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Risk factors and outcomes of postoperative ischemic colitis in contemporary open and endovascular abdominal aortic aneurysm repair

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Objective: Postoperative ischemic colitis (IC) can be a serious complication following infrarenal abdominal aortic aneurysm (AAA) repair. We sought to identify risk factors and outcomes in patients developing IC after open AAA repair and endovascular aneurysm repair (EVAR).

Methods: The American College of Surgeons National Surgical Quality Improvement Program database was used to examine clinical data of patients undergoing AAA repair from 2011 to 2012 who developed postoperative IC. Multi- variate regression analysis was performed to identify risk factors and outcomes.

Results: We evaluated a cohort of 3486 patients who underwent AAA repair (11.6% open repair and 88.4% EVAR). The incidence of postoperative IC was 2.2% (5.2% for open repair and 1.8% for EVAR). Surgical treatment was needed in 49.3% of patients who developed IC. The mortality of patients with IC was higher than that of patients without IC (adjusted odds ratio [AOR], 4.23; 95% confidence interval [CI], 2.26-7.92; P <.01). The need for surgical treatment (AOR, 7.77; 95% CI, 2.08-28.98; P <.01) and age (AOR, 1.11; 95% CI, 1.01-1.22; P [.01) were mortality predictors of IC patients. Predictive factors of IC included need for intraoperative or postoperative transfusion (AOR, 6; 95% CI, 3.08- 11.72; P <.01), rupture of the aneurysm before surgery (AOR, 4.07; 95% CI, 1.78-9.31; P <.01), renal failure requiring dialysis (AOR, 3.86; 95% CI, 1.18-12.62; P [.02), proximal extension of the aneurysm (AOR, 2.19; 95% CI, 1.04-4.59; P [.03), diabetes (AOR, 1.87; 95% CI, 1.01-3.46; P [.04), and female gender (AOR, 1.75; 95% CI, 1.01-3.02; P [.04). Although open AAA repair had three times higher rate of postoperative IC compared with endovascular repair, in multivariate analysis we did not find any statistically significant difference between open repair and EVAR in the development of IC (5.2% vs 1.8%; AOR, 1.25; 95% CI, 0.70-2.25; P [.43).

Conclusions: Postoperative IC has a rate of 2.2% after AAA repair. However, it is associated with 38.7% mortality rate. Rupture of the aneurysm before surgery, need for transfusion, proximal extension of the aneurysm, renal failure requiring dialysis, diabetes, and female gender were significant predictors of postoperative IC. AAA patients who develop IC have four times higher mortality compared with those without IC. Surgical treatment is needed in nearly 50% of IC patients and is a predictor of higher mortality. (J Vasc Surg 2016;63:866-72.)

The development of ischemic colitis (IC) after abdominal aortic aneurysm (AAA) repair is one of the most severe postoperative complications, with a prevalence rate of 2.9%. It has been shown to increase morbidity, mortality, length of hospitalization, and health care costs for patients undergoing aneurysm repair.[1-3] This is also a highly lethal complication, with the mortality of patients developing post- operative IC exceeding 50%.[1,2] Because of these significant rates, it is important to identify possible risk factors that may exacerbate this complication as well as diminish it.

A number of previous studies have identified risk factors contributing to IC after AAA repair in an attempt to control for the extensive morbidity and mortality associated with it. Some of the IC predictors previously identified include aneurysm rupture, preoperative renal insufficiency, preoperative respiratory insufficiency, and duration of operation.[1,2] However, the majority of the literature has shown limited results secondary to small sample sizes, making it difficult to form any conclusions. In addition, there is limited literature evaluating the difference between outcomes in open and endovascular re- pairs in regard to IC. These studies have demonstrated a higher rate of IC in open AAA repair compared with endovascular aneurysm repair (EVAR).[1-3] However, because of the small sample size and inability to perform proper multivariate analysis as well as to adjust for certain factors, further studies are necessary. Therefore, it has been hypothesized that the use of a large nationwide database will allow a deeper and more insightful analysis of patients suffering from postoperative IC. Finally, there is continued controversy about the necessity for reimplantation of the inferior mesenteric artery (IMA) during open AAA repair.[2] A number of studies have reported no benefit of routine reimplantation of the IMA in AAA repair.[4,5] However, there have been reports of decreased postoperative IC with selective implantation of the IMA during AAA repair.[6] In this study, we aimed to report on the incidence, risk factors, and outcomes associated with IC in patients undergoing AAA repair as well as to compare IC in EVAR vs open AAA repair and to investigate outcomes of the reimplantation or reconstruction of the IMA during open AAA repair.

METHODS

This study was performed using the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database[7] from January 1, 2011, to December 31, 2012. ACS NSQIP is a nationally validated, risk-adjusted, outcomes-based program to measure and to improve the quality of surgical care in the United States.[7] It allows the identification of 30-day postoperative surgical outcomes based on clinical data. The NSQIP database is exempt from requiring informed consent from individual patients and is covered within the individual hospital's patient consent forms. Approval for the use of the NSQIP patient- level data in this study was obtained from the Institutional Review Board of the University of California, Irvine Medical Center and NSQIP. Patients were identified who had under- gone open and endovascular AAA repair using the ACS NSQIP target and general files. The variables of the study were chosen from the list of the original variables within the NSQIP database for AAA repair. Overall, 3734 patients in NSQIP 2011 and 2012 databases underwent AAA repair and had documentation of the presence or absence of post- operative IC in their medical records; 248 patients who were identified as younger than 18 years were excluded from the study, leaving 3486 patients for further evaluation. We then separated patients who suffered postoperative IC from patients who did not develop the complication of IC.

Interpretation of the database. Postoperative IC was defined according to the NSQIP definition: if there was a report of a sigmoidoscopy or colonoscopy performed after the AAA repair documenting ischemia of the colon wall or if the discharge summary or inpatient medical record indicated that the patient had postoperative IC. In regard to the management of the IMA, this was defined according to the following definitions in the surgeon's operative report: suture ligation from within the aneurysm sac; external ligation of the IMA close to the AAA wall; over- sewing of the IMA; or tying of the IMA. For endovascular cases, the definition for IMA occlusion was the absence of "back bleeding" from the IMA noted in the surgeon's operative report. For the cases in which the IMA was reimplanted, key words included "the IMA is reimplanted (anastomosed) to the aortic graft."

Preoperative factors that were analyzed included patient age, sex, race, and nine comorbidity conditions, which included congestive heart failure within 30 days before surgery, pre-existing renal failure requiring dialysis within 2 weeks before surgery, diabetes mellitus, weight loss of >10% in the last 6 months, steroid use for any chronic condition, history of severe chronic obstructive pulmonary disease, current smoking status within 1 year, moderate or severe dyspnea, and hypertension requiring medication. Other factors analyzed included rupture of the aneurysm before surgery, need for intraoperative or postoperative blood transfusion, need for >4 units of packed red blood cell transfusion before surgery, admission type (emergent vs nonemergent), proximal extension of the aneurysm (suprarenal vs infrarenal), operative technique (open vs endovascular), IMA patency (chronically occluded, reconstructed, or ligated during surgery), hypogastric artery revascularization, hypogastric artery embolization, aortic aneurysm diameter, and aortic clamp location (suprarenal vs infrarenal). Outcomes analyzed included mortality and hospitalization length. The overall rate of postoperative IC by procedure type (open vs endovascular) was examined, and subanalysis of the data to find risk factors in both groups of open repair and EVAR was performed. Risk-adjusted analysis was performed to identify independent predictors of postoperative IC after AAA repair.

Statistical analysis. Statistical analysis was performed with SPSS software, version 22 (IBM Corp, Armonk, NY). Logistic regression was used to describe the weights assigned to variables that best discriminate patients with IC from those without. *P* values < .05 were considered statistically significant. For each variable, the adjusted odds ratio (AOR) with a 95% confidence interval (CI) was calculated and reported to estimate the relative risk. All variables that had significant association with postoperative IC by univariate analysis or had significant difference rates between EVAR and open AAA repair groups by univariate analysis were entered in logistic regression for multivariate analysis. Adjustments were made for the nine comorbid conditions. Logistic regression was also used to adjust risk of mortality in the presence of an IC complication.

RESULTS

In 2011 and 2012, 3486 patients underwent AAA repair (11.6% open repair and 88.4% EVAR). The mean age of patients was 74 years, with a standard deviation of 9 years; 64.9% of patients were older than 70 years. The majority of patients were white (87.3%) and male (78.7%). However, female patients had higher rates of ruptured aneurysm (4.7% vs 4.5%), proximal extension of the aneurysm (5.8% vs 4.8%), and chronically occluded IMA (3.1% vs 2%) compared with male patients. Most common comorbidities included hypertension (79.9%), chronic obstructive pulmonary disease (19.9%), and diabetes mellitus (15.1%). Complete demographic data of patients are reported in Table I.

Patients who underwent open AAA repair had 4 days longer mean hospitalization compared with patients who underwent endovascular repair (95% CI, 3-5; *P* < .01). Also, patients who underwent open repair had higher rates of diabetes, emergency admission, preoperative packed cell transfusion >4 units, intraoperative or postoperative transfusion, ruptured aneurysm before surgery, proximal extension of the aneurysm, and aortic aneurysm diameter >7 cm (Table II).

Of the patients who underwent AAA repair, 75 patients (2.2%) developed postoperative IC. Incidence of IC in open AAA repair and EVAR was 5.2% and 1.8%, respectively. The complication was diagnosed in the majority of patients in the first 4 days after surgery (77.3%), and only in 7.5% of cases did the complication present after the first week of surgery (Fig). The median time of diagnosis of IC for both open and endovascular AAA repair was postoperative day 2. For patients who suffered from IC, the mean length of stay in the hospital was 20 6 22 days, whereas for patients without IC, it was 5 6 7 days. The adjusted mean difference in hospitalization was 12 days (95% CI, 9-13; P < .01).

In patients who underwent an open AAA repair, 43 (10.64%) had a chronically occluded IMA, of whom 2 (4.7%) had postoperative IC. Ligation of the IMA was performed in 150 patients (37.1%), of whom 11 (7.3%) developed postoperative IC. Ligation and reimplantation of the IMA was performed in 23 patients (5.7%). None in this group developed postoperative IC. Visceral (superior mesenteric and celiac) revascularization was performed in 16 patients (4%) undergoing open AAA repair, of whom 1 (6.25%) developed postoperative IC.

The unadjusted mortality rate in patients with or without IC was 38.7% and 4.3%, respectively. The adjusted risk of mortality in patients with IC was estimated to be more than four times than in those patients without IC (AOR, 4.23; 95% CI, 2.26-7.92; P < .01).

Of the patients who underwent EVAR, 21 patients (0.7%) had conversion to open surgery, of whom 5 (23.8%) had ruptured aneurysm and 7 (33.3%) had aneurysm >7 cm. Despite the need for open conversion, none of them developed postoperative IC. However, patients who had a converted procedure had a seven times higher mortality risk compared with patients who had successfully completed an endovascular procedure (38.1% vs 4.3%; AOR,

Table I. Demographics of patients who had abdominal aortic aneurysm (AAA) surgery

Variables	*Patients without IC (n = 3411)*	*Patients with IC (n = 75)*	P *value*
Age			
Mean ± standard deviation, years	74 ± 9	73 ± 9	.69
Median, years	74	73	—
Sex			
Female	717 (21)	25 (33.3)	.01
Race			
White	2979 (87.3)	66 (88)	.79
Black or African American	164 (4.8)	1 (1.3)	.16
Asian	83 (2.4)	4 (5.3)	.11
Other	8 (0.2)	0	.67
Comorbidity			
Weight loss	47 (1.4)	1 (1.3)	.97
Renal failure requiring dialysis	36 (1.1)	4 (5.3)	<.01
Congestive heart failure	63 (1.8)	0	.23
Steroid use	154 (4.5)	5 (6.7)	.37
Hypertension	2729 (80)	56 (74.7)	.25
Bleeding disorder	407 (11.9)	16 (21.3)	.01
Smoke	1129 (33.1)	32 (42.7)	.08
Chronic obstructive pulmonary disease	676 (19.8)	17 (22.7)	.54
Dyspnea	571 (16.7)	7 (9.3)	.08
Diabetes mellitus	511 (15)	15 (20)	.23
Admission			
Emergency admission	390 (11.4)	35 (46.7)	<.01
Repair techniques			
Endovascular	3028 (88.7)	54 (72)	<.01
Open	383 (11.2)	21 (28)	<.01
Transfusion			
Preoperative packed cell transfusion > 4 units	103 (3)	13 (17.3)	<.01
Intraoperative or postoperative transfusion	1013 (29.7)	62 (82.7)	<.01
Aneurysmal factors			
Ruptured aneurysm	133 (3.9)	26 (34.7)	<.01
Aortic aneurysm diameter > 7 cm	556 (16.3)	29 (38.7)	<.01
Operative details (open repair)			
Proximal extended aneurysm	34 (8.9)	5 (23.8)	.02
Ligation of IMA	139 (36.3)	11 (52.4)	.22
Chronically occluded IMA	41 (10.7)	2 (9.5)	.67
Reimplantation of IMA	23 (6)	0	.19
Visceral revascularization[a]	15 (3.9)	1 (4.8)	.84
Suprarenal aortic clamp	89 (23.2)	10 (47.6)	.01
Operative details (EVAR)			
Proximal extended aneurysm	132 (4.4)	34 (8.9)	.08
Hypogastric artery embolization	189 (6.2)	2 (3.7)	.83
Hypogastric artery revascularization	131 (4.3)	0	.26

EVAR, Endovascular aneurysm repair; *IC*, ischemic colitis; *IMA*, inferior mesenteric artery.
Categorical variables are presented as number (%).
[a]Superior mesenteric and celiac revascularization.

Table II. Comparison of variables between open abdominal aortic aneurysm (*AAA*) repair and endovascular aneurysm repair (*EVAR*)

Variables	*Patients who underwent open AAA repair (n = 404)*	*Patients who underwent EVAR (n = 3082)*	P *value*
Age			
Mean ± standard deviation, years	71 ± 9	74 ± 9	<.01
Median, years	71	74	—
Sex			
Female	96 (23.8)	646 (21)	.19
Race			
White	341 (84.4)	2704 (87.7)	.46
Black or African American	23 (5.7)	142 (4.6)	.27
Asian	9 (2.2)	78 (2.5)	.77
Other	1 (0.2)	7 (0.2)	.91
Comorbidity			
Weight loss	8 (2)	40 (1.3)	.26
Renal failure requiring dialysis	5 (1.2)	35 (1.1)	.85
Congestive heart failure	10 (2.5)	53 (1.7)	.28
Steroid use	12 (3)	147 (4.8)	.10
Hypertension	329 (81.4)	2456 (79.7)	.41
Bleeding disorder	40 (9.9)	383 (12.4)	.14
Smoke	184 (45.5)	977 (31.7)	<.01
Chronic obstructive pulmonary disease	86 (21.3)	607 (19.7)	.45
Dyspnea	53 (13.1)	525 (17)	.04
Diabetes mellitus	46 (11.4)	480 (15.6)	.02
Admission			
Emergency admission	81 (20)	344 (11.2)	<.01
Transfusion			
Preoperative packed cell transfusion > 4 units	24 (5.9)	92 (3)	<.01
Intraoperative or postoperative transfusion	302 (74.8)	773 (25.1)	<.01
Aneurysmal factors			
Ruptured aneurysm	39 (9.7)	120 (3.9)	<.01
Proximal extended aneurysm	39 (9.7)	137 (4.4)	<.01
Aortic aneurysm diameter > 7 cm	125 (30.9)	460 (14.9)	<.01

Categorical variables are presented as number (%).

7.43; 95% CI, 2.21-25.22; P < .01). Also, patients who underwent converted procedures had longer hospitalization compared with patients who had successfully completed endovascular repair (mean difference, 3 days; 95% CI, 3-7 days; P < .01).

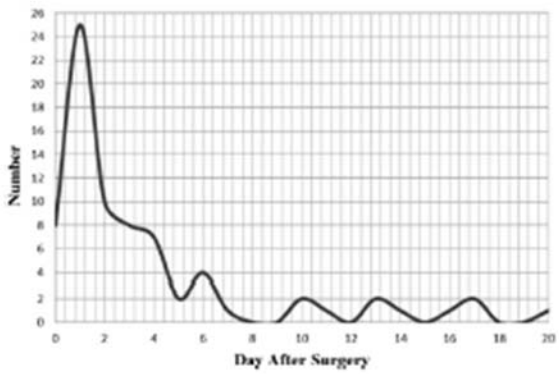

Fig. Frequency of diagnosis of ischemic colitis (IC) based on postoperative day.

Table III. Risk-adjusted analysis of factors associated with postoperative ischemic colitis (IC) in open abdominal aortic aneurysm (AAA) repair and endovascular aneurysm repair (EVAR)

Variables	*AOR*	*95% CI*	P *value*
Age	0.98	0.95-1.01	.29
Sex			
Female	1.75	1.01-3.02	.04
Comorbidity			
Renal failure requiring dialysis	3.86	1.18-12.62	.02
Bleeding disorder	1.58	0.85-2.94	.14
Smoke	1.29	0.76-2.21	.33
Dyspnea	0.53	0.23-1.20	.12
Diabetes mellitus	1.87	1.01-3.46	.04
Repair technique			
Endovascular			
Open	1.25	0.70-2.25	.43
Admission			
Emergency admission	1.54	0.74-3.22	.24
Transfusion			
Preoperative packed cell transfusion > 4 units	1.04	0.46-2.37	.90
Intraoperative or postoperative transfusion	6	3.08-11.72	<.01
Aneurysmal factors			
Ruptured aneurysm	4.07	1.78-9.31	<.01
Proximal extended aneurysm	2.19	1.04-4.59	.03
Aortic aneurysm diameter > 7 cm	1.19	0.65-2.15	.56

AOR, Adjusted odds ratio; *CI*, confidence interval.

Table IV. Risk-adjusted analysis of factors associated with postoperative ischemic colitis (IC) in open abdominal aortic aneurysm (AAA) repair

Variables	*AOR*	*95% CI*	P *value*
Age	0.98	0.94-1.03	.57
Sex			
Female	2.01	0.83-4.84	.11
Comorbidity			
Renal failure requiring dialysis	47.19	1.48-1496.72	.02
Bleeding disorder	3.11	1.06-9.11	.03
Smoke	1.50	0.63-3.56	.35
Dyspnea	0.68	0.17-2.63	.57
Diabetes mellitus	3.42	1.25-9.35	.01
Admission			
Emergency admission	0.68	0.17-2.66	.58
Transfusion			
Preoperative packed cell transfusion > 4 units	1.04	0.28-3.86	.95
Intraoperative or postoperative transfusion	2.18	0.60-7.89	.23
IMA patency			
Reimplantation	Reference	Reference	Reference
Chronically occluded	—[a]	—[a]	1.00
Ligated	—[a]	—[a]	.99
Other factors			
Ruptured aneurysm	7.75	1.90-31.66	<.01
Proximal extended aneurysm	3.35	1.17-9.63	.02
Suprarenal aortic clamp location	1.69	0.71-4.01	.22
Visceral revascularization	0.67	0.09-4.88	.69
Aortic aneurysm diameter > 7 cm	2.42	0.94-6.23	.06

AOR, Adjusted odds ratio; *CI*, confidence interval; *IMA*, inferior mesenteric artery.

[a]As *P* value is close to 1, there is not any reportable AOR and 95% CI.

Hypogastric revascularization was performed for 134 patients (4.3%) who had an EVAR. Despite hypogastric artery revascularization, three patients (2.2%) developed IC, of whom one patient required subsequent bowel resection. Also, hypogastric embolization was performed for 191 patients (6.2%) who had EVAR, of whom 2 patients (1%) developed IC.

In multivariate analysis with risk adjustment, six variables were shown to significantly discriminate between patients with and with postoperative IC. These included gender, renal failure, need for intraoperative or postoperative transfusion, diabetes, proximal extension of the aneurysm, and rupture of the aneurysm before surgery (Table III).

When data in open AAA repair and EVAR were analyzed separately, renal failure and rupture of the aneurysm for open AAA repair were the most important predictors of IC, whereas the need for transfusion and rupture of the aneurysm were the most important predictors in patients undergoing EVAR. Tables IV and V report the predictors of IC in EVAR and open AAA repair.

Approximately half of the patients with postoperative IC were treated nonsurgically (n 38; 50.7%). Among 37 patients who underwent surgical treatment, 21 patients (56.8%) died during that hospitalization. Factors that were associated with mortality of patients who developed post- operative IC are reported in Table VI.

Table V. Risk-adjusted analysis of factors associated with postoperative ischemic colitis (IC) in endovascular aneurysm repair (EVAR)

Variables	*AOR*	*95% CI*	*P value*
Age	1.01	0.96-1.06	.59
Sex			
Female	1.33	0.55-3.19	.52
Comorbidity			
Renal failure need to dialysis	2.26	0.38-13.20	.36
Bleeding disorder	1.27	0.50-3.20	.60
Smoke	1.66	0.69-3.97	.25
Dyspnea	0.55	0.16-1.94	.36
Diabetes mellitus	1.64	0.62-4.34	.31
Admission			
Emergency admission	3.20	1.04-9.87	.04
Transfusion			
Preoperative packed cell transfusion > 4 units	1.82	0.55-6	.32
Intraoperative or postoperative transfusion	4.73	1.88-11.87	<.01
Hypogastric artery patency			
Hypogastric artery revascularization	1.14	0.26-4.90	.85
Hypogastric artery embolization	0.62	0.12-3.15	.56
Aneurysmal factors			
Ruptured aneurysm	3.41	1.002-11.64	.04
Proximal extended aneurysm	2.55	0.56-11.59	.22
Aortic aneurysm diameter > 7 cm	0.68	0.26-1.79	.44

AOR, Adjusted odds ratio; *CI*, confidence interval.

Table VI. Risk-adjusted analysis of mortality predictors of patients with complication of ischemic colitis (IC) in abdominal aortic aneurysm (AAA) repair

Variables	*AOR*	*95% CI*	*P value*
Sex			
Male	Reference	Reference	Reference
Female	0.52	0.12-2.20	.37
Age	1.11	1.01-1.22	.01
Comorbidity			
No comorbidities	Reference	Reference	Reference
Renal failure need to dialysis	0	—	.99
Bleeding disorder	0.74	0.13-4.10	.73
Diabetes	0.74	0.14-3.84	.72
Dyspnea	7.89	0.95-2.43	.06
Smoke	0.65	0.11-3.97	.55
Admission			
Emergency	0.74	0.08-6.37	.79
Aneurysmal factors			
Ruptured aneurysm	0.71	0.07-6.98	.77
Aortic aneurysm diameter > 7 cm	3.05	0.70-13.31	.13
Proximal extended aneurysm	0.67	0.11-3.97	.66
Treatment of ischemic colitis			
Medical treatment	Reference	Reference	Reference
Surgical treatment	7.77	2.08-28.98	<.01
Transfusion			
Transfusion > 4 units	2.32	0.30-17.65	.41
Intraoperative or postoperative transfusion	2.55	0.34-18.92	.35

AOR, Adjusted odds ratio; *CI*, confidence interval.

DISCUSSION

Postoperative IC after AAA repair is associated with a poor prognosis, significant mortality risk, and increased hospital length of stay. The in-hospital mortality rate of patients undergoing AAA repair who suffer from postoperative IC was more than four times higher on an adjusted basis than that of patients who did not develop IC. Similar to previous studies, IC was also found to be significantly associated with increased mean hospitalization length of the affected patients (mean difference, 12 days; 95% CI, 9-13). The median time to diagnosis of IC was postoperative day 2, with the majority of patients being diagnosed within the first 4 postoperative days (77.3%). This is the most critical time in a patient's hospitalization when physicians must be aware of this significant complication (Fig).

EVAR has the contemporary rate of 88.4% of all aortic aneurysmal repairs. This is in line with previous reports that demonstrate a significant shift toward an endovascular approach in the repair of infrarenal AAA.[8,9] Albuquerque et al[9] reported that 84% of AAA repairs were performed with EVAR between 2005 and 2008. Our data, which represent the largest to date on this topic, demonstrate that six perioperative variables in multivariate analysis are associated with IC (renal failure, proximal aneurysm extension [suprarenal], ruptured aneurysm before surgery, diabetes, bleeding disorder, intraoperative or postoperative transfusion). Also, this study confirmed the previously reported association between the development of IC with aneurysm rupture and preoperative renal insufficiency by literature.[1-3,5,10] The strongest associations between IC and the risk variables were intraoperative or postoperative need for transfusion and rupture of the aneurysm before surgery. Because of the inability to reduce the nature of the reported risk factors, it is difficult to determine protective methods. Reimplantation of the IMA during open repair and revascularization of the hypogastric artery during EVAR in patients with multiple risk factors may decrease the risk of postoperative IC; however, further studies on this topic are necessary.

Our data on patient-specific factors show that female gender has a higher risk of postoperative IC compared with male gender. This is consistent with other reports of higher incidence of IC in female gender.[3,10] Surprisingly, this study found higher rates of ruptured aneurysm, proximal extended aneurysm, and a chronically occluded IMA in female patients at the time of surgery. Further studies are indicated to identify if anatomic or disease-specific factors in female gender affect the likelihood of postoperative IC.

We also found the comorbidity of renal failure to be strongly associated with postoperative IC. Patients with renal failure have more than five times increased risk of postoperative IC. This is in line with the report of kidney dysfunction as an independent predictor of IC by Becquemin et al.[1]

Rupture of the aneurysm before surgery and need for intraoperative or postoperative transfusion were the most important perioperative factors that increased the risk of IC by more than four times. The associations may be related to the interruption of IMA blood flow in patients with ruptured aneurysm or need for transfusion.[11] Hagihara et al[11] reported interruption of IMA blood flow as one of the important causes of IC. Considering that the introduced risk factors are not reducible, reimplantation of the IMA or revascularization of the hypogastric artery in patients with ruptured aneurysms requiring significant transfusion may reduce the risk of postoperative IC.

Although the frequency of IC in open AAA repair was nearly three times greater than in EVAR, after adjustment using multivariate analysis, we were unable to identify a statistically significant association between open repair and postoperative IC. Comparison of variables in open repair and EVAR in our study showed that patients who underwent open repair had a higher rate of emergency admission, preoperative packed cell transfusion >4 units, intraoperative or postoperative blood transfusion, ruptured aneurysm before surgery, proximal extension of the aneurysm, and aortic aneurysm diameter >7 cm compared with EVAR. Three of the variables (need for transfusion, proximal extension of the aneurysm, and ruptured aneurysms) were significant predictors of IC after AAA repair. Our data show that the higher IC rate in open AAA repair compared with EVAR is related to the higher rates of the three risk factors in open repair (need for transfusion, proximal extension of the aneurysm, and ruptured aneurysm). This is consistent with a previous report of IC risk in open surgery compared with EVAR by Becquemin et al.[1] They did not find any associations between open surgery and postoperative IC.

Patients with chronically occluded or ligated IMA during surgery have higher incidence of postoperative IC. Although patients with occluded or ligated IMA had a higher incidence rate of IC in the multivariate analysis, we could not demonstrate statistically significant associations between occluded or ligated IMA and postoperative IC. This can be related to the limited number of patients who had an occluded IMA or who had IMA ligation during surgery in this study. It also demonstrates that the majority of patients had collateral blood flow, which is able to perfuse the distal colon without the IMA.

Patients who had reimplantation of the IMA did not have any report of postoperative IC. However, in multivariate analysis of the data, we could not find that reimplantation of the IMA was a protective factor for development of IC because of the limited number of patients. Previously, Senekowitsch et al[10] evaluated 160 patients who underwent AAA repair and could not find any significant difference in risk of postoperative IC in patients who had reimplantation or ligation of the IMA. However, the authors concluded that reimplantation of the IMA does not increase perioperative morbidity or operation time, and they suggested reimplantation in older patients and patients with increased intraoperative blood loss. Considering that almost all of the risk factors for IC introduced by this study are not reducible, discovering the role of reimplantation of the IMA is important. High-risk patients may benefit from reimplantation of the IMA, and further studies are indicated to determine if reimplantation of the IMA in high-risk patients undergoing open AAA repair can decrease the rate of postoperative IC.

Conversion of endovascular repair to open repair is associated with higher mortality and longer hospitalization. Although no patients who underwent a converted procedure developed IC in our study, mortality risk of such patients increased by more than seven times. Further studies are indicated to evaluate the association between the reasons of endovascular procedure conversion and mortality of patients.

Among patients who developed complications of IC, elderly patients who need surgical treatment had the highest mortality rate. Nonsurgical management was performed in half of patients developing IC (50.7%), and surgery was performed in 49.3% of patients. Need for subsequent surgical treatment was the worst prognostic factor, which correlated with an increased mortality of patients by more than seven times. In line with the literature, age was also found to be significantly associated with increased mortality of patients.[3]

Study limitations. This study is a retrospective review and is therefore subject to the inherent biases for retrospective studies, such as selection bias. Data in this study were extracted from the NSQIP database, which collects data from >500 hospitals in the United States with a wide variety of hospital settings and surgeon expertise, which can affect the results. Patients in this study did not form a homogeneous group because of the different indications for open AAA repair and EVAR.[12] The NSQIP database did not provide information on whether the visceral or hypogastric revascularizations were performed at the time of the initial operation or were done sometime within the 30-day postoperative course. There were a significant number of unreported cases regarding patency of the IMA during open repair, which also limits the conclusion for this topic. Even though postoperative IC occurred at a higher rate in patients who had a ligated IMA, in multivariate analysis we did not find statistically significant associations between the patency of the IMA and postoperative IC because of the limited number of patients. Also, details were not available in patients undergoing hypogastric revascularization as to whether a branched iliac device or internal-external iliac bypass was performed or of the patency of the revascularization postoperatively. Finally, the NSQIP database extends to only 30 days postoperatively, and therefore long-term complications cannot be measured. Despite these limitations, this study is the first to report on postoperative IC in AAA repair in this population subset.

CONCLUSIONS

AAA operations complicated by postoperative IC are uncommon (incidence rate of 2.2%) but carry an associated mortality rate of 38.7%. Although the frequency of IC in open AAA repair was nearly three times greater than in EVAR, after adjustment using multivariate analysis, there was no statistically significant association between open repair and postoperative IC compared with endovascular repair. Close surveillance of patients, especially patients with multiple risk factors in the first 4 days after surgery, is recommended because 77.3% of patients were diagnosed in the first 4 days after the procedure. Considering the unreducible nature of many of the reported risk factors in this study, reimplantation of the IMA during open repair and revascularization of the hypogastric artery during EVAR in patients with multiple risk factors may decrease the risk of postoperative IC after AAA repair. However, further studies are indicated to determine if the reimplantation of the IMA or revascularization of the hypogastric artery can decrease the rate of postoperative IC.

AUTHOR CONTRIBUTIONS

Conception and design: ZM, MDS, MJS, RF
Analysis and interpretation: ZM, MDS, SC, NK, MJS, RF
Data collection: ZM
Writing the article: ZM, MDS, SC, NK, MJS, RF
Critical revision of the article: ZM, MDS, SC, NK, MJS, RF
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REFERENCES

1. Becquemin JP, Majewski M, Fermani N, Marzelle J, Desgrandes P, Allaire E, et al. Colon ischemia following abdominal aortic aneurysm repair in the era of endovascular abdominal aortic repair. J Vasc Surg 2008;47:258-63; discussion: 263.
2. Steele SR. Ischemic colitis complicating major vascular surgery. Surg Clin North Am 2007;87:1099-114. ix.
3. Perry RJ, Martin MJ, Eckert MJ, Sohn VY, Steele SR. Colonic ischemia complicating open vs endovascular abdominal aortic aneurysm repair. J Vasc Surg 2008;48:272-7.
4. Kaiser MM, Wenk H, Sassen R, Müller G, Bruch HP. [Ischemic colitis after vascular surgery reconstruction of an abdominal aortic aneurysm]. Chirurg 1996;67:380-6.
5. Piotrowski JJ, Ripepi AJ, Yuhas JP, Alexander JJ, Brandt CP. Colonic ischemia: the Achilles heel of ruptured aortic aneurysm repair. Am Surg 1996;62:557-60; discussion: 560-1.
6. Seeger JM, Coe DA, Kaelin LD, Flynn TC. Routine reimplantation of patent inferior mesenteric arteries limits colon infarction after aortic reconstruction. J Vasc Surg 1992;15:635-41.
7. National Surgical Quality Improvement Program [home page on the Internet]. Chicago, Ill: American College of Surgeons; 2005. Available at: www.acsnsqip.org. Accessed January 17, 2012.
8. Chadi SA, Rowe BW, Vogt KN, Novick TV, Harris JR, Derose G, et al. Trends in management of abdominal aortic aneurysms. J Vasc Surg 2012;55:924-8.
9. Albuquerque FC, Tonnessen BH, Noll RE, Cires G, Kim JK, Sternbergh WC. Paradigm shifts in the treatment of abdominal aortic aneurysm: trends in 721 patients between 1996 and 2008. J Vasc Surg 2010;51:1348-52; discussion: 1352-3.
10. Senekowitsch C, Assadian A, Assadian O, Hartleb H, Ptakovsky H, Hagmüller GW. Replanting the inferior mesentery artery during infrarenal aortic aneurysm repair: influence on postoperative colon ischemia. J Vasc Surg 2006;43:689-94.
11. Hagihara PF, Ernst CB, Griffen WO. Incidence of ischemic colitis following abdominal aortic reconstruction. Surg Gynecol Obstet 1979;149:571-3.
12. Joels CS, Langan EM, Daley CA, Kalbaugh CA, Cass AL, Cull DL, et al. Changing indications and outcomes for open abdominal aortic aneurysm repair since the advent of endovascular repair. Am Surg 2009;75:665-9; discussion: 669-70.

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