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Nationwide Study to Predict Colonic Ischemia after Abdominal Aortic Aneurysm Repair in The Netherlands

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Background: Colonic ischemia remains a severe complication after abdominal aortic aneurysm (AAA) repair and is associated with a high mortality. With open repair being one of the main risk factors of colonic ischemia, deciding between endovascular or open aneurysm repair should be based on tailor-made medicine. This study aims to identify high-risk patients of colonic ischemia, a risk that can be taken into account while deciding on AAA treatment strategy.
Methods: A nationwide population-based cohort study of 9,433 patients who underwent an AAA operation between 2014 and 2016 was conducted. Potential risk factors were determined by reviewing prior studies and univariate analysis. With logistic regression analysis, independent predictors of intestinal ischemia were established. These variables were used to form a prediction model.
Results: Intestinal ischemia occurred in 267 patients (2.8%). Occurrence of intestinal ischemia was seen significantly more in open repair versus endovascular aneurysm repair (7.6% vs. 0.9%; $P < 0.001$). This difference remained significant after stratification by urgency of the procedure, in both intact open (4.2% vs. 0.4%; $P < 0.001$) and ruptured open repair (15.0% vs. 6.2%); $P < 0.001$). Rupture of the AAA was the most important predictor of developing intestinal ischemia (odds ratio [OR], 5.9, 95% confidence interval [CI] 4.4−8.0), followed by having a suprarenal AAA (OR 3.4; CI 1.1−10.6). Associated procedural factors were open repair (OR 2.8; 95% CI 1.9−4.2), blood loss >1L (OR 3.6; 95% CI 1.7−7.5), and prolonged operating time (OR 2.0; 95% CI 1.4−2.8). Patient characteristics included having peripheral arterial disease (OR 2.4; 95% CI 1.3−4.4), female gender (OR 1.7; 95% CI 1.2−2.4), renal insufficiency (OR 1.7; 1.3−2.2), and pulmonary history (OR 1.6; 95% CI 1.2−2.2). Age <68 years proved to be a protective factor (OR 0.5; 95% CI 0.4−0.8). Associated mortality was higher in patients with intestinal ischemia versus patients without (50.6% vs. 5.1%, $P < 0.001$). Each predictor was given a score between 1 and 4. Patients with a score of ≥10 proved to be at high risk. A prediction model with an excellent AUC = 0.873 (95% CI 0.855−0.892) could be formed.

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Conclusions: One of the main risk factors is open repair. Several other risk factors can contribute to developing colonic ischemia after AAA repair. The proposed prediction model can be used to identify patients at high risk for developing colonic ischemia. With the current trend in AAA repair leaning toward open repair for better long-term results, our prediction model allows a better informed decision can be made in AAA treatment strategy.

INTRODUCTION

Colonic ischemia is a severe complication after abdominal aortic aneurysm (AAA) repair. Irrespective whether it develops after endovascular aneurysm repair (EVAR) or open repair, the associated mortality of colonic ischemia remains high, exceeding 50%.[1–6] The reported incidence is relatively low after AAA repair, ranging between 0.5 and 3% after elective EVAR and ranging between 1 and 3% after elective open repair.[4,7,8] Increased incidences are reported among patients operated for a ruptured AAA, in both EVAR and open repair.[1–3,7,9–16] Furthermore, studies show that open repair was associated with a 2.7 or 2.9 increased risk of colonic ischemia compared with EVAR[1,12] The true incidence of postoperative colonic ischemia is suggested to be higher, as routine postoperative colonoscopy reported an incidence of 5–9% after elective AAA surgery and 15–60% after ruptured AAA repair.[4,7,8] However, colonic ischemia varies in severity from transient, reversible mucosal ischemia to irreversible transmural disease.[17,18] Early identification of those patients who will develop transmural colonic ischemia results in improved outcome and lower mortality rate.[4,16] However, establishing the diagnosis can be challenging due to nonspecific clinical presentation and nonreliable, noninvasive diagnostic tests. A colonoscopy or exploratory laparotomy can confirm the diagnosis of colonic ischemia, but results in a delay in diagnosis, which can ultimately lead to transmural colonic ischemia and perforation.[4,16,19–21] As such, much can be gained by identifying those patients with a high risk of developing transmural colonic ischemia in an early stage. Prior studies have distinguished several risk factors predictive of colonic ischemia, including patient factors such as advanced age, preoperative renal failure, and preoperative respiratory insufficiency.[1,2,9,11] Intraoperative factors such as prolonged operation time, prolonged suprarenal aortic cross clamping, or hypogastric artery occlusion increase the risk of transmural colonic ischemia.[11,22,23] However, due to the rarity of the complication, most studies have included a limited number of cases. In 2013, a mandatory national registry for patients undergoing AAA repair in the Netherlands, the Dutch Surgical Aneurysm Audit (DSAA), has been introduced. This prospective registry provides the opportunity to evaluate the occurrence of colonic ischemia and relating preoperative and intraoperative patient characteristics in a population-based setting.

Present insights about open repair compared with EVAR show better long-term results and lower mortality rates, hence recommending open repair for patients with prospects of long-term survival.[24] However, with open repair being one of the main risk factors of colonic ischemia, deciding between these two treatment strategies should be based on tailor-made medicine. This study aims to identify high-risk patients of colonic ischemia, a risk that can be taken into account while deciding on AAA treatment strategy.

METHODS

Design

This population-based cohort study included all AAA operations in the Netherlands between January 1, 2014 and December 31, 2016. The data set is retrieved from the DSAA, established in 2013. The DSAA is a quality registration of the Dutch Institute of Clinical Auditing. This nationwide prospective registration for aneurysms aims to improve the quality of aneurysm surgery. Data are registered via a Web-based survey, which includes all patients with an AAA or thoracic aortic aneurysm getting a surgical or endovascular treatment. Of each surgical procedure, patient and procedure characteristics are registered, as well as 30 days or in hospital postoperative outcome. The DSAA consists of a mandatory minimal registry regarding basic patient characteristics and an extended registry facultative for research purposes. In this study, data from both the minimal and the extended survey were used. Each table shows which variables originated from the minimal and which variables originated from the extended registry. An independent verification committee validates data submitted to the DSAA. The regional ethical committee in The Hague (METC Zuidwest Holland) approved the study design. Under Dutch law, no informed consent was required for this study.

Definition of Variables

Patients with missing data on colonic ischemia, gender, age, urgency of procedure, procedure type, or size of aneurysm were excluded from this study. The method of repair and the urgency of the procedure were simplified in EVAR or open repair and intact or ruptured AAA. The criterion for the diagnosis of colonic ischemia was a clinical presentation of bowel ischemia, low-grade ischemia seen during a routine colonoscopy examination is excluded from this study. Current literature was reviewed to determine which risk factors would be selected for analysis. The risk factors found in the studies of Perry et al.(1), Bjorck et al.(11), and Ultee et al.(12) were selected because of the same study set up, as well as the use of a large database. Baseline characteristics included age, gender, size of aneurysm (mm), and several comorbidities. Age and aneurysm size were analyzed as a continuous variable in a univariate analysis. To benefit the multivariate analysis, age was categorized as younger than 68 years, age 68−75 years or older than 75 years (the 25th and 75th percentile of the study population), and aneurysm size was dichotomized at larger than 70,0 mm (the 75th percentile for the study population). Preoperative comorbidities that were selected for analysis were having pulmonary history, diabetes, hypertension, having a cardiac history, and renal insufficiency. Renal insufficiency was defined as a serum creatinine level >115 umol. A cardiac history included taking medication for hypertension, angina, diuretics, or digoxin as well as having peripheral edema or cardiomegaly. A history of pulmonary disease was defined as having dyspnea on exertion, invalidating dyspnea, or having dyspnea at rest. Smoking was categorized (never smoked, smoked in the past, and current smoking). Cardiac history, pulmonary history, and having diabetes mellitus were dichotomized into yes or no for the purpose of this analysis. The size of the aneurysm was measured on an abdominal ultrasound when possible; otherwise, measurements of an abdominal computed tomography scan were used. Intraoperative characteristics consisted of urgency of the procedure, procedure type, prolonged operative time (>3 hr, 75th percentile), intraoperative blood loss without correction for cell saver, and prolonged suprarenal clamping time (>46 min, 75th percentile). Intraoperative blood loss was categorized (<100 mL, 100−500 mL, 500−1000 mL, and >1000 mL). The variables peripheral arterial disease (PAD, defined as Fontaine IIA or higher) and the type AAA (infrarenal, juxtarenal, or suprarenal) were selected by univariate analysis ($P = 0.018$ and $P < 0.001$, respectively).

Outcome Measures

Postoperative outcome was 30-day mortality, which included any death (all causes) occurring during surgery or within 30 days after surgery.

Statistical Analysis

Baseline, intraoperative characteristics, and postoperative outcomes were compared between patients with and without postoperative bowel ischemia. Continuous variables were analyzed with the Student's *t*-test and Mann-Whitney *U*-test; the Pearson $\chi 2$ test and Fisher exact test were applied for categorical data. The analysis was stratified by the procedure (intact and ruptured AAA) and by surgical procedure used (EVAR/open repair). Continuous variables were expressed as mean + standard deviation (SD). Categorical variables were expressed as a number and frequency in percentages. All tests were two-tailed and used a *P*-value <0.05 to determine significance. Independently associated prognostic factors of intestinal ischemia were identified using multivariable logistic regression analysis. Variables proven to be of importance in previous studies were automatically selected for multivariate analysis. Aside from these previously found risk factors, some other variables were tested by univariate analysis. Factors that were trend-significant with a *P*-value of 0.15 were selected for multivariate analysis as well. The multivariate logistic regression was then performed with enter selection. Adjusted ORs with 95% CIs were estimated from the model.

Score Development

We developed a simple clinical score based on the regression coefficients from the final model. The coefficient of each predictor was divided by the smallest coefficient of all predictors to get a value of 1 or above. The individual scores of each predictor were added together to produce a total risk score for each patient. The individual scores were roughly divided into 4 groups (0 to 2, 3 to 5, 6 to 9, and ≥10), by their total number of patients and number of patients with bowel ischemia. The median was calculated. The predictive value of the final prediction model was calculated by percentage of correct classification and by calculating the ROC curve and area under the curve (AUC). Statistical analysis was performed using SPSS version 24.0 (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0, Armonk, NY: IBM Corp.).

RESULTS

Patients

A total of 10,821 patients were registered, 1,388 patients were excluded due to missing data on basic variables as gender, age, and treatment type. 9,433 patients were included, with 6,809 minimal registries and 2,624 extended registries. The total incidence of patients with clinically evident colonic ischemia was 2.8% (267 patients). A ruptured AAA occurred in 15.2% of the patients, (Tables I and II). EVAR was performed in 6,710 (71.1%) cases, and 2,723 patients (28.9%) underwent open repair. The occurrence of colonic ischemia was significantly higher (7.6% vs. 0.9%; $P < 0.001$) after open repair than EVAR. After stratification by urgency of the procedure, the occurrence remained significantly higher in the open group for both intact (4.2% vs. 0.4%; $P < 0.001$) and ruptured repair (15.0% vs. 6.2%); $P < 0.001$).

Baseline Characteristics

Patients with intestinal ischemia treated with EVAR for intact aneurysms had a larger aneurysm size (67.4 vs. 61.9 mm; $P = 0.007$) and more frequently a history of pulmonary disease (56.0 vs. 26.5%, $P < 0.001$). Patients with bowel ischemia after open repair of an intact AAA were older (74.4 vs. 70.8 years; $P < 0.001$) and contained more women (29.9% vs. 18.9%; $P = 0.016$). Such as the ischemia in the EVAR group, the open ischemia group counted more patients with a history of pulmonary disease (35.1% vs. 21.8%; $P = 0.006$). Among patients with intestinal ischemia treated with EVAR for ruptured AAA, no significant differences were found. Patients with bowel ischemia treated with open repair for an AAA were more often women (20.8% vs. 13.5%, $P = 0.031$), more often had a history of pulmonary disease (23.8% vs. 14.6%; $P = 0.008$), and more often had diabetes mellitus (23.3% vs. 9.9%; $P = 0.031$). Tables I and II show the baseline characteristics. Significant *P*-values are shown in bold.

Postoperative Outcome

Patients with intestinal ischemia had a higher 30-day mortality (50.6% vs. 5.1%, $P < 0.001$). After stratification for urgency and procedure type, this difference remained significant: intact AAA EVAR (44.0% vs. 1.0%, $P < 0.001$), intact open repair (50.6% vs. 4.9%), $P < 00.1$), ruptured EVAR (62.9% vs. 20.0%, $P < 0.001$), and ruptured open repair (48.8% vs. 28.7%, $P < 0.001$).

Predictors of Intestinal Ischemia

Table III shows the results of the multivariate analysis. Ruptured aneurysm was the most important independent predictor of intestinal ischemia (OR = 5.9). The only demographic characteristic with a predictive value for developing intestinal ischemia was the female gender (OR = 1.7). Younger age (<68 years) was associated with a lower risk. Patients aged 68–74 years were at highest risk for developing intestinal ischemia (OR = 1.9). Of the preoperative comorbidities analyzed, having PAD (OR = 2.4), renal insufficiency (OR = 1.7), or having a pulmonary history (OR = 1.6) were identified as risk factors. Procedural factors that influence developing intestinal ischemia were blood loss >1000 mL (OR = 3.6), prolonged operating time (OR = 2.0), and open repair (OR = 2.0). Having a suprarenal AAA was also associated with a higher risk (OR = 3.4).

Prediction Model

With the use of beta coefficient (B), a prediction model for the risk of developing intestinal ischemia was created. All variables listed in Table III were included in this model. A high risk score indicates a high chance of developing postoperative intestinal ischemia. Table IV shows an example of how the score is calculated. In this study, the highest risk score was 16. The median score was 4.01 (2.00–6.00 IQR). The patients in this study were divided into 4 groups shown in Table V.

Predictive Value of the Model

The percentage of correct classification was 97.2% with a cutoff value of 0.5. The AUC for the score showed a very good predictive value: AUC = 0.873 (95% CI 0.855–0.892).

DISCUSSION

General Discussion

Postoperative intestinal ischemia is a well-known complication after AAA repair and associated with high mortality. This cohort study identified several predictors for developing intestinal ischemia, indicating it has a multifactorial origin. The 30-day mortality for patients with intestinal ischemia was increased by a factor 10 compared with patients who did not develop intestinal ischemia. This study has also formulated a prediction model to calculate which patients would be at high risk for developing intestinal ischemia. This study was based on nearly

Table I. Baseline characteristics intact AAA

	Intact AAA (n = 7,998)					
	EVAR			Open		
	Bowel ischemia			Bowel ischemia		
↓ variables	Yes (n = 25)	No (n = 6,119)	P Value	Yes (n = 77)	No (n = 1,777)	P value
Age, years	73.6 (5.5)	74.0 (7.6)	0.76	74.4 (6.0)	70.8 (7.6)	**<0.001**
Female gender	5 (20)	811 (13)	0.32	23 (30)	335 (19)	**0.016**
Size aneurysm	67.4 (14.8)	61.9 (10.9)	**0.007**	65.7 (13.0)	65.4 (13.7)	0.88
Cardiac history	15 (60)	3,053 (50)	0.31	42 (54)	903 (51)	0.52
Hypertension[a]	4 (80)	1,158 (72)	0.68	18 (87)	315 (78)	0.22
Pulmonary history	14 (56)	1,621 (27)	**0.001**	27 (35)	388 (22)	**0.006**
RI$[a]	2 (40)	328 (20)	0.28	4 (19)	78 (18)	0.91
Diabetes[a]	1 (17)	267 (16)	0.98	1 (5)	53 (12)	0.31
Malignancy						
Never	19 (76)	4,889 (79)		63 (82)	1,534 (86)	
Past treatment	4 (16)	914 (15)	0.80	10 (13)	187 (11)	0.46
Current treatment	2 (8)	316 (5)		4 (5)	56 (3)	
Smoking[a]						
Never	2 (40)	317 (20)		5 (24)	83 (19)	
Past	3 (60)	777 (50)	0.29	6 (29)	163 (38)	0.67
Current	0 (0)	457 (30)		10 (48)	182 (43)	

Bold indicates P values with a value of <0.005.
[a]Extended registry. Categorical variables in number (%) and continuous variables in mean and standard deviation (SD). $RI, renal insufficiency.

Table II. Baseline characteristics ruptured AAA

	Ruptured AAA[b] (n = 1,435)					
	EVAR			Open		
	Bowel ischemia			Bowel ischemia		
↓ variables	Yes (n = 35)	No (n = 531)	P value	Yes (n = 130)	No (n = 739)	P value
Age, years	75.8 (7.1)	74.7 (8.6)	0.45	74.1 (6.7)	73.6 (8.0)	0.47
Female gender	4 (11)	69 (13)	0.79	27 (21)	100 (14)	**0.031**
Size aneurysm	78.4 (12.7)	76.0 (15.7)	0.38	80.1 (16.2)	80.5 (16.3)	0.47
Cardiac history	16 (46)	215 (41)	0.54	48 (37)	266 (36)	0.84
Hypertension[a]	2 (29)	87 (63)	0.66	15 (56)	115 (59)	0.76
Pulmonary history	4 (11)	116 (22)	0.14	31 (24)	108 (15)	**0.008**
RI$[a]	2 (29)	29 (22)	0.66	5 (17)	25 (12)	0.47
Diabetes[a]	0 (0)	26 (18)	0.19	7 (23)	21 (10)	**0.031**
Malignancy						
Never	29 (83)	461 (87)		112 (87)	679 (92)	
Past treatment	5 (14)	44 (8)	0.43	13 (10)	46 (6)	0.10
Current treatment	1 (3)	26 (5)		5 (4)	14 (2)	
Smoking[a]						
Never	1 (17)	37 (31)		7 (26)	46 (26)	
Past	2 (33)	49 (41)	0.072	7 (26)	61 (35)	0.64
Current	3 (50)	33 (28)		13 (50)	71 (40)	

Bold indicates P values with a value of <0.005.
[a]Extended registry. Categorical variables in number (%) and continuous variables in mean and standard deviation (SD).
[b]$RI, renal insufficiency.

10,000 patients who underwent AAA repair in the Netherlands. The overall incidence of intestinal ischemia was 2.8%, which is in agreement with previously published results.[1,2,7,12,15] Previous studies have also reported differences in the occurrence of bowel ischemia when stratifying for

Table III. Predictive risk factors and the matching risk score

Variable	B	Points in risk score	OR	95% CI	Sig
Female gender	0.5	1	1.7	1.2−2.3	<0.001
Age					
68−74	0.6	1	1.9	1.3−2.6	<0.001
>75	0.4	1	1.4	1.0−2.2	0.069
Peripheral arterial[a] disease	0.6	1	1.8	1.1−2.9	0.031
Open repair	1.2	3	3.2	2.2−4.7	<0.001
Length OR >3 hr	0.8	2	2.2	1.6−3.1	<0.001
Blood loss[a]					
100−500 mL	0.4	1	1.5	0.9−2,4	0.081
500−999 mL	0.4	1	1.5	0.8−2.6	0.198
>1000 mL	1.8	2	2.5	1.6−3.8	<0.001
Pulmonary history	0.5	1	1.6	1.2−2.2	<0.001
Renal insufficiency[a]	0.5	1	1.7	1.3−2.2	<0.001
Suprarenal AAA[a]	1.3	3	3.4	1.1−10.6	0.037
Ruptured AAA	1.8	4	5.9	4.4−8.0	<0.001

B, beta coëfficiënt.
[a]Extended registry.

urgency (rupture/intact) and procedure type (open/EVAR). In the present EVAR group, the occurrence of intestinal ischemia was nearly identical with the results from Ultee et al.(12) (0.4% vs. 0.3% and 6.4% vs. 6.2%, respectively) and in line with earlier studies. For open repair, the intestinal ischemia numbers were higher than the literature. Depending on the criteria used to define intestinal ischemia, a variable incidence has been reported in the literature for open aneurysm repair. In all studies, the incidence was clearly higher in the rupture group (8−14%) than elective aneurysm repair (1−3.6%). In our study, intestinal ischemia was defined by clinical presentation which may explain the higher incidence in the current series (4.2% intact and 15% ruptured).

Postoperative Outcome

In accordance with other previous reports,[1−7] the present study found a significant increase in mortality in patients with bowel ischemia (50.6%).

Associated Factors

A strong correlation between ruptured aneurysm and the occurrence of bowel ischemia has been reported.[1,2,7,9,10,12] In this series, rupture was the most important predictor for postoperative intestinal ischemia (OR = 5.9; 95% CI 4.4−8.0). A comparison of EVAR and open repair cannot be performed because decision to perform an open repair may have been made on hemodynamic grounds.[2,25] A great body of literature has addressed the relation between suprarenal clamping and intestinal ischemia.[2,9,11,26] Our series did find a higher risk of colonic ischemia in patients who needed suprarenal clamping (OR = 3.4; 95% CI 1.1−10.6). First, this can be explained by the fact that prolonged suprarenal aortic clamping results in an increased risk of embolization of the SMA.[22] Second, the surgical repair of suprarenal AAAs has proven to lead to more ischemic injury to the kidneys and other organs, including the colon because it requires more extensive aortic exposure.[27]

Procedural Factors

Open aneurysm repair showed an increased risk of developing intestinal ischemia (OR = 2.8; 95% CI 1.9−4.2). This finding was also shown in the studies of Perry et al. and Ultee et al.

As expected, complex procedures with more blood loss and prolonged operating time were independently associated risk factors, which were also demonstrated in prior studies.[2,11,12]

Patient Factors

In line with earlier studies (1, 12), the female gender proved to be a predictor (OR = 1.7; 95% CI 1.2−2.4). This may be explained by differences in vascular anatomy, which reduces EVAR eligibility. Open repair is therefore more often performed in women.[28,29] Female gender has also been associated with increased operative complications in EVAR; difficulties in graft placement,[28,30] and increased risk of microembolization.[31−33] These factors could contribute to an increased risk of developing intestinal ischemia.

Table IV. An example of a risk score of a patient

Predictors	Patient A	Risk score
Gender	Female	1
Age	73 years	1
PAD[a]	No PAD	0
Procedure type	Open repair	3
Length OR	>3 hr	2
Bloos loss[a]	>1000 mL	2
Pulmonary history	No pulmonary history	0
Renal insufficiency[a]	No renal insufficiency	0
Type AAA[a]	Infrarenal	0
Urgency of procedure	Ruptured repair	4
	Total Risk score	12

[a]Extended registry.

An interesting finding was the association between PAD and increased risk of bowel ischemia (OR = 2.4; 95% CI 1.3−4.4) which was not shown in other studies. We chose to include PAD in our enter model because other vascular risk factors (hypertension, cardiac disease, and renal disease) indicate the occurrence of intestinal ischemia is closely related to an increased vascular risk profile.

Another important risk factor (OR = 1.7; 95% CI 1.3−2.2) was pre-existent renal dysfunction, which was also documented in the studies of Bjorck et al. and Becquemin et al. In the study of Ultee et al., it was not an independently associated risk factor in the multivariate analysis; It can only be speculated how chronic renal dysfunction increases the risk of intestinal ischemia in aortic surgery. Bjorck et al. suggested that more inotropic support is used in patients with renal disease during the procedure, which lead to higher incidences of bowel ischemia in two studies.[34,35]

Having a pulmonary medical history is related to an increased incidence in AAAs and an increased occurrence of rupture of the AAA.[36,37] In the series of Becquemin et al. and Ultee et al., having a pulmonary history was associated with a higher occurrence of intestinal ischemia in univariate analysis but was not an independent variable in multivariate analysis. In our series, it was determined as an independent predictor (OR = 1.6; 95% CI 1.2−2.2). Even though an association between chronic obstructive pulmonary disease and intestinal ischemia is described,[38] the mechanism is unclear. It can only be speculated that patients who have a deteriorating oxygen saturation preoperatively are more susceptible to intestinal ischemia. The association could also be linked with exposure to cigarette smoking, which would increase the incidence of systemic small vessel disease. However, smoking

Table V. Postoperative chance of developing colonic ischemia correlated to the risk score

Points in risk score	Chance of developing CI
≤2	0,2%
3−5	1.0%
6−9	5.4%
10+	15.6%

CI, colonic ischemia.

was not established as an independent variable on its own. The studies that have addressed the association between age and postoperative intestinal ischemia have provided contradictory results. Ultee et al. reported a positive association where age per 10 years increased the postoperative risk, the study of Bjorck et al. and the present study found no support for such association. However, a negative association was found for patients younger than 68 years, meaning these patients were less likely to develop intestinal ischemia (OR = 0.5; 95% CI 0.4−0.8).

Prediction Model

Our study has shown that several patient and procedural characteristics influence the risk of developing intestinal ischemia. These independently associated risk factors all give a patient a higher chance of developing intestinal ischemia. The accuracy of the prediction model was shown in Figure 1, with the percentage of correct classification and an excellent AUC. This model can therefore be used to screen patients preoperatively to decide which patients are more likely to develop postoperative bowel ischemia.

A patient with a total risk score of 6−9 was considered to be at increased risk and should be monitored closely by taking clinical measurements regularly and pain assessment scores if possible. Early colonoscopy is suggested in this group of patients. Patients with a score of above 10 were considered to be at high risk and a laparoscopy or laparotomy should be considered early if showing worsening clinical conditions.

Limitations

Limitations of this study are related to the retrospective study design. At first, the choice of hospitals to fill in the extended or the minimal registry. Many possible predictors were only documented in the extended registry, which included 2,624 patients. Another limitation is missing data on several risk factors, with proven significance in previous studies, which were not recorded in the DSAA. Specifically

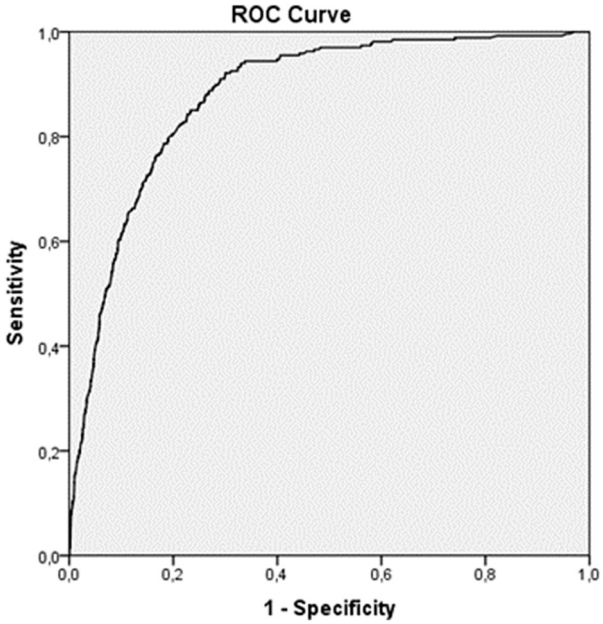

Fig. 1. ROC curve for total risk score.

detailed patient anatomical and operative variables were not recorded, such as whether IMA ligation occurred[9,12] or whether there was hypogastric artery interruption.[15,32,33] In addition, the severity and extent of the intestinal ischemia was not mentioned, even though the degree of intestinal ischemia is said to have large influence on its mortality risk.[39] In addition, it is unknown how many patients needed a bowel resection in this study. In this series, the diagnosis of bowel ischemia could be made by clinical presentation only, where most other studies required a colonoscopy. This makes comparing these studies challenging, and could mean that in our studies more patients were diagnosed with intestinal ischemia.

CONCLUSIONS

In conclusion, this large and population-based cohort study provided evidence that colonic ischemia is associated with a high mortality and that open repair is one of the main risk factors. This prediction model can be used to identify high risk patients early on. With the current trend in AAA repair leaning toward open repair for better long-term results, our prediction model could help clinicians in deciding on AAA treatment strategy.

Future research should supplement our prediction model with additional variables, focusing on anatomical and perioperative factors to increase the reliability of the model.

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