Nomogram for predicting mandatory ICU admission after gastrectomy for gastric cancer

Haoquan Huang, Zhixiao Han, Xia Liang, Yanni Fu, Zhongqi Liu, Minghui Cao

Department of Anesthesiology, Sun Yat-sen Memorial Hospital, Sun Yat-sen University, Guangzhou, China

Contributions: (I) Conception and design: H Huang, Z Han; (II) Administrative support: M Cao; (III) Provision of study materials or patients: H Huang, X Liang; (IV) Collection and assembly of data: Z Han, X Liang, Y Fu; (V) Data analysis and interpretation: H Huang, Z Han, Z Liu; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Minghui Cao. NO. 107 Yanjiang West Road, Yuexiu District, Guangzhou, China. Email: caomh@mail.sysu.edu.cn.

Background: This study aimed to identify risk factors that were associated with mandatory intensive care unit (ICU) admission after gastrectomy for gastric cancer. We then employed these risk factors to construct and validate a nomogram for predicting mandatory ICU admission after gastrectomy, which may identify those who require ICU indeed and improve ICU utilization.

Methods: A number of 999 gastric cancer patients undergoing gastrectomy from January 2010 to June 2019 were included in the retrospective study. Forty-three patients were classified into mandatory ICU admission groups, and the remaining 956 patients were allocated into the no need for ICU admission group. The candidate variables, including patient demographic characteristics, preoperative laboratory tests and surgical variables, were compared between the two groups. We then carried out univariate and multivariate logistic regression analyses to find out risk factors for mandatory ICU admission. In order to develop the predictive model, we used Akaike information criterion (AIC) to select risk factors via a step-down backward process from the multivariate regression model.

Results: A number of risk factors for mandatory ICU admission were identified and subsequently used to build the nomogram: age [odds ratio (OR), 1.03; 95% CI, 1.00–1.07; P=0.031], ASA status (III–IV *vs.* I–II: OR,1.74; 95% CI, 0.88–3.46; P=0.114), tumor size (OR, 1.28; 95% CI, 1.08–1.51; P=0.004), estimated blood loss (OR, 1.001; 95% CI, 1.000–1.001; P=0.082) as well as intraoperative transfusion (Yes *vs.* No: OR, 3.82; 95% CI, 1.87–7.82; P<0.001). C-index of the nomogram was 0.800, indicating good discrimination. Both Calibration curve and Hosmer-Lemeshow goodness-of-fit tests (P=0.128) showed that there was a high degree of agreement between the prediction and actual outcome.

Conclusions: A nomogram to predict mandatory ICU admission after gastrectomy for gastric cancer was constructed and validated. Clinicians could apply this predictive model to improve usage of limited ICU resources effectively.

Keywords: Intensive care unit (ICU) admission; gastrectomy; gastric cancer; nomogram

Introduction

As the fifth most common cancer, gastric cancer is the third leading cause of cancer death around the world (1). Gastrectomy is still the only option for curative treatment for gastric cancer (2). Even though gastrectomy has been performed for several decades (3,4) and surgical and anesthesia techniques have improved, postoperative morbidity and mortality remain high (5-8). Previous researches showed that the morbidity rate after gastrectomy was about 20% (6,9) and the 30-day mortality varies from 5.2% to 12.8% (5,6,9). Even the serious complications,

including septic shock and cardiac arrest, were reportedly to occur in 23.6% following gastrectomy for gastric cancer (5).

Once serious morbidity occurs, a part of these patients will require higher levels of postoperative surveillance and medical management, which may include transferring to intensive care unit (ICU). However, as there is high demand for close monitoring and supportive therapies for high-risk patients, ICU resources are relatively limited (10,11). One possible explanation is that a portion of patients admitted to ICU are only for surveillance purpose, which results in overlooking those who require intensive care in deed. In addition, ICU admission is a main driver of health care costs (12). Thus, in order to improve resource allocation and reduce costs, it is necessary to identify patients who may require mandatory ICU admission after gastrectomy for gastric cancer.

Previous studies have developed surgical Apgar score to predict postoperative ICU admission after general surgery (13,14). However, both of the previous studies have not distinguished mandatory ICU admission from unnecessary ICU admission. Mandatory ICU admission was defined as meeting at least one of the following criteria: acute respiratory failure, hemodynamic instability, using a variety of vasoactive drugs, maintenance of mechanical ventilation and reintubation. Unnecessary ICU admission was defined as immediately transferring to ICU after operation only for the purpose of surveillance and subsequently transferred to the general ward the day after operation. A previous study has found that age, American Society of Anesthesiologists (ASA) status, and duration of procedure were associated with unplanned ICU admission after surgery (12), which is classified as mandatory ICU admission. However, there is no study focusing on risk factors of mandatory ICU admission after gastrectomy. With regard to the scare ICU resources and the high risk of gastrectomy, there is a need to study the risk factors and develop a predictive model for mandatory ICU admission after gastrectomy for gastric cancer.

Nomogram is a practical tool for clinicians to predict each patient's outcome (15,16). This study aimed to identify risk factors for mandatory ICU admission and use them to develop a nomogram for predicting mandatory ICU admission after gastrectomy for gastric cancer.

We present the following article in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/apm-21-178).

Methods

Patients

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by Institutional Ethics Committee of Sun Yat-sen Memorial Hospital (NO. SYSEC-KY-KS-2020-185) and individual consent for this retrospective analysis was waived. All consecutive patients who underwent gastrectomy for pathological diagnosed gastric adenocarcinoma from January 2010 to June 2019 in Sun Yat-sen Memorial Hospital were extracted from the electronic database. Patients were excluded if they had one of the following features: under the age of 18, underwent gastrectomy previously, admitted to ICU preoperatively, had blood transfusion preoperatively, had neoadjuvant chemotherapy preoperatively, emergency surgery, palliative gastrectomy, had other synchronous cancers and missing data. Emergency surgery was an emergency operation carried out within 12 h after admitting to hospital or after the onset of associated symptoms. After selection, a total of 999 patients were eligible for analysis.

Data collection

Patient demographic characteristics including age, sex, weight, ASA status, Charlson comorbidity index (CCI) score as well as comorbidities were extracted. Preoperative laboratory examinations such as hemoglobin, platelet and albumin were also extracted. In addition, tumor size, location and stage were also included in this study. Surgery-related variables, such as type of gastrectomy, approach method, extragastric organ resection, estimated blood loss and operation time, were obtained from the database. Postoperative variables included intensive care unit (ICU) admission, postoperative length of stay, complications, Clavien-Dindo severity classification of complications and in-hospital mortality. The detailed definitions of variables are presented in Table S1.

Primary outcome

The primary outcome was mandatory ICU admission. Since there are no existing criteria for mandatory ICU admission after gastrectomy, we defined the mandatory ICU admission criteria in this study referring to the definition

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in other surgical fields (12,17), as well as the practice in our hospital. It was defined as meeting at least one of the following criteria: acute respiratory failure, hemodynamic instability, using a variety of vasoactive drugs, maintenance of mechanical ventilation and reintubation. These features highlighted the specific needs that can be only addressed in the ICU environment, which is consistent with the ICU admission guideline (18). Patients who were admitted to ICU postoperatively were classified into three subgroups: (I) unnecessary ICU admission group: patients immediately transferred to ICU only for the purpose of surveillance and subsequently transferred to the general ward the day after operation; (II) necessary ICU admission group: those admitted to ICU immediately postoperatively and met the requirement of mandatory ICU admission; (III) unplanned ICU admission group: those who admitted to general ward immediately postoperatively and transferred to ICU following the presence of emergent situations, such as sepsis shock and cardiac arrest, requiring intensive care. The mandatory ICU admission group included (II) necessary ICU admission group and (III) unplanned ICU admission group.

Statistical analysis

Univariate and multivariate logistic regression analyses were carried out to find out risk factors for mandatory ICU admission after gastrectomy. Only variables with P<0.02 were selected into the multivariate logistic regression analyses. Variance inflation factor (VIF) was employed to detect whether there was multicollinearity in multivariate logistic regression analysis. If VIF was above 10, the variable was considered to have multicollinearity.

The Akaike information criterion (AIC) was used to choose risk factors from the full multivariate regression model. Specifically, AIC is a selection criterion that creates the best-fit model which explains the greatest amount of variation using the fewest possible independent variables. Subsequently, we incorporated the selected variables into the nomogram to predict mandatory ICU admission after gastrectomy.

The concordance index (C-index) was employed to evaluate the discrimination of nomogram. And then a calibration curve was used to estimate the calibration through utilizing 1,000 bootstrap resamples.

The t-test or the Mann-Whitney U-tests was employed to assess the continuous variables according to the normality of variables. The chi-square test or the Fisher exact test

was used to assess the categorical variables according to the frequencies of variables. All statistical analyses were performed through R software version 3.4.2 (Institute for Statistics and Mathematics, Vienna, Austria; https://www.r-project.org/), and a two-tailed P value <0.05 was considered to be statistically significant.

Results

Patients' baseline characteristics

A total of 999 gastric cancer patients with gastrectomy were eligible for the analysis. Among the 999 patients, 956 (95.7%) patients were in the no need for ICU admission group and 43 (4.3%) patients were in the mandatory ICU admission group (*Figure 1*). Specifically, the patients in the unplanned ICU admission within 3 days after operation group were transferred to ICU on postoperative day 3.0 (2.0–10.0). The reason, the postoperative day of transferring to ICU and the length of ICU stay in unplanned ICU admission group were listed in *Table 1*. Among the 25 patients, eight of them admitted to ICU after reoperation for intraabdominal bleeding [length of ICU stay: 3.5 (3.0–4.75) days], seven of them were admitted due to the pulmonary infection [3.0 (3.0–4.5) days], four of them were transferred to ICU due to sepsis [9.0 (8.0–10.75) days].

Table 2 displayed all variables stratified by the ICU status. Patients in the mandatory ICU admission group were prone to be older [median age in patients with transfusion 69.0 (61.5–74.0) *vs.* 59.0 (51.0–66.0) years in those without; P<0.001], to have higher ASA status (ASA III–IV: 65.1% *vs.* 35.5%; P<0.001) and higher CCI scores (CCI ≥4: 81.4% *vs.* 50.6%; P<0.001). The size of tumor in the mandatory ICU group were significantly greater than the one in the no need for ICU admission group [5.86 (4.31–7.11) *vs.* 4.62 (2.98–6.38) cm; P=0.005]. Moreover, patients in the mandatory ICU admission group were more likely to have extragastric organ resection (30.2% *vs.* 13.2%; P=0.003). Regarding preoperative laboratory tests, patients in the mandatory ICU group had lower hemoglobin level {110 [88–139] *vs.* 124 [102–139] g/L; P<0.001}. With regard to surgical and postoperative variables, patients in the mandatory ICU group had more estimated blood loss {200 [100–400] *vs.* 100 [100–200] mL; P<0.001} and were more likely to have intraoperative transfusion (53.5% *vs.* 26.6%; P=0.003). Compared to those in the no ICU admission group, the amount of total fluid was similar {2,250 [2,000–2,750] *vs.* 2,000 [1,750–2,500] mL; P=0.135} and
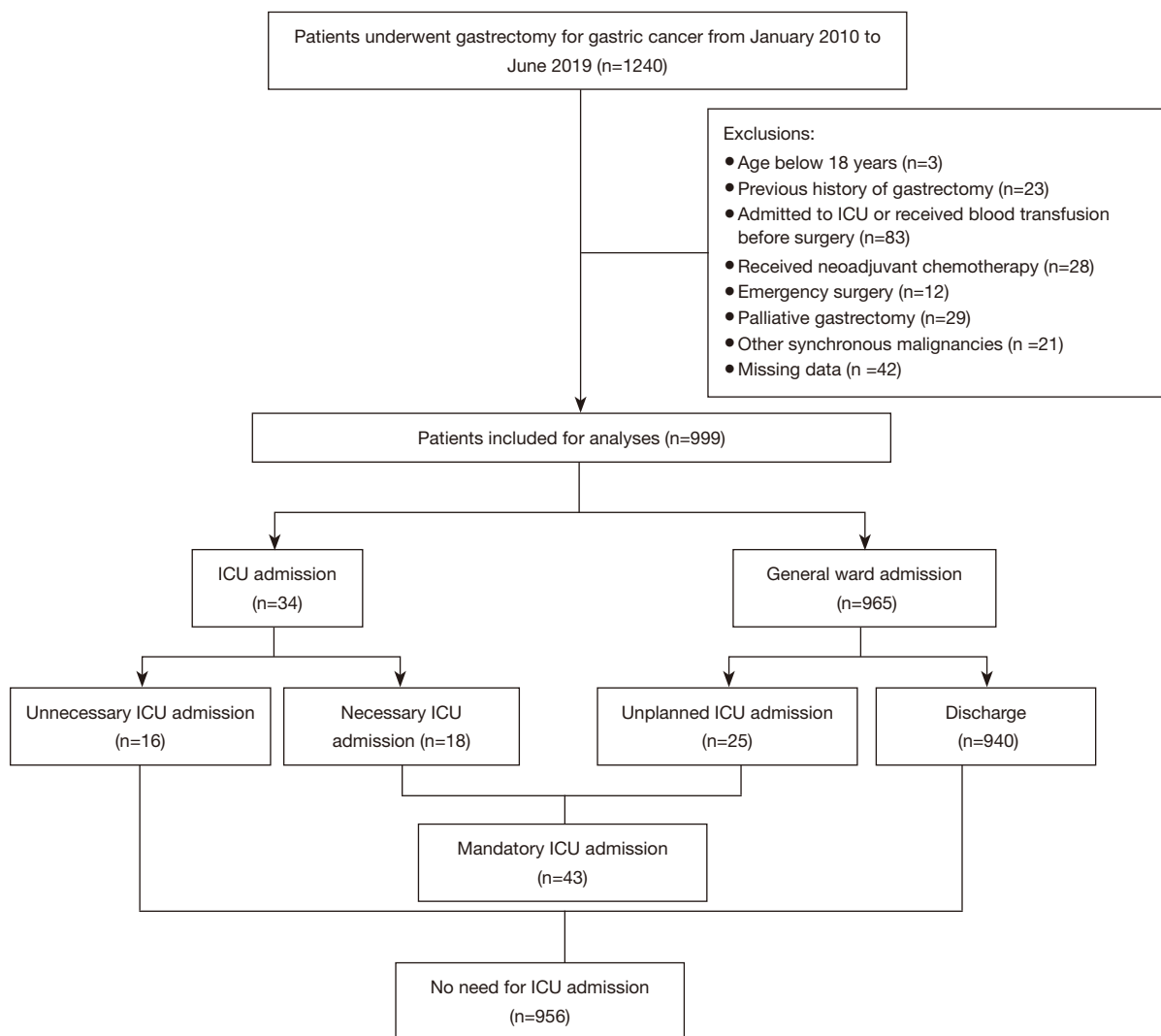
Figure 1 Flowchart of patient selection.

the intraoperative infusion rate was faster [10.1 (8.06–12.5) vs. 9.22 (6.87–11.8) mL/kg/h; P=0.068] in patients with mandatory ICU admission. In addition, patients in the mandatory ICU group had longer postoperative length of stay [17.0 (11.5–27.0) vs. 12.0 (9.0–15.0) days; P<0.001], more complications (30.2% vs. 11.1%; P<0.001) and higher mortality rate (16.3% vs. 0.3%; P<0.001). When it comes to the severity classification of complications, patients with mandatory ICU admission were more likely to have severer complications (grade III or greater: 23.2% vs. 4.4%, P<0.001).

Incidences of abscess, ileus, anastomotic leakage, intestinal obstruction, intraabdominal bleeding, pulmonary infection, pleural effusion, pulmonary failure and cardiac

failure were significantly higher in the mandatory ICU admission group, compared to the no need for ICU admission group (*Table 3*).

Univariate and multivariate analysis

Table 4 displayed the univariate and multivariate analyses. In univariate analyses, age, ASA status, CCI score, tumor size, extragastric organ resection, preoperative hemoglobin, preoperative albumin level, estimated blood loss and intraoperative transfusion were significantly associated with mandatory ICU admission in gastric patients undergoing gastrectomy. In AIC-based multivariate analysis, age, ASA status, tumor size, estimated blood loss and intraoperative

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Table 1 Reason, the postoperative day of transferring to ICU and the length of ICU stay in unplanned ICU admission group

ICU type	Reason	The postoperative day of transferring to ICU	Length of ICU stay (days), median [Q1, Q3]
Unplanned ICU admission (n=25)		3.0 [2.0, 10.0]	4.0 [3.0, 8.0]
	Reoperation for intraabdominal bleeding (n=8)	5.5 [2.0, 9.75]	3.5 [3.0, 4.75]
	Pulmonary infection (n=7)	5.0 [2.5, 8.5]	3.0 [3.0, 4.5]
	Pleural effusion (n=2)	6.0*	10.5*
	Pneumothorax (n=1)	2.0*	9.0*
	Renal failure (n=1)	2.0*	9.0*
	Cardiac failure (n=2)	1.0*	8.0*
	Sepsis (n=4)	9.5 [4.25, 13.25]	9.0 [8.0, 10.75]

*, shown as median without [Q1, Q3] due to the limited sample size.

transfusion were found out to be independent risk factors for mandatory ICU admission in gastric patients undergoing gastrectomy.

Construction and validation of nomogram

The identified risk factors in AIC-based multivariate analysis were employed to construct the nomogram to predict mandatory ICU admission for gastric cancer surgery (*Figure 2*).

The C-index of the nomogram was 0.800, indicating high accuracy in predicting the risk of mandatory ICU admission. The C-indexes for each risk factor employed in the nomogram were shown in *Table 5*. While age had the strongest prediction ability with C-index 0.728, tumor size had the lowest C-index 0.626. Calibration curve was employed to assess the calibration (*Figure 3*). What's more, P values for the Hosmer-Lemeshow goodness-of-fit test was 0.128. Both the calibration curve and the Hosmer-Lemeshow goodness-of-fit test showed that there was a high degree of agreement between the prediction and actual outcome.

Discussion

Gastrectomy is the only option for curative treatment for gastric cancer. Due to its significant morbidity, ICU admission is needed in a part of cancer patients with gastrectomy. In this study, 4.3% of total patients were in the mandatory ICU admission group. This study demonstrated that age, ASA status, tumor size, estimated blood loss and intraoperative transfusion were independent risk factors for predicting mandatory ICU admission after gastric cancer surgery. Communication between surgeons, anesthesiologists and intensivists is essential to improve utilization of ICU resources. The nomogram developed in this study could be served as an easy-to-use tool to screen those who may require mandatory ICU admission after gastric cancer surgery.

There are several differences between our study and previous studies about predicting ICU admission after surgery (15,18). Firstly, a study by Sobol *et al.* merely focused on immediate ICU admission after high-risk intraabdominal surgery (13). In this study, while 41.9% of patients with mandatory ICU admission admitted immediately after surgery, 58.1% transferred to ICU from general ward (*Figure 1*). This result suggested that unplanned ICU admission after gastrectomy accounted for a large part of ICU admission. Thus, unplanned ICU admission should be taken into account when developing a predictive tool for ICU admission postoperatively. Secondly, a study by Glass *et al.* included both immediate ICU admission patients and unplanned ICU admission patients (14). However, among patients with immediate ICU admission, this previous study has not distinguished between necessary and unnecessary ICU admission. In contrast, unnecessary ICU admission was defined as no need for ICU admission in this study, since it was only for surveillance purpose and subsequently resulted in overlooking those who require intensive care in deed. Thirdly, both of the previous studies

Table 2 Patient characteristics

Characteristics	No ICU admission (n=956)	Mandatory ICU admission (n=43)	P
Age (years)			
Median [Q1, Q3]	59.0 [51.0, 66.0]	69.0 [61.5, 74.0]	<0.001[†]
Sex			
Female	324 (33.9%)	13 (30.2%)	0.740*
Male	632 (66.1%)	30 (69.8%)	
Weight (kg)			
Median [Q1, Q3]	58.0 [51.0, 65.0]	56.0 [50.0, 60.0]	0.306[†]
ASA status			
I–II	617 (64.5%)	15 (34.9%)	<0.001*
III–IV	339 (35.5%)	28 (65.1%)	
CCI score			
0–3	472 (49.4%)	8 (18.6%)	<0.001*
≥4	484 (50.6%)	35 (81.4%)	
Comorbidities			
No	772 (80.8%)	30 (69.8%)	0.115*
Yes	184 (19.2%)	13 (30.2%)	
Tumor size (cm)			
Median [Q1, Q3]	4.62 [2.98, 6.38]	5.86 [4.31, 7.11]	0.005[†]
Tumor location			
Upper	115 (12.0%)	5 (11.6%)	0.900*
Middle	269 (28.1%)	14 (32.6%)	
Lower	537 (56.2%)	22 (51.2%)	
Diffuse	35 (3.7%)	2 (4.7%)	
cTNM stage			
I	207 (21.6%)	8 (18.6%)	0.890*
II	215 (22.5%)	10 (23.3%)	
III	534 (55.9%)	25 (58.1%)	
LN dissection			
D1/D1+	154 (16.1%)	7 (16.3%)	1.000*
D2/D2+	802 (83.9%)	36 (83.7%)	
Type of gastrectomy			
Total	258 (27.0%)	14 (32.6%)	0.530*
Subtotal	698 (73.0%)	29 (67.4%)	
Approach method			
Laparoscopy	357 (37.3%)	12 (27.9%)	0.275*
Open	599 (62.7%)	31 (72.1%)	
Extragastric organ resection			
No	830 (86.8%)	30 (69.8%)	0.003*
Yes	126 (13.2%)	13 (30.2%)	

Table 2 (*continued*)

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Table 2 (*continued*)

Characteristics	No ICU admission (n=956)	Mandatory ICU admission (n=43)	P
Preoperative hemoglobin (g/L)			
Median [Q1, Q3]	124 [102, 139]	110 [88, 139]	<0.001[†]
Preoperative INR			
Median [Q1, Q3]	1.01 [0.960, 1.06]	1.02 [0.970, 1.08]	0.414[†]
Preoperative platelet (×10^9/L)			
Median [Q1, Q3]	260 [210, 314]	268 [220, 312]	0.686[†]
Preoperative albumin (g/L)			
Median [Q1, Q3]	39.6 [36.2, 42.7]	39.3 [32.7, 42.6]	0.145[†]
Estimated blood loss (mL)			
Median [Q1, Q3]	100 [100, 200]	200 [100, 400]	<0.001
Intraoperative transfusion			
No	702 (73.4%)	20 (46.5%)	0.003*
Yes	254 (26.6%)	23 (53.5%)	
Total fluid (mL)			
Median [Q1, Q3]	2,000 [1,750, 2,500]	2,250 [2,000, 2,750]	0.135[†]
Total crystalloid (mL)			
Median [Q1, Q3]	1,250 [1,000, 1,500]	1,000 [1,000, 1,500]	0.058[†]
Total colloid (mL)			
Median [Q1, Q3]	1,000 [500, 1,030]	1,000 [1,000, 1,500]	<0.001[†]
Intraoperative infusion rate (mL/kg/h)			
Median [Q1, Q3]	9.22 [6.87, 11.8]	10.1 [8.06, 12.5]	0.068[†]
Operation time (min)			
Median [Q1, Q3]	240 [195, 291]	242 [208, 268]	0.894[†]
Postoperative length of stay (days)			
Median [Q1, Q3]	12.0 [9.00, 15.0]	17.0 [11.5, 27.0]	<0.001[†]
Complications			
No	850 (88.9%)	30 (69.8%)	<0.001*
Yes	106 (11.1%)	13 (30.2%)	
Clavien-Dindo severity classification of complications			
None	850 (88.9%)	30 (69.8%)	<0.001*
Grade II	64 (6.7%)	3 (7.0%)	
Grade III or greater	42 (4.4%)	10 (23.2%)	
In hospital mortality			
No	953 (99.7%)	36 (83.7%)	<0.001*
Yes	3 (0.3%)	7 (16.3%)	

*, chi-squared test or Fisher exact test; [†], Mann-Whitney U test. ASA status, the American Society of Anesthesiologists physical status; CCI, Charlson comorbidity index; cTNM stage, Clinical Tumor-Lymph Node-Metastasis; LN dissection, lymph node dissection; INR, international normalized ratio; ICU, intensive care unit.

Table 3 Comparison of complications between no need for ICU admission group and mandatory ICU admission group

Complication type	No need for ICU admission (n=956)	Mandatory ICU admission (n=43)	P*
Surgical complication, n (%)			
Wound infection	22 (2.3)	2 (4.7)	0.277
Stenosis	17 (1.8)	1 (2.3)	0.550
Abscess	12 (1.3)	4 (9.3)	0.004
Ileus	5 (0.5)	2 (4.7)	0.033
Anastomotic leakage	1 (0.1)	2 (4.7)	0.005
Intestinal obstruction	1 (0.1)	2 (4.7)	0.005
Pancreatitis	1 (0.1)	1 (2.3)	0.084
Intraabdominal bleeding	2 (0.2)	8 (18.6)	<0.001
Medical complication, n (%)			
Pulmonary infection	3 (0.5)	12 (27.9)	<0.001
Pleural effusion	3 (0.3)	2 (4.7)	0.017
Pulmonary failure	1 (0.1)	4 (9.3)	<0.001
Cardiac failure	0 (0)	2 (4.7)	0.002
Renal failure	2 (0.2)	1 (2.3)	0.124
Urinary retention	1 (0.1)	0 (0)	1.000
Stroke	3 (0.3)	1 (2.3)	0.162
Others	5 (0.5)	1 (2.3)	0.233

*, calculated by Fisher exact test.

merely included intraoperative factors such as heart rate, mean arterial blood pressure and estimated blood loss as predictive variables for ICU admission. On the contrary, preoperative and intraoperative factors were employed to identified risk factors for mandatory ICU admission in this study. The C-indexes for preoperative factors such as age and ASA status were even greater than the intraoperative transfusion. This result indicated that preoperative factors were as important as intraoperative factors for predicting mandatory ICU admission after gastrectomy for gastric cancer.

Previous studies have shown that advanced age and ASA classification were independent risk factors for mortality and morbidity after gastrectomy (6,19,20). In this study, age and ASA status were significantly associated with increased risk of mandatory ICU admission. In addition, age had the highest C-index compared to other variables in this study, indicating that age played a major role in predicting mandatory ICU admission after gastrectomy.

In our study, patients with mandatory admission were associated with more complications, which is consistent with previous findings (21-23). Pulmonary complications were the main reason for unplanned ICU admission. Additionally, pulmonary complications were one of the most common complications following gastrectomy (6,24). Thus, early identification and prevention of pulmonary complications is needed in terms of improving postoperative outcomes and reducing risk of unplanned ICU admission after gastrectomy.

There are several limitations in this study. Firstly, the nomogram has inherent limitations because it was based on a retrospective study using database from a single hospital. In view of this point, it is necessary to carry out a multicenter prospective cohort study to verify the results in this study. Secondly, this study merely focused on patients with malignancy. To develop a generalized predictive model, patients requiring gastrectomy for benign diseases will be included in our future study.

Table 4 Univariable and multivariable logistic regression analysis of factors associated with mandatory ICU admission

Characteristics	Univariable logistic regression*		Multivariable logistic regression		AIC-based multivariable logistic regression	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Age (years)	1.08 (1.05–1.11)	<0.001	1.04 (0.99–1.08)	0.096	1.03 (1.00–1.07)	0.031
Sex						
Female	Reference		–		–	
Male	1.18 (0.62–2.38)	0.620	–	–	–	–
Weight (kg)	0.99 (0.96–1.02)	0.436	–	–	–	–
ASA status						
I–II	Reference		Reference		Reference	
III–IV	3.40 (1.82–6.61)	<0.001	1.75 (0.87–3.51)	0.117	1.74 (0.88–3.46)	0.114
CCI score						
0–3	Reference		Reference		–	
≥4	4.27 (2.06–9.98)	<0.001	0.91 (0.31–2.60)	0.853	–	–
Comorbidities						
No	Reference		–		–	
Yes	1.82 (0.90–3.48)	0.081	–	–	–	–
Tumor size (cm)	1.26 (1.08–1.49)	0.005	1.28 (1.08–1.51)	0.004	1.28 (1.08–1.51)	0.004
Tumor location						
Upper	Reference		–		–	–
Middle	1.20 (0.45–3.77)	0.736	–	–	–	
Lower	0.94 (0.38–2.86)	0.906	–	–	–	
Diffuse	0.75 (0.18–6.39)	0.750	–	–	–	
cTNM stage						
I	Reference		–		–	
II	1.26 (0.49–3.36)	0.631	–	–	–	
III	1.32 (0.61–3.16)	0.507	–	–	–	
LN dissection						
D1/D1+	Reference		–		–	
D2/D2+	0.99 (0.46–2.46)	0.976	–	–	–	–
Type of gastrectomy						
Total	Reference		–		–	
Subtotal	0.77 (0.41–1.51)	0.423	–	–	–	–
Approach method						
Laparoscopy	Reference		–		–	
Open	1.54 (0.80–3.15)	0.213	–	–	–	–

Table 4 (*continued*)

Table 4 (*continued*)

Characteristics	Univariable logistic regression*		Multivariable logistic regression		AIC-based multivariable logistic regression	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Extragastric organ resection						
No	Reference		Reference		–	
Yes	2.85 (1.41–5.51)	0.002	1.42 (0.63–3.17)	0.398	–	–
Preoperative hemoglobin (g/L)	0.99 (0.98–1.00)	0.020	–	–	–	–
Preoperative INR	7.87 (0.37–96.5)	0.139	–	–	–	–
Preoperative platelet (×10⁹/L)	1.002 (0.999–1.004)	0.255	–	–	–	–
Preoperative albumin (g/L)	0.93 (0.88–0.98)	0.011	1.01 (0.95–1.07)	0.870	–	–
Estimated blood loss (mL)	1.001 (1.000–1.002)	0.005	1.001 (1.000–1.001)	0.182	1.001 (1.000–1.001)	0.082
Intraoperative transfusion						
No	Reference		Reference			
Yes	3.12 (1.72–5.93)	<0.001	3.83 (1.84–7.98)	<0.001	3.82 (1.87–7.82)	<0.001
Intraoperative infusion rate (mL/kg/h)	1.06 (0.98–1.13)	0.115	–	–	–	–
Operation time (mins)	1.001 (0.997–1.005)	0.481	–	–	–	–

*, performed with each single variable with different classifications. ASA status, the American Society of Anesthesiologists physical status; CCI, Charlson comorbidity index; cTNM stage, Clinical Tumor-Lymph Node-Metastasis; LN dissection, lymph node dissection; INR, international normalized ratio; ICU, intensive care unit.
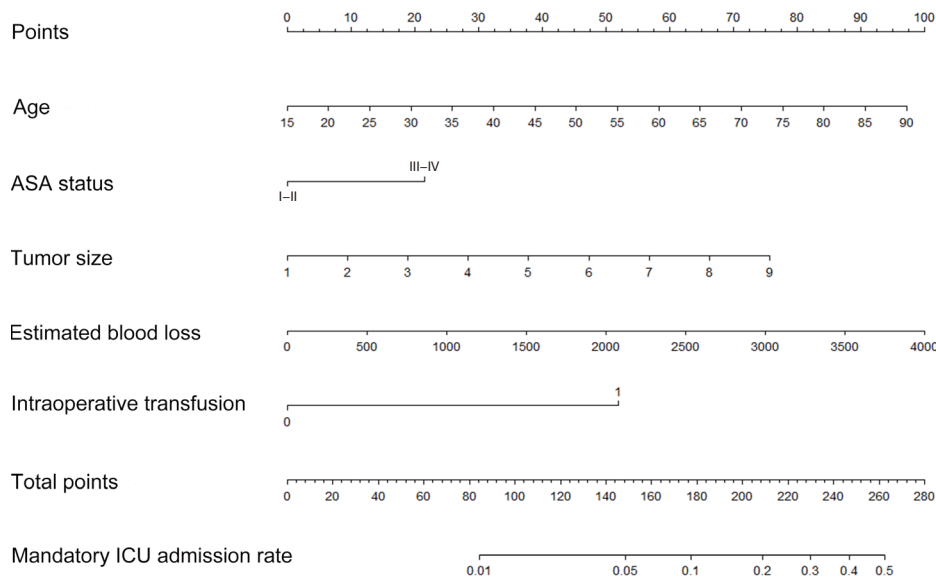
Figure 2 Nomogram predicting the probability of mandatory ICU admission after gastrectomy for gastric cancer. ASA status, the American Society of Anesthesiologists physical status.

Table 5 C-index for nomogram and each predictor of the nomogram

Predictor	C-index
Nomogram	0.800
Age	0.728
Estimated blood loss	0.681
ASA status	0.648
Intraoperative transfusion	0.635
Tumor size	0.626

ASA, American Society of Anesthesiologists.
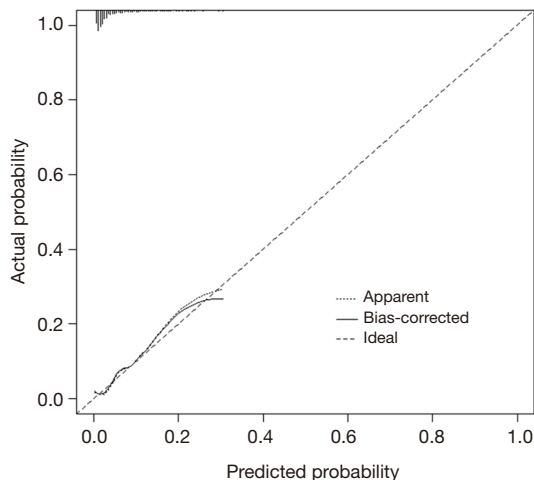
Figure 3 Calibration curve of the nomogram.

Conclusions

In this study, a nomogram was developed and validated to predict the probability of mandatory ICU admission after gastric cancer surgery. Appropriate use of the nomogram in this study may identify those who require ICU indeed, improving patient safety and ICU utilization.

Acknowledgments

Footnote

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Table S1 Definitions of variables

Variables	Definitions
Sex	Male or female
Age	In years
Weight	Most recent value measured before the surgery
ASA status	1-5 recorded in the database
CCI score	Calculated based on the CCI scoring system
Comorbidities	
Hypertension	History of hypertension requiring anti-hypertensive medication
Diabetes	A diagnosis of diabetes requiring oral medication or insulin
Coronary heart disease	Documented in the patient's chart and confirmed by preoperative ultrasonic cardiogram, electrocardiogram and myocardial enzyme
Stroke	History of stroke recorded in the database
COPD	A diagnosis of COPD based on the preoperative pulmonary function test
Others	Included chronic kidney disease and liver disease
Tumor size	Recorded in the database
Tumor location	Categorized into upper, middle, lower and diffuse stomach recorded the database
cTNM stage	Clinical TNM stage was based on the images of enhanced scan of Multi-detector computed tomography.
Type of gastrectomy	Categorized into total gastrectomy or subtotal gastrectomy according to procedure name recorded in the database
Total gastrectomy	Defined as total gastric resection with gastrointestinal reconstruction
Subtotal gastrectomy	Included distal gastrectomy and proximal gastrectomy, and excluded wedge non-anatomic gastric resection
LN dissection	Categorized into D1/D1+ or D2/D2+ according to the procedure name recorded in the database
Approach method	Documented in the database
Extragastric organ resection	Performed due to tumor invasion into adjacent structures or simultaneous resection of other organs because of benign disease. Included splenectomy, cholecystectomy, partial pancreatectomy, partial colectomy
Preoperative haemoglobin (g/L)	Most recent value measured before surgery
Preoperative INR	Most recent value measured before surgery
Preoperative platelet (×10^9/L)	Most recent value measured before surgery
Preoperative albumin (g/L)	Documented in the database
Estimated blood loss	The sum of crystalloid and colloid infused during surgery
Total fluid (mL)	
Total crystalloid	Documented in the database
Total colloid	Documented in the database
Intraoperative infusion rate (ml/kg/h)	The volume of fluid infusion per kilogram of body weight per hour.
Operation time (min)	From skin incision to skin closure
ICU admission	Postoperatively admitted to ICU
Unnecessary ICU admission	Those who were admitted to ICU immediately postoperatively only for surveillance purpose and subsequently transferred to the general ward the day after surgery
Necessary ICU admission	Those admitted to ICU immediately postoperatively and met the requirement of mandatory ICU admission
Unplanned ICU admission group	Those who admitted to general ward immediately postoperatively and transferred to ICU following the presence of emergent situations, such as sepsis shock and cardiac arrest, requiring intensive care
Mandatory ICU admission group	Included the necessary ICU admission group and the unplanned ICU admission group
Postoperative length of stay (days)	From the surgery to discharge from the hospital
Complications	Documented in the database and included medical complications and surgical complications
Medical complications	Included pulmonary, renal, urinary, cardiac and neurologic problems
Surgical complications	Included wound infection, stenosis, abscess, ileus, anastomotic leakage, intestinal obstruction, pancreatitis and intraabdominal bleeding
Clavien-Dindo severity classification of complications	Based on the Clavien–Dindo severity classification of complications. Grade 1 complications were not included for further analysis due to their litter clinical relevance, whereas grade 2 or greater complications requiring medical or surgical interventions were included.
In hospital mortality	Death during the hospital stay for the surgery

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