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ORIGINAL ARTICLE

Development and validation of a nomogram predicting postoperative pneumonia after major abdominal surgery

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Abstract

Purpose Postoperative pneumonia (POP) is a common complication that can adversely affect the outcomes after surgery. This study aimed to devise and validate a model for stratifying the probability of POP in patients undergoing abdominal surgery.

Methods We included 1050 patients who underwent major abdominal surgery between 2012 and 2013. A nomogram was devised by evaluating the predictive factors for POP.

Results Of the 1050 patients, 56 (5.3%) developed POP. Multivariable logistic regression analysis revealed that the independent predictive factors for POP were age, male sex, history of cerebrovascular disease, Brinkman Index (BI) ≥ 900, and upper midline incision. A nomogram was devised by employing these five significant predictive factors. The prediction model showed a relatively good discrimination performance, with a concordance index of 0.77.

Conclusions A nomogram based on age, male sex, history of cerebrovascular disease, BI ≥ 900, and upper midline incision may be useful for identifying patients with a high probability of developing POP after major abdominal surgery.

Keywords Postoperative pneumonia · Major abdominal surgery · Upper midline incision · Predictive factor

Abbreviations

POP	Postoperative pneumonia
BI	Brinkman Index
ICU	Intensive care unit
POD	Postoperative day
PS	Performance status
CI	Cerebral infarction
ASA	The American society of anesthesiologists physical status classification system
PNI	Prognostic nutritional index
IQR	Interquartile ranges
ORs	Odds ratios
CIs	Confidence intervals
BMI	Body mass index

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Introduction

Postoperative pneumonia (POP) is a common complication after abdominal surgery, with an incidence ranging from 1 to 18% [1–7]. It is reported to be associated with prolonged hospital stay, an increased cost of hospital care, and increased morbidity and mortality [8–11]. Various predictive factors have been reported to be associated with the development of POP after abdominal surgery in previous studies, including older age, smoking, neurologic disorders, chronic obstructive pulmonary disease, emergency surgery, assisted mechanical ventilation, postoperative intensive care unit (ICU) stay, and routine nasogastric decompression tube usage [6, 12–16]. These predictive factors were used to identify patients with a high probability of POP. The identification of patients with high probability of developing POP may be useful for decision-making regarding close monitoring and the strict performance of evidence-based perioperative managements, including preoperative oral care [17, 18], preoperative inspiratory muscle training [19], and early mobilization after surgery [20, 21]. However, no predictive models for POP after abdominal surgery have been reported.

The aim of the present study was to devise a model that stratifies the probability of POP in patients undergoing abdominal surgery based on the evaluation of predictive factors for POP.

Materials and methods

Patients

From April 2012 to December 2013, a total of 1666 consecutive patients underwent abdominal surgery under general anesthesia at Asahi General Hospital. The collected data were retrieved from prospectively maintained databases and included baseline patient characteristics (e.g., demographic data, preoperative risk factors, and co-morbidities), operative characteristics, and postoperative outcomes. Patients who underwent less invasive abdominal surgery procedures, such as appendectomy, laparoscopic cholecystectomy, abdominal wall hernioplasty, and explorative laparotomy, were excluded from the analysis. All operations were performed after obtaining informed consent from the patients. This study was approved by the local institutional review board (ID: 2,013,091,712).

Definition of postoperative pneumonia

POP was defined based on the presence of a new and persistent or progressive pulmonary infiltration on two or more serial X-rays, with at least two of the following criteria: body temperature > 38 °C or < 35 °C; leukocytosis > 12,000 mm^3 or leukopenia < 4000 mm^3; and purulent sputum production.

Preoperative management to prevent postoperative pneumonia

Preoperative counseling was delivered to the patients in the outpatient clinic, as recommended by the early recovery after surgery (ERAS) program [22–24]. A checklist showing the rehabilitation plan, the daily mobilization plan, and the nutritional goals was provided. Patients were routinely asked to consult a dentist for preoperative oral care [17, 18] and underwent inspiratory muscle training (Triball Volumetric Exerciser, Medtronic) for 4 weeks before surgery.

Anesthesia

All patients were given epidural and general anesthesia, which consisted of remifentanil, fentanyl, propofol, O_2–N_2O sevoflurane, rocuronium, vecuronium, and sugammadex, without premedication. Nasogastric tubes were routinely removed in the operating room.

Postoperative management

Postoperative management was generally based on the ERAS program [22–26] and was partly modified according to the patients' conditions at the attending surgeons' discretion. Liquid intake was started on postoperative day (POD) 1. Depending on the patients' conditions, solid food intake was started on POD 2, 3, or later, especially in patients with cognitive disorder or dysphagia. Epidural analgesia was generally used until POD 3 or 4. Intravenous opioid administration was initiated when pain was not well-controlled by epidural analgesia, acetaminophen, and/or non-steroidal anti-inflammatory drugs. On POD 1, the patients were encouraged to perform mobilization exercises, including walking around the ward with a physical therapist, and to perform inspiratory muscle training. The urinary catheter and the abdominal drainage tubes were removed as soon as possible. Screening for complications was performed based on clinical symptoms, blood test results, and X-ray imaging on PODs 1, 3, and 5, or later, as needed. Computed tomography was performed, as necessary, to detect complications.

Postoperative morbidity was graded according to the Clavien–Dindo classification [27], which defines grade III, IV, and V complications as major.

Study criteria and definitions

A nomogram to predict the probability of POP was designed by evaluating the factors associated with the development of POP.

The Eastern Cooperative Oncology Group performance status (PS) was used to assess the functional status of the patients. The Brinkman Index (BI) was calculated by multiplying the number of cigarettes smoked per day by the number of smoking years. The definitions of comorbid diseases were as follows: Cardiac disease was defined as having one of the following diseases: coronary artery disease, heart failure, severe valvular heart disease, myocardial disease, or arrhythmia. Pulmonary disease included asthma, chronic obstructive pulmonary disease, bronchiectasis, sequelae of pulmonary tuberculosis or tuberculous pleurisy, and interstitial lung disease. Cerebrovascular disease included intracerebral hemorrhage and cerebral infarction. Psychiatric disease included depression, manic depression, and schizophrenia. All patients were referred to anesthesiologists for preoperative assessment and classification into one of the six grades by the American Society of Anesthesiologists Physical Status classification system. The prognostic nutritional index (PNI) was used as an indicator of the nutritional status and was calculated as PNI = 10 × albumin (g/dl) + 0.005 × lymphocyte count (/μL) [28].

To assess the influence of each surgical procedure on POP development, the surgical procedures were divided into the following five categories: (1) upper gastrointestinal surgery, including esophagectomy and gastrectomy; (2) colorectal surgery, including colectomy and rectal resection; (3) hepatopancreatobiliary surgery, including hepatectomy, pancreatectomy, splenectomy, open cholecystectomy, and cholecystolithotomy; (4) vascular surgery, which mainly included abdominal aortic aneurysm repair; and (5) other operations, including ileus operation, stoma construction or closure, surgical drainage, and operations on the intestine.

Statistical analysis

Categorical variables were expressed as the number (%) and were compared using the chi-squared test or Fisher's exact test, as appropriate. Continuous variables were expressed as the median [interquartile range (IQR)] and were compared using the Wilcoxon rank sum test. A multivariable prediction model was developed and validated based on the TRIPOD statement [29]. The logistic regression model was used to generate a nomogram predicting the incidence of POP. The logistic regression model analysis initially included the following factors: age (continuous), sex, BMI (≥ 25 vs. < 25 kg/m^2), BI (> 900 vs. ≤ 900), diabetes mellitus, hypertension, cardiac dysfunction, pulmonary dysfunction, pulmonary dysfunction, renal dysfunction, cerebrovascular disease, psychiatric disease, concurrent malignant neoplasm, PS (≥ 2 vs. < 2), white blood cell count (≥ 6000 vs. < 6000 /μl), hemoglobin level (< 12 vs. ≥ 12 g/dl), albumin level (< 3.8 vs. ≥ 3.8 g/dl), estimated glomerular filtration rate (< 60 vs. ≥ 60 mL/min/1.73 m^2), PNI (< 40 vs. ≥ 40), type of surgery (upper gastrointestinal, colorectal surgery, hepatopancreatobiliary, vascular, or other), upper midline incision, laparoscopic approach, and emergency operation. A backward elimination with a threshold *P* value of 0.05 was used to select variables for the final models. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for each factor. The predictive performance of the nomogram was internally validated using the bootstrapping method [30]. Harrell's C-statistic of the identified model was calculated using 100 bootstrap samples [31, 32]. The predicted probability of POP was compared with the observed probability of POP in the total study population, again using bootstrapping with 100 resamples. The cutoff level for PNI was set at 40, based on a previous report [28]. The cutoff level for BI was set based on Youden's index using a receiver operating characteristic curve analysis. The other continuous variables were categorized by their institutional lower limits. *P* values of < 0.05 were considered to indicate statistical significance. All statistical analyses were conducted using the JMP software program (version 13.0.0; SAS Institute Inc., Cary, NC, USA) and the SAS® University Edition (SAS Inc., Cary, NC, USA).

Results

Patients

A total of 1050 patients were selected after excluding 616 patients who underwent less invasive operations, such as appendectomy (*n* = 204), laparoscopic cholecystectomy (*n* = 310), abdominal wall hernioplasty (*n* = 75), and explorative laparotomy (*n* = 26). The rate of postoperative complication was low in the excluded 616 patients (1.6%). There were 696 men and 354 women, with a median age of 71 years (IQR, 62–78 years). The operative procedures included upper gastrointestinal surgery in 300 (28.6%) patients; colorectal surgery in 332 (31.6%); hepatopancreatobiliary surgery in 169 (16.1%); vascular surgery, which mainly included abdominal aortic aneurysm repair, in 69 (6.6%); and other operations in 180 (17.1%), which mainly included ileus operation in 71 (6.8%) and stoma construction or closure in 63 (6.0%).

Of the 1050 patients, 56 (5.3%) developed POP (the pneumonia group) after upper gastrointestinal surgery (7.3%, 22 of 300); colorectal surgery (3.6%, 12 of 332); hepatobiliary pancreatic surgery (4.1%, 7 of 169); vascular surgery (11.6%, 8 of 69); and other operations (3.9%, 7 of 180). The remaining 994 (94.6%) did not develop POP (the non-pneumonia group). POP had an onset at 3.5 days (IQR, 3.0–7.8 days) after operation days.

The demographic data were compared between the pneumonia and the non-pneumonia groups (Table 1). Compared with the non-pneumonia group, the pneumonia group had significantly higher values for age (75 years vs. 70 years, *P* < 0.001) and BI [600 (IQR, 0–1200) vs. 0 (IQR, 0–760), *P* < 0.001] and higher frequency of men (85.7% vs. 65.1%, *P* = 0.001); cerebrovascular disease (23.2% vs. 10.0%, *P* = 0.006), and PS score ≥ 2 (14.3% vs. 6.2%, *P* = 0.028). There were no significant differences between the groups with regard to body mass index, artificial tooth use, presence of other comorbidities, and laboratory data.

Table 1 The demographic characteristics of the two groups

Variables	Pneumonia group ($n=56$)	Non-pneumonia group ($n=994$)	P value
Preoperative characteristics			
Age, years	75.0 (69.3–80.5)	70.0 (62.0–78.0)	< 0.001
Male/female	48/8	648/346	0.001
BMI (kg/m^2)	22.2 (20.1–25.1)	22.5 (20.0–25.1)	0.713
BI	600 (0–1200)	0 (0–760)	< 0.001
Comorbidity			
Diabetes mellitus, %	19 (33.9)	241 (24.3)	0.112
Hypertension, %	25 (44.6)	363 (36.5)	0.255
Cardiac dysfunction, %	19(33.9)	269 (27.1)	0.282
Pulmonary dysfunction, %	4 (7.1)	54 (5.4)	0.544
Renal dysfunction, %	10 (17.9)	112 (11.3)	0.135
Cerebrovascular disease, %	13 (23.2)	99 (10.0)	0.006
Dementia, %	0 (0)	11 (1.1)	> 0.999
Psychiatric disease, %	1 (1.8)	32 (3.2)	> 0.999
Concurrent malignant neoplasm, %	37 (66.1)	685 (68.9)	0.658
PS ≥ 2, %	8 (14.3)	62 (6.2)	0.028
ASA status ≥ 3	14 (25.0)	180 (18.1)	0.214
Preoperative laboratory data			
White blood cell (/μl)	5850 (4700–7650)	5900 (4800–7700)	0.483
Hemoglobin (g/dl)	11.8 (10.3–13.9)	12.2 (10.3–13.7)	0.797
Albumin (g/dl)	3.8 (2.8–4.1)	3.9 (3.1–4.3)	0.109
Total bilirubin (mg/dl)	0.6 (0.5–0.8)	0.7 (0.5–0.9)	0.144
eGFR (mL/min/1.73 m^2)	62.6 (51.0–80.2)	66.7 (54.2–80.2)	0.505
PNI*	44.2 (34.7–52.0)	46.7 (37.6–52.2)	0.219

BMI body mass index, *BI* Brinkman Index (calculated using the number of cigarettes smoked per day multiplied by the number of smoking years), *PS* performance status, *ASA* the American Society of Anesthesiologists Physical Status classification system, *eGFR* estimated glomerular filtration rate; PNI, prognostic nutritional index

*Data not available for PNI in 5 patients

Comparison of intraoperative outcomes between the groups

The intraoperative outcomes are shown in Table 2. Compared with the non-pneumonia group, the pneumonia group had significantly higher rates of vascular surgery (14.3% vs. 6.1%, $P=0.026$) and upper midline incision (73.2% vs. 51.2%, $P=0.001$); significantly longer operation time (298 min vs. 249 min, $P=0.003$); and significantly higher amount of estimated blood loss (366.5 ml vs. 150.0 ml, $P=0.002$).

Comparison of the postoperative outcomes between the groups

The postoperative outcomes are summarized in Table 3. All patients in the pneumonia group were treated with appropriate antibiotics based on sputum and/or blood culture; tracheal intubation was required in 9 (16.1%) patients and lasted for 12 days (IQR, 4.0–16.5 days). In comparison to the non-pneumonia group, the pneumonia group showed significantly longer median lengths of ICU and hospital stay (13 days vs. 5 days, $P<0.001$; 27 days vs. 9 days, $P<0.001$, respectively) and significantly higher rates of morbidity other than pneumonia (64.3% vs. 37.7%, $P<0.001$); major complications other than pneumonia (42.8% vs. 12.6%, $P<0.001$); and in-hospital (12.5% vs. 3.3%, $P=0.004$), at 90 days (17.9% vs. 4.1%, $P<0.001$), and 180-day (19.6% vs. 6.0%, $P<0.001$) mortality.

Predictive factors associated with postoperative pneumonia

The multivariable logistic regression analysis (Table 4) showed that the independent predictive factors for POP were age (OR 1.05, 95% CI 1.02–1.09, $P=0.002$); male sex (OR 2.36, 95% CI 1.04–5.38, $P=0.040$); history of cerebrovascular disease (OR 2.33, 95% CI 1.18–4.59, $P=0.015$); BI ≥ 900 (OR 2.70, 95% CI 1.49–4.91, $P=0.001$), and upper midline incision (OR 2.28, 95% CI 1.23–4.23, $P=0.009$).

Table 2 The operative outcomes of the two groups

Variables	Pneumonia group ($n=56$)	Non-pneumonia group ($n=994$)	P value
Operative procedures			
Type of surgery			
Upper gastrointestinal[a], %	22 (39.3)	278 (28.0)	0.093
Colorectal[b], %	12 (21.4)	320 (32.2)	0.105
Hepatopancreatobiliary[c], %	7 (12.5)	162 (16.3)	0.576
Vascular[d], %	8 (14.3)	61 (6.1)	0.026
Others[e], %	7 (12.5)	173 (17.4)	0.465
Upper midline incision, %	41 (73.2)	509 (51.2)	0.001
Laparoscopic approach, %	5 (8.9)	175 (17.6)	0.103
Emergency operation, %	9 (16.1)	179 (18.0)	0.858
Intraoperative variables			
Operation time (min)	298.0 (205.0–420.8)	249.0 (165.8–332.0)	0.003
Blood loss (mL)	366.5 (98.8–595.3)	150.0 (20.0–433.5)	0.002
Epidural anesthesia, %	46 (82.1)	795 (80.0)	0.863

[a]Esophagectomy and gastrectomy

[b]Colectomy and rectectomy

[c]Hepatectomy, pancreatectomy, splenectomy, open cholecystectomy and cholecystolithotomy

[d]Abdominal aortic aneurysm repair and other artery repairs

[e]Ileus operation, stoma construction and closure, surgical drainage, and small intestine operation

Table 3 The postoperative outcomes of the two groups

Variables	Pneumonia group ($n=56$)	Non- pneumonia group ($n=994$)	P value
Postoperative ICU stay, %	18 (32.1)	83 (8.4)	<0.001
Length of ICU stay, days	13 (8–22)	5 (2–9)	<0.001
Length of hospital stay, days	27 (13–51)	9 (7–15)	<0.001
Postdischarge institutionalization, %	4 (7.1)	26 (2.6)	0.071
Morbidity, %	56 (100.0)	375 (37.7)	<0.001
Morbidity except pneumonia, %	36 (64.3)	375 (37.7)	<0.001
Ileus, %	14 (25.0)	93 (9.4)	<0.001
Delirium, %	13 (23.2)	66 (6.6)	<0.001
CI, %	2 (3.6)	7 (0.7)	0.079
Major complication except pneumonia, %	24 (42.8)	128 (12.6)	<0.001
Hospital mortality, %	7 (12.5)[a]	33 (3.3)	0.004
90-day mortality, %	10 (17.9)	41 (4.1)	<0.001
180-day mortality, %	11 (19.6)	60 (6.0)	<0.001

ICU intensive care unit, *CI* cerebral infarction

[a]Including mortality associated with postoperative pneumonia ($n=5$)

Construction and internal validation of a nomogram for postoperative pneumonia

A nomogram was generated by incorporating the five significant predictive factors, including age, sex, history of cerebrovascular disease, BI $\geq$ 900, and upper midline incision on the basis of the following regression models; Log $[p/(1-p)] = -8.117 + 0.0506 \times (\text{age}) + 0.861 \times$ (sex, male = 1 and female = 0) + 0.845 × (celebrovascular disease, yes = 1 and no = 0) + 0.995 × [(BI > 900) = 1 and (BI ≤ 900) = 0] + 0.826 × (Upper midline incision, yes = 1 and no = 0), p = Predicted probability of POP (Fig. 1). The prediction model had a calculated concordance index of 0.77 (95% CI 0.72–0.82) and 0.772 (0.776–0.777) based on the bootstrapping method, which showed a relatively good discrimination. Calibration plots for our model using 100 bootstrap samples showed that the predicted proportions of POP lay within 5% of the margin of error (Fig. 2).

The ability of this five-factor model to distinguish between patients with a low probability of POP and those

Table 4 Multivariable odds ratio for postoperative pneumonia

Variables	No. of patients	No. of events	Multivariable OR[a]	95% CI	*P* value
Age (continuous)	–	–	1.05	1.02–1.09	0.002
Sex					
Male	696	48	2.36	1.04–5.38	0.040
Female	346	8	1 (referent)		
Cerebrovascular disease					
Yes	112	13	2.33	1.18–4.59	0.015
No	938	43	1 (referent)		
Brinkman index					
≥ 900	199	25	2.70	1.49–4.91	0.001
< 900	851	31	1 (referent)		
Upper midline incision					
Yes	550	41	2.28	1.23–4.23	0.009
No	500	15	1 (referent)		

Of the 1050 patients, 1045 patients were analyzed because data were unavailable for PNI in 5 patients

[a]The logistic regression model analysis initially included the following factors: age (continuous), sex, BMI (≥ 25 vs. < 25 kg/m2), BI (≥ 900 vs. < 900), diabetes mellitus, hypertension, cardiac dysfunction, pulmonary dysfunction, pulmonary dysfunction, renal dysfunction, cerebrovascular disease, psychiatric disease, concurrent malignant neoplasm, PS (≥ 2 vs. < 2), white blood cell count (≥ 6000 vs. < 6000/μl), hemoglobin level (< 12 vs. ≥ 12 g/dl), albumin level (< 3.8 vs. ≥ 3.8 g/dl), estimated glomerular filtration rate (< 60 vs. ≥ 60 mL/min/1.73 m2), PNI (< 40 vs. ≥ 40), type of surgery (upper gastrointestinal, colorectal surgery, hepatopancreatobiliary, vascular, or others), upper midline incision, laparoscopic approach, and emergency operation. A backward elimination with a threshold P value of 0.05 was used to select variables for the final models

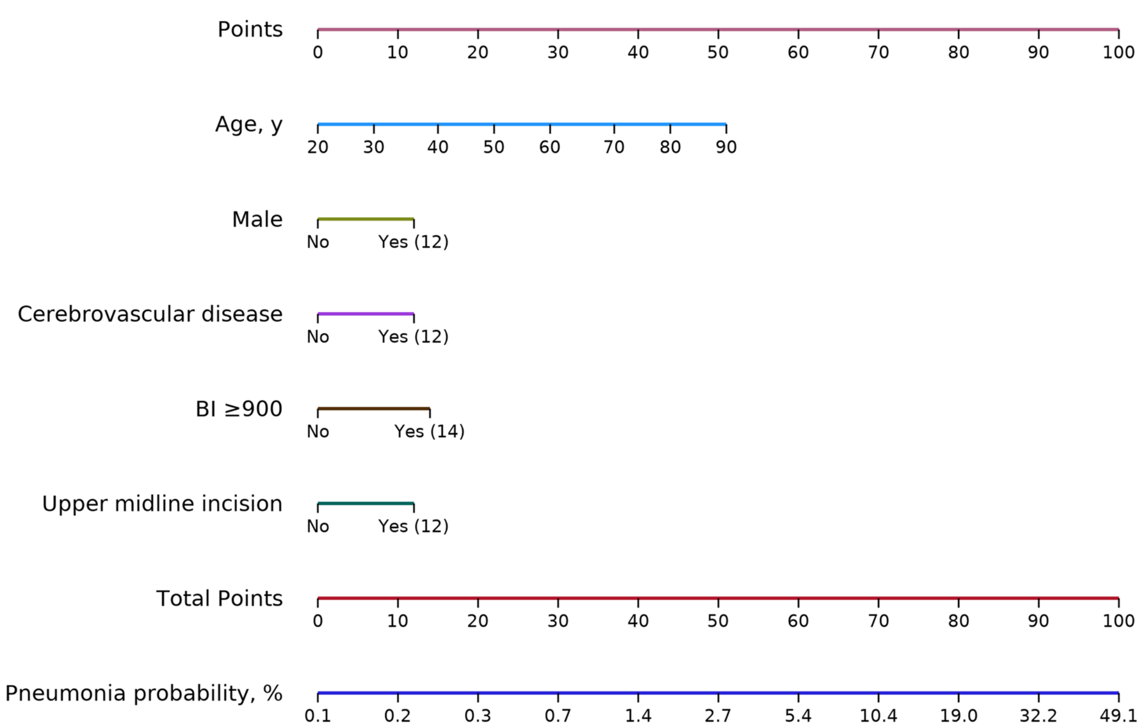

Fig. 1 Nomogram. The established nomogram employed five predictive factors, including age, male sex, history of cerebrovascular disease, BI ≥ 900, and upper midline incision. The discrimination concordance index of the predictive model was 0.77 (95% CI 0.72–0.82) and 0.772 (0.776–0.777) based on the bootstrapping method

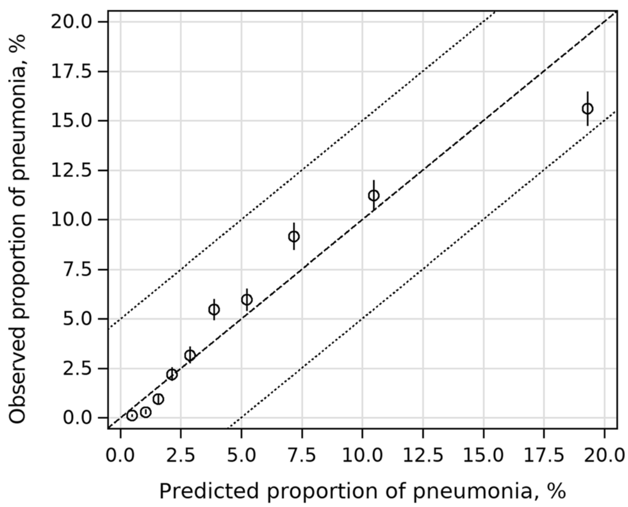

Fig. 2 Calibration plots for our nomogram using the bootstrap method. The observed proportions of. patients with POP for patients within each decile are plotted against the predicted proportions of POP. All the predictions lie within 5% of the margin of error (within the dotted line). The dashed line reflects perfect calibration of the model prediction. The error bar shows 95% confidence interval

with a high probability of POP can be demonstrated by considering two hypothetical individuals who might be encountered in practice. One is a 50-year-old female patient (patient A) with BI < 900 and no history of cerebrovascular disease who undergoes sigmoidectomy (lower midline incision); the other is a 70-year-old male (patient B) with a BI of ≥ 900 and a history of cerebrovascular disease who undergoes gastrectomy (upper midline incision). Our model predicted that patient A would have a 0.4% probability of developing POP, whereas patient B would have a 25.9% probability of developing POP; patient B's predicted probability of developing POP was 64.8 times greater than patient A's predicted probability.

Discussion

Our study identified five independent predictors of POP after major abdominal surgery: age, male sex, history of cerebrovascular disease, BI ≥ 900, and upper midline incision. Using the five variables, the nomogram that was devised showed a relatively good discrimination ability for predicting patients with a high probability of developing POP.

In line with a previous report [1], this study showed that the postoperative course of the patients who developed POP was worse than that of those who did not, likely because of the high rates of major complications other than pneumonia and mortality. The worse postoperative course may impair the health economics. Indeed, studies reported that the development of postoperative pneumonia was associated with a longer hospital stay and a higher hospital charges [33, 34]. Thus, perioperative intervention is important to prevent POP and to predict patients with a high probability of developing POP. Previous studies reported that smoking cessation, inspiratory muscle training, preoperative oral care, early postoperative mobilization, selective use of postoperative nasogastric decompression, epidural analgesia, and immunonutrition were effective for reducing the incidence of POP [10, 15, 16]. For the patients in this study, smoking cessation, oral care, and inspiratory muscle training were performed as routine preoperative interventions. Postoperatively, early mobilization, including walking around the ward with physical therapists, was encouraged on POD 1. Nonetheless, 5.3% of patients developed POP in this study. Given the poor prognosis of POP, patients with a high probability of developing POP should receive different perioperative management from patients with a low probability of developing POP. The use of immunonutrition is one potential approach to reducing the the probability of POP [35, 36]. Another approach is to improve the compliance by carefully monitoring patients before surgery; in our patients, the daily use of a portable inspiratory muscle training device was encouraged 1 month before surgery, but the actual compliance of the patients was not confirmed.

In this study, age, male sex, history of cerebrovascular disease, BI ≥ 900, and upper midline incision were the independent predictors of POP. The first three factors identified as predictors of POP in previous studies [6, 12–16]; however, upper midline incision has rarely been reported to increase the probability of POP after abdominal surgery [12, 37]. Moreover, the results of our multivariable logistic regression showed that the incidence of POP was associated with upper midline incision, rather than with the type of surgery. The reduction of lung vital capacity secondary to diaphragmatic dysfunction at 1 week after upper abdominal surgery, which was recently reported [38, 39], is most likely brought about by the wound pain from an upper midline incision. A decrease in diaphragmatic motion may limit pulmonary ventilation and the expansion of the lower part of the lungs. Thus, a nomogram was devised using these five factors. Our nomogram may be useful for preoperatively identifying patients with a high probability of developing POP and could be used to closely monitor and strictly apply evidence-based perioperative managements in cases involving such patients.

The present study was associated with several limitations. First, the present study was retrospective in nature and the number of patients in the POP group was relatively small, which may have weakened the analyses. Second, although we performed internal validation using bootstrapping with 100 resamples, the present study lacked robust external validation with an established nomogram. Thus, the results of this study and those of other groups should be validated by further analyses.

In conclusion, age, male sex, history of cerebrovascular disease, BI ≥ 900, and upper midline incision were independent predictors of POP in patients undergoing major abdominal surgery. A nomogram-type classification model based on these factors may be useful for predicting patients with a high probability of developing POP and may be convenient for nurses, other healthcare professionals, and doctors.

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Compliance with ethical standards

Conflict of interest The authors declare no conflicts of interest in association with the present study.

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