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A novel scoring system to predict postoperative mortality after colorectal cancer surgery: a retrospective cohort study

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ABSTRACT

Background: Many scoring systems have been developed to predict outcomes after surgery, but it has limitations due to differences in population, comorbidity, type of surgery, or hospital effects. External validation from these scoring systems sometimes failed to achieve good discriminatory power consistently. This study aims to develop a novel scoring system for predicting postoperative mortality and comparing its performance with the AFC, CR-POSSUM, IRCS, and ACS-NSQIP SRC model.

Methods: Data were collected retrospectively from all consecutive patients (n=1,294) undergoing colorectal cancer surgery in Dr. Soetomo Hospital between 2011 and 2020. After excluding missing data and 215 patients who did not satisfy the inclusion criteria, multivariate logistic regression analysis was performed in 1,079 patients to estimate odds ratios (ORs) and 95% confidence intervals (CIs) linking the explanatory variable postoperative mortality, and a Surabaya scoring system was constructed. Data were analyzed using SPSS version 23 for Windows.

Results: Variables identified as the strongest predictors based on Odds Ratio (OR) postoperative mortaliy were albumin < 3.4 g/dL (6.93; 95%CI: 4.37-10.99; p< 0.001), pulse > 120 times per-minute (5.49; 95%CI: 2.11-14.29; p< 0.001), totally dependent functional status (4.43; 95%CI 2.06-9.49; p<0.001) or partially dependent (2.34: 95%CI: 1.28-4.28; p< 0.001), ascites (3.58; 95%CI: 1.84-6.94; p=0.001), major procedure (2.48; 95%CI: 1.38-4.33; p=0.009), dyspnea (2.40; 95%CI: 1.19-4.84; p=0.014), and haemoglobin < 10 g/dL (1.85; 95%CI: 1.12-3.04; p=0.016). The Surabaya model predicted postoperative mortality with a predictive performance (0.831; 95%CI: 0.790-0.871) in the validation population. In this population the predictive performance of the AFC score was 0.630 (95%CI: 0.498-0.762), CR-POSSUM 0.698 (95%CI: 0.563-0.833), IRCS 0.564 (95%CI: 0.426-0.702), and ACS-NSQIP SRC 0.674 (95%CI: 0.541-0.806).

Conclusion: The Surabaya score has been shown as a good predictor of postoperative mortality after colorectal cancer surgery despite the relatively low number of risk factors.

Keywords: Colorectal Cancer Surgery, 30-Day Postoperative Mortality, Risk Factors, New Scoring System.
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INTRODUCTION

Surgery for Colorectal Cancer (CRC) offers the longest survival benefit in CRC cure and palliation, but it is highly invasive and has high mortality rates. Thirty-day postoperative mortality rate after CRC surgery is approximately 1.5% in high-income countries, and it is four times higher in resourcefour timesetting.[1] This outcome is influenced by patient-related variables, disease severity, surgical team and the surgery itself, and perioperative care.[2] Various colorectal surgery-specific scoring systems have been developed to identify high-risk patients that may benefit from early identification and additional perioperative monitoring or treatment. But none have been developed in Indonesia based on only preoperative variables. The most widely used surgery scoring system is the P-POSSUM, which uses a 12-factor. Several modifications of the P-POSSUM model have been developed by subspecialties, including CR-POSSUM.[3] Validation of CR-POSSUM, IRCS, and AFC scoring systems recently concluded that none resulted in optimal discriminatory power (AUC values < 0.70).

Based on those mentioned above, this study aims to detect factors associated with 30-day postoperative mortality after colorectal cancer surgery in a Surabaya population-based study, to formulate and internally validate a simple scoring system for predicting postoperative mortality that is simple to use and accurate. And we wanted to validate and compare AFC, CR-POSSUM, IRCS, and ACS-NSQIP SRC models against our novel scoring system for colorectal cancer surgery in our institution.

MATERIALS AND METHODS

This observational retrospective cohort study was based on records of all consecutive patients who were operated for CRC in Dr. Soetomo General Hospital between January 2011 and December 2020. Patients whose outcomes were not recorded and patients who had undergone abdominal surgery within 1 month were excluded from the study.

Data we recorded on gender, age, body mass index, functional status, ASA status, smoking history, systolic blood pressure, pulse rate, hemoglobin, BUN, albumin, CRC stage, operative urgency, operative severity, and the surgeon subspecialization. Furthermore, data were collected concerning signs and symptoms of dyspnea, ascites, steroid therapy, hemodialysis, acute kidney injury, congestive heart failure, chronic obstructive pulmonary disease, diabetes mellitus, ventilator support, antihypertensive therapy, and systemic infection. The primary outcome was 30-day postoperative mortality, defined as mortality of any cause within 30-day of the intervention, whether occurring in the hospital or after discharge.

The analysis was performed using the SPSS version 23 for Windows. Univariate logistic regression analysis calculated the odds ratios (ORs) identified the association between 30-day mortality and 26 independent variables was identified by univariate logistic regression analysis calculating the odds ratios (ORs). Then, a multivariate logistic regression analysis was performed, using independent variables yielded $p < 0.05$ on univariate analysis, using a backward stepwise approach. The final predictors of mortality generated from the multivariate analysis were calculated, creating an equation for the Surabaya score. Then we simplified the equation weighted each variable according to the coefficient regression.

Then we validated the discriminating power of this new model and compared it with 4 other scoring systems (AFC, CR POSSUM, IRCS, and ACS-NSQIP SRC), which revealed its ability to predict higher probabilities of mortality to patients who die than to those patients who live, estimated by the area under the receiver-operator characteristic (ROC) curve. Values between 0.70 and 0.80 represent good discrimination, and values >0.80 represent good discrimination.

RESULTS

A total of 1,079 (83.4%) of 1294 patients undergoing surgery for CRC satisfied the selection criteria. A summary of the independent variables and their associated 30-day postoperative mortality is shown in table 1, which also shows the results of multivariate analysis. Incomplete data was only for the CRC stage (2.13%). The patient's mean age was 51.29 (range 14-92). The tumors were 70.53% in the rectosigmoid and rectum, and the remainder in the colon. The operation was performed in 60.24% of elective surgeries vs. 39.76% of emergency surgeries, with statistically significant differences ($p <$ 0.001). Most patients presented in stage III-IV CRC (81.28%) (Table 1).

The overall operative mortality rate in this series was 12.9%. Univariate analysis revealed significant differences positively associated with 30-day postoperative mortality were age, BMI, functional status, ASA classification, smoking habit, systolic blood pressure, pulse rate, hemoglobin, BUN, albumin, CRC stage, dyspnea, ascites, steroid, hemodialysis, acute renal failure, congestive heart failure, COPD, diabetes mellitus, systemic infection, operative urgency, operative severity, and surgeon specialization (p<0.05) (Table 1).

The strongest predictors of mortality included albumin < 3.4 g/dL (OR 6.93; 95%CI: 4.37-10.99; p<0.001), pulse > 120 times per-minute (OR 5.49; 95%CI: 2.11-14.29; p<0.001), totally dependent functional status (OR 4.43; 95%CI: 2.06-9.49; p<0.001) or partially dependent (OR 2.34; 95%CI: 1.28-4.28; p< 0.001), ascites (OR 3.58; 95%CI: 1.84-6.94; p=0.001), major operative procedure (OR 2.48; 95%CI: 1.38-4.44; p=0.009), dyspnea (OR 2.40; 95%CI: 1.19-4.84; p=0.014), and haemoglobin < 10 g/dL (OR 1.85; 95%CI: 1.12-3.04; p=0.016). The equation generated from these analysis as follows: = exp [—4.104 + (1.936 x albumin < 3.4 g/dL) + (1.702 x pulse rate > 120 kali/menit) + (1.488 x totally dependent functional status) + (1.275 x ascites) + (0.908 x major operative procedure) + (0.875 x dyspnea) + (0.850 x partially dependent functional status) + (0.613 x haemoglobin < 10 g/dL)].

This regression model was simplified generated points for each variable to calculate the Surabaya score (Table 2). The possible scores ranged from 0 to 32 points. The episode with the highest score in this sample series produced a score of 28 points. The score-risk correlation is shown in Table 3. Patients with a total score of 0 were included 348 patients with 2.9% mortality risk, patients with total scores 19-22, 24-26, and 28 had a 100% mortality, and there were no patients with total score 23, 27, and 29-32 in which the mortality risk can not be determined. Using a ROC curve, the cut-off value of this Surabaya score is 5.5 (Figure 1). Patients who gained a total score < 5.5 were considered low-risk with a mortality rate of 23.7%, and a total score > 5.5 had a high risk of mortality as much as 76.3% (Table 4).

A comparison of AUC ROC curves for mortality presents in Table 5 shows the discriminative performance of this Surabaya score, AFC, CR-POSSUM, IRSCS, and ACS-NSQIP SRC scoring systems. Surabaya score showed a discriminating capacity of 0.831 (95%CI: 0.790-0.871). The predictive performance in this population of the AFC score was 0.630 (95%CI: 0.498-0.762), CR-POSSUM 0.698 (95%CI: 0.563-0.833), IRCS 0.564 (95%CI: 0.426-0.702), and ACS-NSQIP SRC 0.674 (95%CI: 0.541-0.806) (Table 5).

DISCUSSION

The higher mortality rate in this study (12.9%) compared with developed countries are often due to the advanced stage of presentation, in which > 80% of patients presented with stage III-IV CRC upon admission in this study. The mortality rate reported by García-Torrecillas JM et al., was 4.2% from the Spanish population.[4] Meanwhile, Hariharan S et al., reported a 6.9% overall mortality rate for patients undergoing surgery for CRC in Trinidad and Tobago.[5]

This is the first predictive model to be developed in Indonesia to estimate the risk of 30-day postoperative mortality in patients undergoing surgery for CRC. All of the variables can be obtained in the preoperative period and easily used, which can help the doctor and patients or their families to decide in emergency or elective situations. The study shows that the Surabaya score can stratify patients' 30-day postoperative mortality who are undergoing surgery for CRC.

There were 7 risk factors found in the multivariate analysis: albumin < 3.4 g/dL, pulse rate >120 times/minute, totally or partially dependent functional status,

Table 1. Patient and disease characteristics, associated 30-day postoperative mortality, and univariate and multivariate logistic regression analysis results.

Variable	Total (N=1,079)	Outcome (N=1,079)		Univariate analysis OR (95% CI)	Multivariate analysis OR (95% CI)
		Alive (N=940)	Death (N=139)		
Sex, n (%)				0.793	*
Male	571	496 (86.9)	75 (13.1%)	1	
Female	508	444 (87.4)	64 (12.6%)	0.95 (0.67—1.36)	
Age, n (%)				0.038	*
<50	480	418 (87.1)	62 (12.9%)	1	
50 – <65	440	394 (89.5)	46 (10.5%)	0.79 (0.52—1.18)	
65-85	155	125 (80.6)	30 (19.4%)	1.62 (1.00—2.61)	
>85	4	3 (75.0)	1 (25.0%)	2.25 (0.23—21.95)	
BMI (kg/m^2), n (%)				0.001	*
18.5 – 24.9	909	807 (88.8)	102 (11.2%)	1	
<18.5	157	122 (77.7)	35 (22.3%)	2.27 (1.48—3.48)	
25 – 29.9	13	11 (84.6)	2 (15.4%)	1.44 (0.31—6.59)	
≥30	-	-	-	-	
Functional status, n (%)				<0.001	<0.001
Independent	783	727 (92.8)	56 (7.2%)	1	1
Partially dependent	215	172 (80.0)	43 (20.0%)	3.25 (2.11—4.99)	2.34 (1.28—4.28)
Totally dependent	81	41 (50.6)	40 (49.4%)	12.67 (7.58—21.16)	4.43 (2.06—9.49)
ASA classification, n (%)				<0.001	*
ASA 1	-	-	-	-	
ASA 2	626	584 (93.3)	42 (6.7)	1	
ASA 3	321	278 (86.6)	43 (13.4)	2.15 (1.37—3.37)	
ASA 4	132	78 (59.1)	43 (40.9)	9.63 (6.03—15.36)	
ASA 5	-	-	-	-	
Smoking, n (%)				0.162	*
No	863	758 (87.8)	105 (12.2)	1	
Yes	216	182 (84.3)	34 (15.7)	1.35 (0.89—2.05)	
SBP (mmHg), n (%)				<0.001	*
>170	17	16 (94.1)	1 (5.9)	1	
100 – 170	701	641 (91.4)	60 (8.6)	1.49 (0.19—11.49)	
90 – 99	254	222 (87.4)	32 (12.6)	2.31 (0.29—17.99)	
<90	107	61 (57.0)	46 (43.0)	12.07 (1.54—94.31)	
Pulse rate, n (%)				<0.001	<0.001
60 – 100	795	731 (91.9)	64 (8.1)	1	1
101 – 120	239	196 (82.0)	43 (18.0)	2.51 (1.65—3.80)	0.69 (0.36—1.33)
>120	45	13 (28.9)	32 (71.1)	28.11 (14.05—56.25)	5.49 (2.11—14.29)
<60	-	-	-	-	-
Hb (g/dL), n (%)				<0.001	0.016
10 – < 13	772	700 (90.7)	72 (9.3)	1	1
< 10	307	240 (78.2)	67 (21.8)	2.71 (1.89—3.90)	1.85 (1.12—3.04)
>16 – 18	-	-	-	-	-
13 – 16	-	-	-	-	-
BUN (mg/dL), n (%)				<0.001	*
<20	911	824 (90.5)	87 (9.5)	1	
20 – 40	68	55 (80.9)	13 (19.1)	2.24 (1.18—4.26)	
>40	100	61 (61.0)	39 (39.0)	6.05 (3.82—9.56)	
Albumin (g/dL), n (%)				<0.001	<0.001
≥ 3.4	878	804 (91.57)	74 (8.23)	1	1
< 3.4	201	136 (67.66)	65 (32.34)	3.12 (2.73—6.12)	6.93 (4.37—10.99)
CRC stage, n (%)				0.008	*
1	27	24 (88.9)	3 (11.1)	1	
2	152	142 (93.4)	10 (6.6)	0.56 (0.14—2.19)	
3	534	473 (88.6)	61 (11.4)	1.03 (0.30—3.53)	
4	343	284 (82.8)	59 (17.2)	1.66 (0.48—5.70)	
Missing	23	-	-	-	
Dyspnea, n (%)				<0.001	0.014
No	965	874 (90.6)	91 (9.4)	1	1
Yes	114	66 (57.9%)	48 (42.1)	6.98 (4.54—10.74)	2.40 (1.19—4.84)
Ascites, n (%)				<0.001	0.001

Variable	Total (N=1,079)	Outcome (N=1,079) Alive (N=940)	Death (N=139)	Univariate analysis OR (95% CI)	Multivariate analysis OR (95% CI)
No	1,008	891 (88.4)	117 (11.6)	1	1
Yes	71	49 (69.0)	22 (31.0)	3.42 (1.99—5.86)	3.58 (1.84—6.94)
Steroid, n (%)				0.640	*
No	1,067	929 (87.1)	138 (12.9)	1	
Yes	12	11 (91.7)	1 (8.3)	0.61 (0.78—4.78)	
Hemodialysis, n (%)				<0.001	*
No	1,024	902 (88.1)	122 (11.9)	1	
Yes	55	38 (69.1)	17 (30.9)	3.31 (1.81—6.04)	
AKI, n (%)				<0.001	*
No	992	886 (89.3)	106 (10.7)	1	
Yes	87	54 (62.1)	33 (37.9)	5.11 (3.17—8.23)	
CHF, n (%)				0.006	*
No	1,034	907 (87.7)	127 (12.3)	1	
Yes	45	33 (73.3)	12 (26.7)	2.59 (1.31—5.16)	
COPD, n (%)				<0.001	*
No	1012	892 (88.1)	120 (11.9)	1	
Yes	67	48 (71.6)	19 (28.4)	2.94 (1.67—5.18)	
Diabetes Mellitus, n (%)				0.034	*
No	971	853 (87.8%)	118 (12.2)	1	
Yes	108	87 (80.6%)	21 (19.4)	1.74 (1.04—2.92)	
Ventilator Support, n (%)				0.999	*
No	1076	940 (87.4%)	136 (12.6)	1	
Yes	3	-	3 (100.0)	-	
Hypertension, n (%)				0.080	*
No	874	769 (88.0%)	105 (12.0)	1	
Yes	205	171 (83.4%)	34 (16.6)	1.46 (0.96—2.22)	
Systemic infection, n (%)				<0.001	*
No	823	746 (90.6 %)	77 (9.4)	1	
Yes	256	194 (75.8%)	62 (24.2)	3.09 (2.14—4.49)	
Operative urgency, n (%)				<0.001	*
Elective	650	608 (93.5%)	42 (6.5)	1	
Emergency	429	332 (77.4%)	97 (22.6)	4.23 (2.87—6.22)	
Operative severity, n (%)				<0.001	0.009
Minor	271	242 (89.3%)	29 (10.7)	1	1
Major	413	331 (80.1%)	82 (19.9)	2.07 (1.31—3.26)	2.48 (1.38—4.44)
Complex major	395	367 (92.9%)	28 (7.1)	0.64 (0.37—1.09)	1.84 (0.89—3.78)
Surgeon, n (%)				<0.001	*
Consultant	357	333 (93.3%)	24 (6.7)	1	
Trainee	285	247 (86.7%)	38 (13.3)	2.13 (1.25—3.65)	
Resident	437	360 (82.4%)	77 (17.6)	2.97 (1.83—4.80)	

BMI: body mass index; ASA: American Society of Anaesthesiology; BUN: Blood Urea Nitrogen; CRC: Colorectal Cancer; COPD: Chronic Obstructive Pulmonary Disease; AKI: Acute Kidney Injury; Hb: Hemoglobin; CHF: Congestive Heart Failure; SBP: Systolic Blood Pressure

Variables with statistically significant association with 30-day postoperative mortality in univariate analysis

* Variables that were not statistically significant associated with 30-day postoperative mortality in multivariate analysis

Table 2. The Surabaya score chart.

Risk factors	Point
Albumin < 3.4 g/dL	8
Pulse rate > 120 times/minute	7
Totally dependent functional status	6
Ascites	4
Major operative procedure	2
Dyspnea	2
Partially dependent functional status	2
Haemoglobin < 10 g/dL	1
Total skor	32

Table 3. Surabaya score regarding risk correlation of 30-day postoperative mortality.

Total points of Surabaya score	n	30-day postoperative mortality	
		n	Risk (%)
0	348	10	2.9
1	80	4	5.0
2	181	6	3.3
3	58	5	8.6
4	60	4	6.7
5	36	4	11.1
6	17	2	11.8
7	19	4	21.1
8	71	14	19.7
9	33	7	21.2
10	48	11	22.9
11	29	8	27.6
12	20	7	35.0
13	15	6	40.0
14	8	6	75.0
15	6	2	33.3
16	15	10	66.7
17	17	12	70.6
18	6	5	83.3
19	2	2	100
20	1	1	100
21	2	2	100
22	1	1	100
24	2	2	100
25	1	1	100
26	2	2	100
28	1	1	100
Total	1079	139	12.9

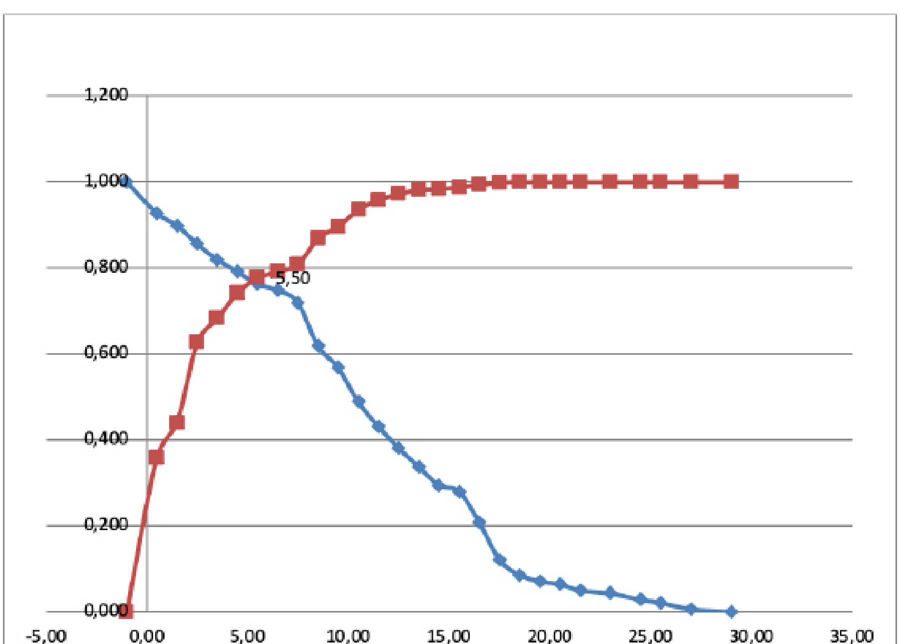

Figure 1. The optimal cut-off point of the ROC curve for Surabaya score (Cut-Off point 5.5; Sensitivity 76.3%; and Specificity 77.7%).

ascites, major operative procedure, dyspnea, and hemoglobin < 10 g/dL. Albumin is the main determinant of oncotic plasma pressure as well as antioxidant, immunomodulatory, and detoxification functions.[6] Hypoalbuminemia in the perioperative period may affect organ vascularization, hamper the distribution of antibiotics, perpetuate inflammation, and induce intravascular coagulation.[7] Albumin level has long been used as a nutritional parameter and a risk factor for in-hospital and postoperative morbidity and mortality. Chiang JM et al., found that each 0.1 g/dL increase in albumin level generally decreased the mortality rates by 15.6%.[8]

Tachycardia has long been known to reflect the systemic condition of the patient, more often found in emergency settings, had higher ASA status, and was associated with SIRS, sepsis, and septic shock. Oumer KE et al., found that sepsis in the preoperative period increased postoperative mortality significantly (OR 6.7).[9]

Functional status before the operation is a well-known risk factor for elderly populations in developed countries. Gilbert T et al., found that geriatric is the major user of acute health care, and the fact that aging is related to frailty, the declines function of several organ systems.[10] He found that the chronological age did not reflect the frailty in the geriatric population, and functional status correlates well with frailty and suboptimal recovery and rehabilitation postoperatively.[10] Bilimoria KY et al., incorporated functional status in his model and proposed that functional status is an independent risk factor for postoperative morbidity and mortality in almost every procedures.[11]

Tekkis PP et al., found that the operative severity increment significantly increased the postoperative mortality risk (major procedures OR 4.75 and major complex procedures OR 8.79).[3] Only the major procedures were associated with mortality (OR 2.48).[3] It may be partly because the major procedures were mainly conducted in emergency settings (56.66%), whereas 94.94% of the major complex procedures were in elective settings.

Ascites in this study reflect the advanced stage of the disease. Sixty-five

Table 4. Surabaya risk classification and 30-day postoperative mortality risk.

Mortality risk	Surabaya score	Alive (%)	Death (%)
Low risk	0—5.5	730 (77.7%)	33 (**23.7%**)
High risk	5.5—17	210 (22.3%)	106 (**76.3%**)

Table 5. Predictive performance of Surabaya, AFC, CR-POSSUM, IRCS, and ACS-NSQIP SRC scoring systems.

Scoring systems	AUC	95%CI
AFC	0.630	0.498—0.762
CR-POSSUM	0.698	0.563—0.833
IRCS	0.564	0.426—0.702
ACS-NSQIP SRC	0.674	0.541—0.806
Surabaya	0.831	0.790—0.871

of 71 patients with ascites were related to peritoneal metastasis, an independent poor prognostic factor. The proportion of stage IV CRC in our study (32.48%) far exceeds that in the literature (10-20%).[3,5,12] Most scoring systems did not incorporate ascites as risk factors, maybe because of the low incidence of stage IV in their population and the low number of patients with ascites.

Low hemoglobin count in the preoperative period reflects the chronicity of the disease, the physiology status of the patient, the complication from the CRC itself (bleeding, obstruction, advanced stage), and more commonly presented in an emergency setting. Fowler AJ stated that anemia significantly increases postoperative mortality (OR 2.9), acute kidney injury (OR 3.75), and infection rate (OR 1.93).[13]

The AFC scoring system, constructed from 1,049 patients French population, included 4 independent variables associated with mortality: urgent surgery, loss of >10% body weight in the last 6 months, neurological history, and age > 70. Like the IRCS score, this model uses only 4 parameters that are easy to obtain, but these scoring systems have never been validated in Indonesia.

CR-POSSUM was constructed based on a regression analysis of the original P-POSSUM model, using 6 physiological and 4 operative variables. External validation of this model yielded varying results, over-predict or under-predict mortality.[14-16] ACS-NSQIP SRC is an extensive model using 15 risk factors that estimate morbidity, serious morbidity, and mortality. The added value of this model has included the influence of hospitals on the outcome. The Surabaya score shows better discriminative performance despite its lower number of variables compared with the AFC, CR-POSSUM, IRCS, and ACS-NSQIP SRC scoring systems. This is reflected by the AUC of the ROC curve of 0.831.

Limitations of this study were it was conducted in a single tertiary hospital that may not represent Surabaya or Indonesia population and the quality standards of hospital services/resources. The retrospective nature of this study is susceptible to bias in terms of being under-recorded. And a number of important risk factors were not included due to not being routinely checked or recorded, and they might be relevant to 30-day postoperative mortality.

CONCLUSION

This retrospective study generated a new Surabaya scoring system conducted on the Surabaya population. It demonstrated that the Surabaya score is an accurate and reliable predictor of 30-day postoperative mortality after surgery for CRC. The other models analyzed in this study showed the moderate performance to discriminate the risk of 30-day postoperative mortality. The validity of the Surabaya score needs to be evaluated prospectively in a population other than that used to develop the model.

CONFLICT OF INTEREST

The authors declared that they have no competing interests regarding the manuscript.

ETHICS CONSIDERATION

The Clinical Research Ethics Committees of Dr. Soetomo General Hospital Surabaya approved the study.

FUNDING

No funding was received to carry out this study.

AUTHOR CONTRIBUTIONS

All authors contribute to the study from the conceptual framework, data acquisition, data analysis until reporting the study results through publication.

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