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Research Paper

Predictors of emergency abdominal surgery for patients aged 90 years or older: A retrospective study

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ABSTRACT

Background: With the aging of the population, more and more patients ≥90 years old are undergoing surgery. We retrospectively examined factors affecting morbidity and in-hospital mortality among patients ≥90 years old who underwent emergency abdominal operations.

Materials and methods: Forty-six cases of emergency abdominal surgery for patients ≥90 years old who underwent surgery at our hospital between 2011 and 2022 were included in this study. Factors affecting morbidity and in-hospital mortality were analyzed statistically. Physiological and operative severity score for the enumeration of mortality and morbidity (POSSUM)-predicted morbidity and Portsmouth-POSSUM (P-POSSUM)-predicted mortality were calculated.

Results: Postoperative complications occurred in 30 patients (65.2 %) and 5 patients (10.8 %) died in the hospital. Factors affecting morbidity included American Society of Anesthesiologists physical status score, operative time and blood loss, and operative severity score. Multivariate analysis identified male sex, operative severity score, and length of hospital stay as factors affecting morbidity. Eastern Cooperative Oncology Group performance status and physiological score were identified as factors influencing mortality in hospital, and only physiological score was identified in the multivariate analysis. Area under the receiver operating characteristic (ROC) curve for POSSUM-predicted morbidity was 0.796 and area under the ROC curve for P-POSSUM-predicted mortality was 0.805, both of which were moderately accurate.

Conclusion: Risk of emergency abdominal surgery in patients ≥90 years old may be predictable to some extent, and we are able to provide convincing explanations to patients and families based on these data.

Introduction

According to statistics from the Ministry of Health, Labour and Welfare in Japan, the population ≥ 90 years old accounts for about 2 % of the total population, and the average life expectancy at 90 years old is 4.38 years for men and 5.74 years for women [1]. Merely being older is not considered a reason to avoid surgery. However, in a study of the proportion of patients undergoing surgical procedures in the last year of life, 33 % of individuals in their 80s underwent surgery, compared to 23.6 % of individuals in their 90s. The authors concluded that postoperative complications were more frequent among patients ≥90 years old, and the benefit may be judged as less [2].

Few case studies of abdominal surgery in patients ≥90 years old have been reported. Based on those cases, the mortality rate with elective surgery ranged from 0 % to 9.6 %, while that in emergency surgery was very high, ranging from 8.3 to 35% [3–11]. In addition, postoperative complications and mortality rates increase with age, and the risk of surgery is said to increase with advancing age [12]. When surgery is the only life-saving option, the decision regarding whether to perform the operation is often difficult in patients ≥90 years old because of their very old age. Understanding the characteristics of patients ≥90 years old would be of great help in deciding indications for surgery and providing explanations to their families before and after surgery. We therefore retrospectively analyzed emergency abdominal surgery cases in our hospital for patients ≥90 years old, and investigated the characteristics of these cases and factors affecting mortality and complication rates.

Material and methods

Forty-six patients ≥90 years old who underwent emergency

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abdominal surgery at our hospital between 2011 and 2022 were included in the study. Emergency surgery was defined as a case performed within approximately 24 h of the decision to operate. Preoperative status was classified by American Society of Anesthesiologists (ASA) physical status score and Eastern Cooperative Oncology Group performance status (ECOG-PS). Postoperative complications were classified according to the Clavien–Dindo (CD) classification, with patients showing CD ≥2 classified as having postoperative complications. Factors affecting the occurrence of complications and in-hospital death were statistically analyzed.

Pre- and postoperative explanations were basically given to the individual patient, but in cases where the patient had impaired cognitive abilities or it was difficult for the patient to listen to the explanation due to pain or other symptoms when coming to the hospital, explanations were given to the family and consent for the surgery was obtained. Explanations about postoperative conditions were also given to family members. Our hospital serves as an emergency and critical care center in this region and patients who wish to receive aggressive treatment, including surgery, are transported to our hospital. Only one patient did not wish to undergo surgery during this period, after preoperative explanations were provided.

Predicted morbidity was calculated using Physiological and Operative Severity Score for the enumeration of Mortality and morbidity (POSSUM) [13], and predicted mortality was calculated using Portsmouth-POSSUM (P-POSSUM) [14]. POSSUM-predicted morbidity was calculated by applying the following formula to the 12-item physiologic score (PhS) and the 6-item operative severity score (OSS): $\ln[R/(1\text{-}R)] = -5.91 + (0.61 \times \text{PhS}) + (0.91 \times \text{OSS})$, where R is the predicted risk of morbidity. P-POSSUM-predicted morality was calculated by applying the following formula: $\ln[R/(1\text{-}R)] = -9.065 + (0.1692 \times \text{PhS}) + (0.1550 \times \text{OSS})$, where R is the predicted risk of mortality.

Numerical data are expressed as median and interquartile range, with the Mann–Whitney *U* test used for analyzing the difference in medians between two groups and Fisher's exact test for the difference in proportions between groups. Logistic regression analysis was used for multivariate analysis and the stepwise reduction method was used for variable selection. For POSSUM-predicted morbidity and P-POSSUM-predicted mortality, receiver operating characteristic (ROC) curves were created and areas under the ROC curves were calculated to evaluate accuracy.

All statistical analyses were performed using EZR version 1.54 (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (version 4.1.0, The R Foundation for Statistical Computing, Vienna, Austria). More precisely, EZR is a modified version of R Commander designed to add statistical functions frequently used in biostatistics [15].

Results

Between 2011 and 2022, emergency abdominal surgery was performed on 588 patients in our hospital, with 281 patients <65 years old, 261 patients ≥65 years old but <90 years old and 46 patients ≥90 years old (Table 1). The number of patients with acute appendicitis was very high in the <65 years old group and differed significantly from the other two groups; a comparison between the ≥65 year older but <90 years old group and the ≥90 years old group showed a higher frequency of small bowel ileus in the ≥90 years old group. Otherwise, the composition of patients was generally similar. The number of postoperative deaths was 0 within 30 days and 1 death later than 30 days among patients <65 years old; 9 deaths within 30 days and 10 deaths later than 30 days among patients ≥65 years old but <90 years old; and 1 death within 30 days and 4 deaths later than 30 days among patients ≥90 years old. The in-hospital mortality rate was 0.3 % for patients <65 years old, 7.2 % for patients ≥65 years old but <90 years old; and 10.8 % for patients ≥90 years old. The in-hospital mortality rate was significantly lower for patients <65 years old than for patients ≥65 years older but <90 years old and patients ≥90 years old ($p = 0.0000087$ and $p = 0.00024$, respectively). Similarly, no significant difference in in-hospital mortality rates was evident between patients ≥65 years old but <90 years old and those ≥90 years old ($p = 0.378$).

Table 1
Emergency abdominal surgery (2011−2022).

Diagnosis	Age group		
	<65 years (in-hospital death)	≥65 but <90 years (in-hospital death)	≥90 years (in-hospital death)
Small bowel obstruction	19	50 (1)	16 (1)
Large bowel obstruction	10 (1)	26 (2)	5
Perforation of upper digestive tract	16	31 (5)	4 (2)
Perforation of lower digestive tract	20	66 (10)	12 (2)
Appendicitis	180	25	4
Hernia intussusception	14	17	4
Acute cholecystitis	6	23	0
Other	16	24 (1)	1
Total	281 (1)	261 (19)	46 (5)
In-hospital mortality	0.3	7.2	10.8

Patients comprised 16 male patients and 30 female patients, with a mean age of 93.6 years (range, 90–101 years). Diagnoses at surgery included 16 cases of small bowel ileus, 5 cases of large bowel ileus, 4 cases of upper gastrointestinal perforation, 12 cases of lower gastrointestinal perforation, 4 cases of appendicitis, 4 cases of hernia insertion, and 1 case of gastrointestinal bleeding. All patients showed some preoperative comorbidities, including hypertension in 33 cases, cardiovascular disease in 18 cases, cerebrovascular disease in 10 cases, pulmonary disease in 2 cases, and dementia in 10 cases. Eight cases were associated with malignancy.

Thirty cases showed complications with CD ≥2. Table 2 shows the results of statistical analysis of factors affecting the occurrence of postoperative complications. In univariate analysis, male sex and ASA ≥3 were associated with the risk of complications. On the other hand, the presence of preoperative comorbidities had no effect on the occurrence of postoperative complications. Diagnosis at surgery also had no effect on the occurrence of postoperative complications. Significant differences were identified in operative time, blood loss, length of hospital stay, PhS, OSS, and POSSUM-predicted morbidity between patients with and without complications. Multivariate analysis of these factors identified male sex, OSS, and length of hospital stay as factors influencing the occurrence of complications.

In this study, five in-hospital deaths were encountered, including one death within 30 days. Statistical analysis of factors influencing in-hospital mortality is presented in Table 3. In univariate analysis, ECOG-PS was identified as a factor affecting mortality. PhS and P-POSSUM-predicted mortality differed significantly between survivors and non-survivors. Multivariate analysis identified only PhS as a factor affecting mortality.

The ROC curves for POSSUM-predicted morbidity and P-POSSUM-predicted mortality are shown in Figs. 1 and 2. The ROC curve for POSSUM-predicted morbidity showed that a threshold value of 0.577 resulted in a specificity of 0.625, a sensitivity of 0.867, and an area under the ROC curve of 0.796 (95 % confidence interval, 0.663–0.929), indicating moderate accuracy. The ROC curve for P-POSSUM-predicted mortality showed that a threshold value of 0.148 offered a specificity of 0.805, a sensitivity of 0.800, and an area under the ROC curve of 0.805 (95 % confidence interval, 0.572–1), indicating moderate accuracy.

Discussion

With the aging of the population, performing abdominal surgery for patients ≥90 years old is no longer uncommon. Independent of

Table 2
Analysis of factors affecting postoperative complications.

Univariate analysis				
Variable		Non-postoperative complications ($n = 16$)	Postoperative complications ($n = 30$)	*P*-value
Age, years		94.5 (92.7–96)	92.5 (90.2–96)	0.217
Sex	Male	2	14	0.004
	Female	17	13	
ASA physical status score	≤2	10	8	0.027
	>2	6	22	
ECOG-PS	0 or 1	8	12	0.263
	2 or 3	7	10	
	4	1	8	
Preoperative comorbidities				
Hypertension	Yes	12	21	1.000
	No	4	9	
Heart disease	Yes	5	13	0.533
	No	11	17	
Respiratory disease	Yes	0	2	0.536
	No	16	25	
Cerebrovascular disease	Yes	3	7	1.000
	No	13	23	
Dementia	Yes	2	8	0.455
	No	14	22	
Malignancy	Yes	1	7	0.230
	No	15	23	
Diagnosis				0.160
Small bowel obstruction		5	11	
Large bowel obstruction		1	4	
Perforation of upper digestive tract		2	2	
Perforation of lower digestive tract		2	10	
Appendicitis		3	1	
Hernia intussusception		3	1	
Gastrointestinal bleeding		0	1	
Operative time (min)		73.5 (46.5–88)	124 (83.7–175)	0.005
Blood loss (ml)		0 (0–1.2)	63.5 (0–357)	0.013
Respirator	Yes	0	7	0.078
	No	16	23	
Length of stay (days)		13 (9–17.2)	21.5 (15–66.7)	0.002
Physiological score		22 (21–23.2)	26 (24–30.5)	<0.001
Operative severity score		12.0 (10.75–13.5)	14.5 (12.0–19)	0.019
POSSUM-predicted morbidity		0.512 (0.429–0.711)	0.800 (0.632–0.902)	0.001

Multivariate analysis			
Variable	Odds ratio	95 % confidence interval	P-value
Sex male	25.4	2.63–246	0.005
Operative severity score	1.41	1.11–1.82	0.029
Length of stay	1.11	1.0–1.22	0.045

ASA: American Society of Anesthesiologists; ECOG-PS: Eastern Cooperative Oncology Group performance status;
POSSOM: Physiological and Operative Severity Score for the enumeration of Mortality and morbidity.

Table 3
Analysis of factors affecting in-hospital death.

Variable		Univariate analysis		
		Survivors ($n = 41$)	Non-survivors ($n = 5$)	P-value
Age		93 (91–96)	94 (93–97)	0.270
Sex	Male	18	1	0.387
	Female	23	4	
ASA physical status score	≤2	17	1	0.634
	>2	24	4	
ECOG-PS	0 or 1	20	0	0.016
	2 or 3	15	2	
	4	6	3	
Preoperative comorbidities				
Hypertension	Yes	29	4	1.000
	No	12	1	
Heart disease	Yes	15	3	0.365
	No	26	2	
Respiratory disease	Yes	2	0	1.000
	No	39	5	
Cerebrovascular disease	Yes	9	1	1.000
	No	32	4	
Dementia	Yes	7	3	0.060
	No	34	2	
Malignancy	Yes	6	2	0.203
	No	35	3	
Diagnosis				0.304
Small bowel obstruction		15	1	
Large bowel obstruction		5	0	
Perforation of upper digestive tract		2	2	
Perforation of lower digestive tract		10	2	
Appendicitis		4	0	
Hernia intussusception		4	0	
Gastrointestinal bleeding		1	0	
Operative time (min)		94 (65–156)	93 (55–131)	0.646
Blood loss (ml)		5 (0−330)	0 (0–0)	0.142
Respirator	Yes	5	2	0.160
	No	36	3	
Length of stay (days)		16 (13–32)	45 (43–127)	0.080
Physiological score		24 (22–27)	34 (33–35)	0.012
Operative severity score		13 (12–18)	16 (14–17)	0.644
P-POSSUM-predicted mortality		0.066 (0.034–0.131)	0.300 (0.148–0.303)	0.028

Variable	Multivariate analysis		
	Odds ratio	95 % confidence interval	P-value
Physiological score	1.37	1.08–1.75	0.010

ASA: American Society of Anesthesiologists; ECOG-PS: Eastern Cooperative Oncology Group performance status;
P-POSSOM: Portsmouth-Physiological and Operative Severity Score for the enumeration of Mortality and morbidity.

complications and procedural factors, however, perioperative risk increases with age [16]. This effect is amplified by frailty and sarcopenia, which increase the risk of postoperative complications by a factor of 1.2–2.4 [17]. Very elderly patients, particularly those ≥90 years old, lack the reserves and compensatory capacity for invasive surgeries, and mortality and morbidity are likely to be high in situations such as emergency surgery, when the general condition of the patient is already deteriorating [18,19]. Table 4 summarizes the mortality and morbidity from recent reports of abdominal surgeries for patients ≥90 years old [3–11]. Compared to elective surgery, emergency surgery showed a 2- to 3-fold increase in mortality and morbidity. As shown in the mortality data in Table 3, several reports examined prognosis at 1 year. A sharp increase was seen in mortality up to 30 days postoperatively, followed by a gradual increase in mortality up to 1 year postoperatively, with a 2- to 2.5-fold increase in mortality. This indicates that the stress of surgery has long-term effects for patients over 90 years old.

Patients ≥90 years old are characterized by a high prevalence of comorbidities, which are present in around 90 % of patients [3–7,10,11]. In our study, 100 % of patients had comorbidities, and Pelavski et al. [6] reported higher morbidity and mortality in patients with many comorbidities. In addition, the presence of malignancy, impaired renal function, stroke, heart failure, and respiratory disease have been reported to affect mortality. However, in our study, these individual comorbidities did not significantly differ between morbidity or mortality groups, and others have reported no significant differences

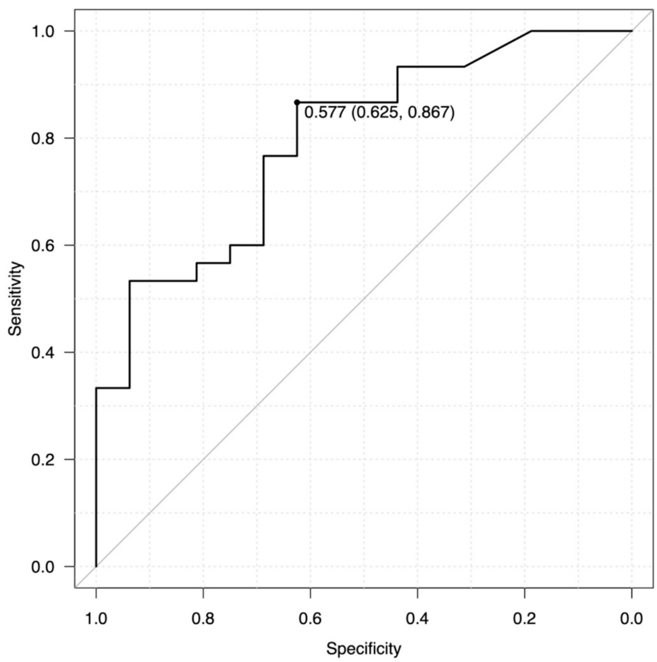

Fig. 1. ROC curve for POSSUM-predicted morbidity. The threshold value of 0.577 offers specificity of 0.625, sensitivity of 0.867, and an area under the curve of 0.796 (95 % confidence interval: 0.663–0.929).

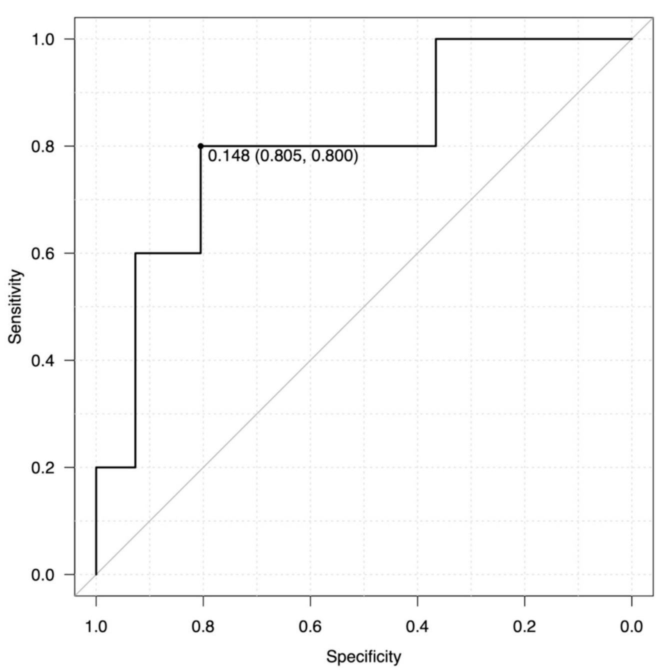

Fig. 2. ROC curve for P-POSSUM-predicted mortality. The threshold value of 0.148 offers specificity of 0.805, sensitivity of 0.800, and an area under the curve of 0.805 (95 % confidence interval: 0.572–1).

in mortality. Blansfield et al. [4] also suggested that the impact of these comorbidities on general health should be evaluated when considering indications for surgery.

Several studies have examined factors influencing the outcomes of surgery in the elderly. Among these, many have reported that a high ASA score is associated with mortality and morbidity [5,7,10,20]. In our study, an ASA score ≥ 3 was also a factor affecting morbidity. ECOG-PS has also been reported to correlate with mortality [10], supporting our

Table 4
Mortality and morbidity in surgery for patients ≥90 years old.

Authors	Emergency			Elective		
	n	Mortality (%)	Morbidity (%)	n	Mortality (%)	Morbidity (%)
Rigberg D (2000)	22	13.6*	68	10	0	20
Blansfield JA (2004)	72	19*	41	28	4	26
Arenal JJ (2007)	137	31*		56	9	
Pelavaski AD (2011)	119	29.4*				
Racz J (2012)	72	20.8* (49.1***)	81.9	73	9.6	61.6
Imaoka Y (2017)	36	8.3**	61.6			
Sudlow A (2018)	103	9.7** (28.2***)		58	0	
Perregaard H (2021)	157	35** (54***)	69			
Porinari M (2022)	85	33.3** (64.4***)	70.5			
Our cases (2024)	46	10.8*	65.2			

* Perioperative or in-hospital mortality; ** 30-day mortality; *** 1-year mortality.

findings. In a 5-year follow-up study of residents ≥90 years old, dementia and declines in activities of daily living were reported as predictors of mortality, while fewer comorbidities and better cognitive status were reported as predictors of long-term survival [21]. In other words, in the elderly, the level of independence in daily living affects postoperative outcomes. Both ASA score and ECOG-PS are very simple indices that do not require a variety of tests and are thought to be useful in predicting postoperative outcomes in the elderly.

Other parameters of surgical stress correlated with morbidity in our study, such as operative time, blood loss, and OSS. In addition, multivariate analysis identified male sex, OSS, and length of hospital stay. Sex has rarely been reported to affect prognosis, and only Morse et al. [22] identified male sex as a poor prognostic factor. Regarding surgical stress, Sudlow et al. [9] showed that performance of a major operation such as colonic resection or gastrectomy was a factor affecting 90-day mortality. In our study, the parameter of surgical stress significantly affected morbidity, but not mortality. Severity of postoperative complications has been reported to correlate with mortality, and factors that affect morbidity may also affect mortality, but this was not the case in our study. Although surgical stress is an important factor affecting postoperative outcomes, as with preoperative comorbidities, it is not the influence of individual parameters, but rather the overall influence of those parameters that is important.

POSSUM calculates predicted morbidity and predicted mortality by applying a PhS comprising 12 items, including age, blood pressure, hemoglobin, and electrolytes, and an OSS comprising 6 items related to surgical findings, to a calculation formula [13]. Whiteley et al. [14] indicated that POSSUM overcalculated predicted mortality, particularly for minor operations, and devised P-POSSUM as a modification. In our study, POSSUM-predicted morbidity correlated with observed morbidity, and P-POSSUM-predicted mortality correlated with observed mortality. Those correlations were likely due to the fact that patients ≥90 years old had various comorbidities and were at high risk for emergency surgery. Brooks et al. [23] also reported that both POSSUM and P-POSSUM were useful for predicting outcomes in a study of 949 selected high-risk cases, excluding day surgery and minor surgery. Others reported the POSSUM as useful in predicting the outcomes of emergency abdominal surgery in elderly patients [8,24,25]. However, some studies have reported that POSSUM was not useful in predicting the outcomes of emergency surgery for patients ≥90 years old [7,11], and consensus on the evaluation remains unsettled. POSSUM is a predictor that includes intraoperative findings and cannot be used for preoperative evaluation. In the present study, PhS calculated from preoperative parameters was the only factor identified as influencing mortality in a multivariate analysis. Those suggested that the decision to perform emergency abdominal surgery on patients ≥90 years old should be based on preoperative physiological status, taking into account comorbidities and health status, rather than age.

Conclusions

ASA and factors of surgical invasiveness correlated with the incidence of postoperative complications, while ECOG-PS and Physiological Score correlated with in-hospital mortality. In addition, POSSUM-predicted morbidity and P-POSSUM-predicted mortality were moderately accurate. These findings suggested that we can predict the risk of emergency abdominal surgery in patients ≥90 years old to some extent. Further, the in-hospital mortality of patients ≥90 years old did not differ significantly compared with that of patients ≥65 years old and < 90 years, suggesting that surgery is worth performing even if the risk is considered high. In explaining the indications for surgery and predicted postoperative conditions to family members, convincing explanations can be provided based on these data.

CRediT authorship contribution statement

Atsushi Horiuchi: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Shun Akehi:** Supervision. **Yuta Fujiwara:** Resources, Investigation. **Sakura Kawaharada:** Resources, Investigation. **Takayuki Anai:** Resources, Investigation.

Declaration of competing interest

The authors reported no proprietary or commercial interest in any product mentioned or concept discussed in this article.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Ethics approval

This study was performed in accordance with the Declaration of Helsinki, with an opt-out methodology and was approved by the Ehime Prefectural Niihama Hospital Clinical Research Review Committee (approval no. 04–002) on June 9, 2022.

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