increased the risk for PPC. Longo *et al*[26], studied 5 853 patients undergoing colectomy for colon cancer to define the risk factors for complications, and found that low serum albumin is one of the preoperative factors that predict a high risk of 30-d mortality. Smetana[27] reported that low serum albumin is associated with PPC. Garibaldi *et al*[4], found that postoperative pneumonia is highly associated with low serum albumin at admission, which is related to the severity of underlying diseases. Comorbid diseases, such as functional failure of heart, liver, or kidney, are common in patients with low serum albumin. Fluid leaks out into the interstitial space, resulting from the lower serum colloid osmotic pressure. It can lead to edema and attenuate the function of material transportation and alimentation. This is disadvantageous to the recovery after operation, and increases the risk for PPC.

Patients undergoing upper gastrointestinal surgery in our hospital almost routinely required nasogastric intubation before operation. Seven hundred and fifty-one of one thousand and two cases in our study were inserted nasogastric tubes before operation. Nasogastric intubation might lead to aspiration of the oral and pharyngeal secretion and gastric contents, resulting in aspiration pneumonia. The risk for infection increases with the length of intubation. Ephgrave *et al*[28], found that the presence of gastric bacteria during operation and transmission of gastric bacteria to the pulmonary tree after operation are associated with postoperative pneumonia in patients requiring nasogastric intubation after selective surgical procedures.

Long-term intratracheal intubation and mechanical ventilation increase the risk for PPC, which is related to the following reasons. Intratracheal intubation destroys the normal defensive system of the respiratory tract by damaging mucosa of the air way and impairs the cleaning capacity of cilia, thus facilitating the stay and proliferation of bacteria. Bacteria in upper respiratory tract are brought to the lower respiratory tract, thus resulting in the subsequent infection. Secretions around the tracheal tube balloon often accumulate and drop into the lower air way, promoting the transmission of bacteria and infection. Contamination of medical devices (especially aerosol atomizer, moisturizing bottle, and oxygen tube), environment of the wards, and improper aseptic procedure are associated factors for pulmonary infection.

Four hundred and ninety-nine cases in our study received preoperative antibiotics therapy, ranging from 1 to 18 d, and the average was 3.74±2.83 d. We found that only 55 cases presented signs of preoperative respiratory infection, and no infection was identified in the other cases. We used antibiotics in the other 444 patients for surgical prophylaxis. Multivariate logistic analysis identified that preoperative antibiotic therapy was a risk factor for PPC. Inappropriate use of surgical antibiotic prophylaxis is common in hospitals[29]. Antibiotics abuse or long-term use disturbs the balance of normal flora, thus changing the normal microbes residing in the human body. The damage to sensitive non-pathogenic flora facilitates the proliferation of pathogenic microbes and causes infection.

Preoperative chemotherapy is often used in progressive cancer. Without destruction of blood vessels by operation, tumor has abundant blood supply and is more sensitive to chemotherapy before operation. Furthermore, preoperative chemotherapy can reduce the size of tumor and lower the tumor stage, so that the opportunity for radical operation increases and metastasis will be reduced or postponed[30]. However, our study showed that chemotherapy 2 wk before the operation is a risk factor for PPC (OR = 3.24). This may be related to the cytotoxicity of chemotherapy drugs, which may cause bone marrow suppression, lead to neutropenia and increase the risk of infection. Moreover, the gastrointestinal toxic effect causes nausea and vomiting, thus resulting in aspiration pneumonia. The pulmonary toxic effect of chemotherapy drugs can cause pulmonary interstitial injury and decrease the pulmonary function[31]. Avendano *et al*[32], reported that preoperative chemoradiotherapy is a significant risk factor for pulmonary complications after esophagectomy.

In previous studies, the risk factors were often analyzed as bicategorical variables, lacking quantitative analysis of independent variables. In our study, variables which entered analyses included most possible factors for PPC, and we tried to use the continuous variable to reflect the quantitative variation of the factors.

In conclusion, old patients are easier to develop PPC.

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