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ORIGINAL ARTICLE—ALIMENTARY TRACT

Characteristics, outcomes, and risk factors of surgery for acute lower gastrointestinal bleeding: nationwide cohort study of 10,342 hematochezia cases

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Abstract

Background Current evidence on the surgical rate, indication, procedure, risk factors, mortality, and postoperative rebleeding for acute lower gastrointestinal bleeding (ALGIB) is limited.

Methods We constructed a retrospective cohort of 10,342 patients admitted for acute hematochezia at 49 hospitals (CODE BLUE J-Study) and evaluated clinical data on the surgeries performed.

Results Surgery was performed in 1.3% (136/10342) of the cohort with high rates of colonoscopy (87.7%) and endoscopic hemostasis (26.7%). Indications for surgery included colonic diverticular bleeding (24%), colorectal cancer (22%),

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and small bowel bleeding (16%). Sixty-four percent of surgeries were for hemostasis for severe refractory bleeding. Postoperative rebleeding rates were 22% in patients with presumptive or obscure preoperative identification of the bleeding source and 12% in those with definitive identification. Thirty-day mortality rates were 1.5% and 0.8% in patients with and without surgery, respectively. Multivariate analysis showed that surgery-related risk factors were transfusion need ≥ 6 units ($P < 0.001$), in-hospital rebleeding ($P < 0.001$), small bowel bleeding ($P < 0.001$), colorectal cancer ($P < 0.001$), and hemorrhoids ($P < 0.001$). Endoscopic hemostasis was negatively associated with surgery ($P = 0.003$). For small bowel bleeding, the surgery rate was significantly lower in patients with endoscopic hemostasis as 2% compared to 12% without endoscopic hemostasis.

Conclusions Our cohort study elucidated the outcomes and risks of the surgery. Extensive exploration including the small bowel to identify the source of bleeding and endoscopic hemostasis may reduce unnecessary surgery and improve the management of ALGIB.

Keywords Acute lower gastrointestinal bleeding · Surgery · Endoscopic hemostasis

Abbreviations

SRH	Stigmata of recent hemorrhage
ALGIB	Acute lower gastrointestinal bleeding
NSAIDs	Non-steroidal anti-inflammatory drug
WBC	White blood cell
Hb	Hemoglobin
Plt	Platelet
CRP	C-reactive protein
PT-INR	Prothrombin time-international normalized ratio
CT	Computed tomography

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TAE	Transcatheter arterial embolization
SD	Standard deviation
CDB	Colonic diverticular bleeding
BMI	Body mass index
PS	Performance status
CCI	Charlson comorbidity index
HSE	Hypertonic saline-epinephrine

Introduction

Acute lower gastrointestinal bleeding (ALGIB) occurs with sudden hematochezia and is caused by various diseases, including colonic diverticular bleeding (CDB), colorectal cancer, and ischemic colitis. Although bleeding is often self-limiting, therapeutic interventions such as endoscopic hemostasis or transcatheter arterial embolization (TAE) are required for massive bleeding or rebleeding accompanied by hemorrhagic shock. If these interventions do not stop bleeding or if the hemorrhage cause is neoplastic, emergent or elective surgery is performed [1–5].

Although emergent surgery is generally considered as a high-risk intervention, there are a limited number of reports on surgery for ALGIB. Most of those included 10–60 surgery cases, and thus, data on implementation rate, indication, procedure, and mortality of the surgery remain insufficient to decide appropriate management. Surgery rates in ALGIB ranged from 0.2 to 46% [6–18] and mortality rates ranged from 5 to 27% depending on cohort or age of publication. A recent large-scale study reported that emergency colectomy performed in 1614 cases was associated with high 30-day mortality (12.2%) [11]. However, the dataset lacked diagnoses of ALGIB or bleeding sources, which are essential for proper management. Moreover, there are few reports on surgery-related risk factors and postoperative rebleeding. Because of these situations, evidence on indication, outcome, and risk factor of surgery for ALGIB remain limited and the guideline for ALGIB [19] expresses that the quality of the evidence regarding surgery for ALGIB is poor and mostly derived from small, retrospective reviews.

To identify factors leading to surgery and measures to avoid surgery as a severe outcome, we analyzed the data obtained by a multicenter large-scale cohort study of 10,342 acute hematochezia cases hospitalized from 2010 to 2019 by collecting more than 200 items of data, including surgery and its short- or long-term outcomes [20, 21].

Methods

Study design and patients

This retrospective multicenter cohort study, the CODE BLUE-J Study (COlonic DivErticular Bleeding Leaders Update Evidence from multicenter Japanese Study), was conducted at 49 hospitals across Japan. At each hospital, data were collected from the electronic medical records and entered into an Excel spreadsheet. This spreadsheet was sent to the secretariat's institution to assess any omissions or errors in the data entered for each hospital, any data that needed to be corrected were emailed to the person responsible for the data at each hospital with comments on the Excel spreadsheet. The above process was repeated at least three times per hospital in order to obtain more complete data. A total of 10,342 adult patients were hospitalized for acute hematochezia between January 1, 2010 and December 31, 2019 [20, 21]. Of these patients, we retrospectively analyzed the detailed data of those who had undergone surgery. Approval was obtained from the ethical committees and institutional review boards of all 49 participating hospitals using the opt-out method. We excluded patients with insufficient clinical information and patient records of another hospitalization for ALGIB before admission in which surgery was performed (Fig. 1). To analyze surgery-related factors, we used the surgery group by excluding those who underwent surgery for adverse events induced by endoscopy or TAE and surgery for incidentally diagnosed lesions unrelated to ALGIB. In terms of emergency services, we classified the 49 participating hospitals into a high-volume group (more than 5000 emergency services in 2019) and a low-volume group (less than 5000 emergency services) according to our previous report [22]. In terms of hospital type, we classified these hospitals into an academic or non-academic and examined the relationship between surgery rates and the hospital-related factors.

Variables and outcomes

We analyzed diseases indicated for surgery, intraoperative adverse events, postoperative adverse events (wound infection, anastomotic failure or bleeding, intestinal obstruction, intraperitoneal abscess, and wound bleeding), general postoperative adverse events (pneumonia, cardiovascular disorders, and others), the purpose of surgery, the urgency of surgery, preoperative identification of the bleeding site, postoperative rebleeding rate, number of days until postoperative rebleeding, observation period of postoperative rebleeding, and postoperative overall mortality rate. Rebleeding episodes were evaluated and defined as significant amounts of fresh bloody or wine-colored stool. According to the purposes, surgeries were classified into (i) surgery for hemostasis for severe refractory bleeding and (ii) surgery mainly not for hemostasis but resection of the original disease such as neoplasia. Furthermore, surgery for hemostasis was classified into (i) emergency surgery for severe refractory bleeding and (ii) elective surgery, in which bleeding has stopped once, but surgery is required for cancer or hemostasis due to the

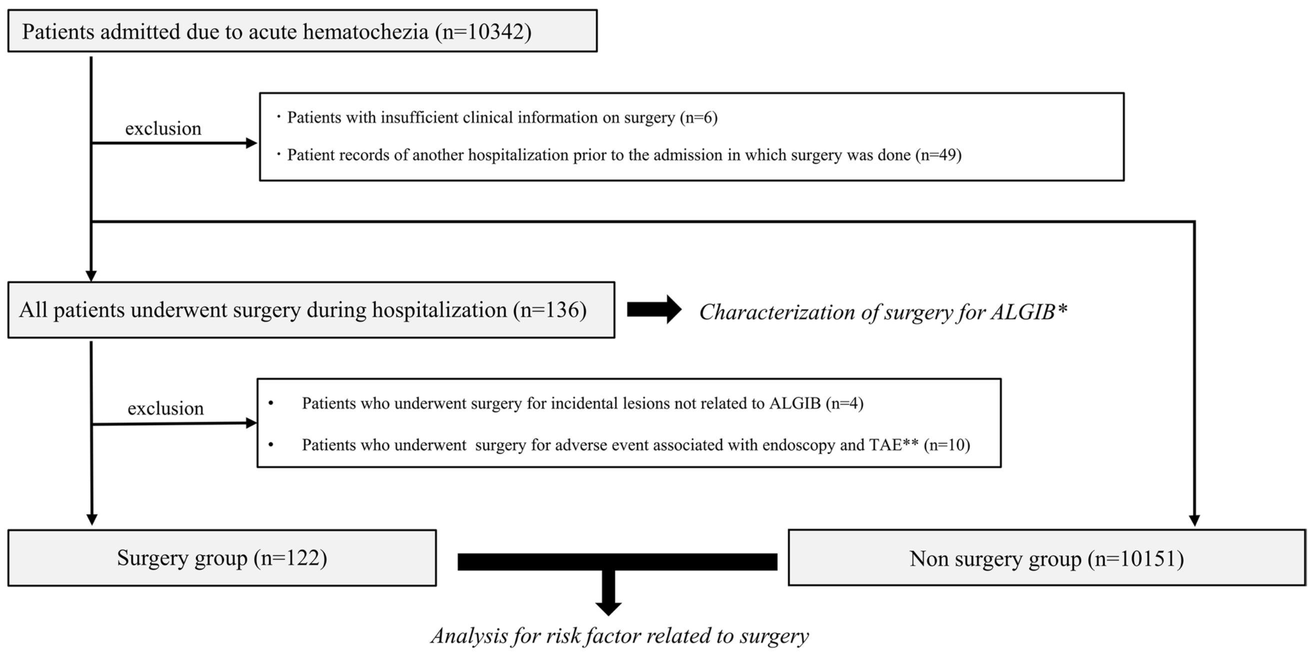

Fig. 1 Study Flow diagram of the study. **ALGIB* acute lower gastrointestinal bleeding, ***TAE* transcatheter arterial embolization

risk of rebleeding. Confidence levels for preoperative identification of the bleeding site were classified into (i) definitive, (ii) presumptive, or (iii) obscure. The definitive diagnosis was based on endoscopic visualization of SRH, which was determined stigmata of recent hemorrhage such as active bleeding, a visible vessel, or an adherent clot. The presumptive diagnosis was determined according to the presence of fresh blood localized in the colon, in which the patient had a potential bleeding source without SRH on colonoscopy, and a negative upper endoscopy, or small bowel endoscopy. The obscure diagnosis was determined according to no fresh blood in the colon, in which the patient had no potential bleeding source by colonoscopy with other tests showing negative results, including upper GI endoscopy or small bowel endoscopy. Of the 49 hospitals that participated in this study, 46 hospitals were able to perform small bowel capsule endoscopy or balloon-assisted endoscopy. Three hospitals were unable to perform small bowel examination except for CT scan. Surgical procedures were divided into (i) total or subtotal colectomy, (ii) segmental colectomy, (iii) segmental resection of the small bowel, and (iv) non-resection surgery. Moreover, the postoperative rebleeding rate, mortality rate, and observation period were examined as outcomes of hemostasis surgery.

In the analysis of risk factors associated with surgery, age < 65, sex, body mass index (BMI) > 25, current drinker, current smoker, performance status (PS) ≥ 3, syncope, fever, shock index (SI) > 1, diarrhea, abdominal pain, WBC > 10,000 (/μl), Hb < 7.0 (g/dl), Plt ≤ 15.0 (/μl), PT-INR ≥ 1.5, creatinine ≥ 1.5 (mg/dl), hemodialysis, albumin < 3.0 (g/dl), history of LGIB, Charlson comorbidity index (CCI) ≥ 2 [23], non-steroidal anti-inflammatory drugs (NSAIDs), low dose aspirin (LDA), non-LDA antiplatelet, anticoagulant, extravasation on CT, TAE, colonoscopy, stigmata of recent hemorrhage (SRH) detection, endoscopic hemostasis, transfusion need ≥ 6 units [24], in-hospital rebleeding, high-volume group, academic group, CDB, small bowel bleeding, colorectal cancer, hemorrhoids, inflammatory bowel disease, intestinal ischemia, rectal ulcer, post-endoscopic therapy bleeding, and others were analyzed as variables.

Patients underwent pre-colonoscopy bowel preparation using 2–4 L of a solution containing polyethylene glycol or enema on the day of the colonoscopy, considering the patient's condition. The endoscopic cap and water jet device were used based on the practitioner's preference and decision. All colonoscopies were performed using an electronic video endoscope (Olympus Optical, Tokyo, Japan, or Fujifilm Corporation, Tokyo, Japan).

The final diagnosis was obtained by inpatient examinations after hospitalization due to the suspicion of acute lower gastrointestinal bleeding. SRH type was categorized as active or non-active bleeding (adherent clot and/or visible vessel). Endoscopic hemostasis included clipping, band ligation, detachable snare ligation, electrocoagulation, and hypertonic saline-epinephrine, which were selected at the endoscopist's discretion and in accordance with hospital policy.

Statistical analysis

Pearson's chi-square, Fisher's exact, and Mann–Whitney U tests were used to analyze surgery-associated factors. In addition, odds ratios and 95% confidence intervals (CI) were calculated by uni- and multivariate logistic regression analysis and for risk factors associated with surgery needs. Variables with a univariate significance of P less than 0.05 were entered into the multivariate analysis. The data were analyzed using SPSS statistical software version 25 (IBM, New York, NY, USA), and a P value <0.05 was considered significant. In the multivariate analysis of surgery-related risk factors, explanatory variables that were significantly different $P<0.05$ in the univariate analysis were used so that the number of explanatory variables was statistically valid according to the number of events.

Results

Characteristics and outcomes of all surgery cases

Surgery was performed in 142 cases during hospitalization, and data analysis was performed in 136 cases, excluding six with insufficient clinical information. Of the 49 hospitals participating in the study, 29 (59%) had enrolled patients who were undergoing surgery during their hospital stay. The rate of surgery for ALGIB at each of the 29 hospitals ranged from 0.25 to 5.6%, with a median of 1.16%. The indications for surgery were CDB in 33 cases (24.3%), colorectal cancer in 30 (22.1%), small bowel bleeding in 22 (16.2%), adverse events of endoscopy and interventional radiology performed for bleeding in ten (7.4%), hemorrhoid bleeding in seven (5.1%), inflammatory bowel disease in six (4.4%), intestinal perforation with bleeding in five (3.7%), intestinal ischemia in five (3.7%), rectal ulcer bleeding in three (2.2%), and the others in 15 (11.0%) (Fig. 2). Regarding small bowel bleeding, surgery rates were significantly lower ($p=0.03$) at 2% (1/54) in patients with endoscopic hemostasis as compared with 12% (21/179) in those without endoscopic hemostasis.

In the classification according to purpose, surgeries for hemostasis to severe refractory bleeding were performed in 87 cases (64%), and surgeries mainly not for hemostasis were performed in 49 (36%) (Table 1). Emergency surgeries for hemostasis were performed in 19 patients (22%), including those for CDB ($n=9$, 47%), small bowel bleeding ($n=5$, 26%), and rectal hemorrhagic ulcer ($n=2$, 11%). Elective surgeries for hemostasis were performed in 68 patients (78%), including those for CDB ($n=24$, 35%),

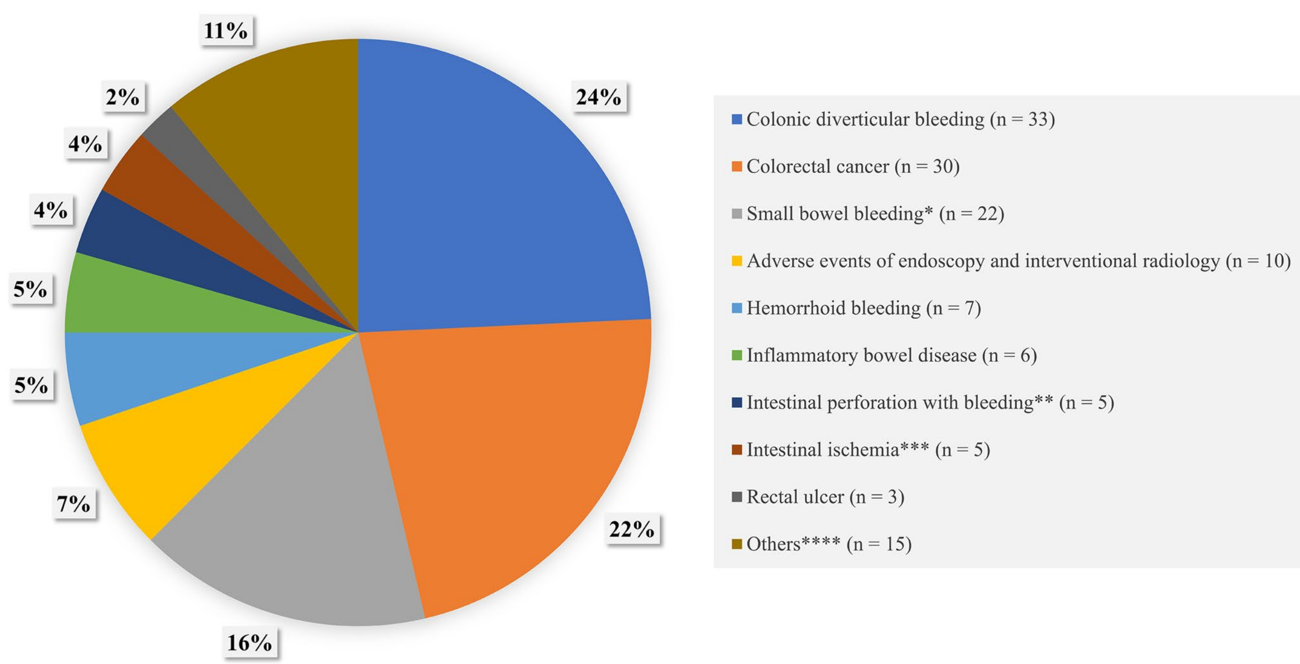

Fig. 2 Causative disorders for surgery ($n=136$). *Meckel's diverticulum ($n=9$), vascular lesion ($n=5$), cancer ($n=2$), non-specific ulcerative lesion ($n=2$), Behçet's disease ($n=1$), malignant lymphoma ($n=1$), intestinal invasion from hepatoma ($n=1$), and submucosal lesion ($n=1$). **colonic perforation ($n=4$) and small bowel perforation (n = 1). ***gangrenous ischemic colitis ($n=2$), small bowel ischemia ($n=1$), non-occlusive mesenteric ischemia ($n=1$), and stricture type of ischemic colitis ($n=1$). ****incidentally diagnosed lesion not related to hematochezia ($n=4$), upper gastrointestinal bleeding ($n=2$), ovarian cancer with colonic invasion ($n=2$), rectal bleeding of unknown origin ($n=2$), cytomegalovirus enteritis ($n=1$), arteriovenous malformation ($n=1$), bowel intussusception ($n=1$), rectal injury ($n=1$) and perirectal abscess ($n=1$)

Table 1 Characteristics of surgery

Purpose of surgery	
Surgery for hemostasis to severe refractory bleeding	87/136 (64%)
Surgery mainly not for hemostasis	49/136 (36%)
Surgical urgency	
Emergency surgery for hemostasis	19/87 (22%)
Elective surgery for hemostasis	68/87 (78%)
Surgical procedures	
Total or subtotal colectomy	8/136 (6%)
Segmental colectomy	78/136 (57%)
Segmental resection of small bowel	21/136 (15%)
Non-resective surgery[a]	29/136 (21%)

[a]Diverting ileostomy or colostomy ($n=10$), hemorrhoid surgery ($n=7$), transanal surgery ($n=4$), operative closure for perforation ($n=2$), bypass surgery ($n=1$), proximal gastrectomy ($n=1$), rectal laceration repair surgery ($n=1$), surgical suturing hemostasis ($n=1$), exploratory laparoscopy ($n=1$), and surgical gastrostomy ($n=1$)

small bowel bleeding ($n=14$, 21%), and colorectal cancer ($n=11$, 16%). Emergency surgeries mainly not for hemostasis included those for refractory ulcerative colitis, necrotic ischemic enteritis, and intussusception with bleeding. Elective surgeries, mainly not for hemostasis, included those for colorectal cancers that had stopped bleeding but required surgical resection. Surgical procedures included total or subtotal colectomy in eight cases (6%), segmental colectomy in 78 cases (57%), segmental resection of small bowel in 21 cases (15%), and non-resective surgeries in 29 cases (21%) (Table 1). Intraoperative adverse events were observed in only one case (0.7%) (transfusion-induced anaphylaxis occurred during surgery), postoperative adverse events in 28 cases (20%), surgical adverse events in 13 cases (9.6%), and general adverse events in 11 cases (8.1%).

Surgeries for hemostasis were performed in 87 cases, and confidence levels for preoperative identification of bleeding site were definitive in 50 patients (57%), presumptive in 33 (38%), and obscure in four (5%). Postoperative rebleeding was observed in 14 of 87 cases (16%), and the median length until postoperative rebleeding was 99 days (Inter quartile range: 32–652). The causes of rebleeding in the six cases with definitive preoperative identification of the bleeding site were mostly bleeding from the anastomotic site (3/6) or anal rebleeding from a hemorrhoid or perianal abscess (2/6). Only one case involved rebleeding from the colon diverticula after right hemicolectomy in cases with definitive preoperative identification of the bleeding site of the ascending

Table 2 Outcomes of surgery

Postoperative rebleeding rate	
in all cases with surgery for hemostasis	14/87 (16%)
in cases with definitive preoperative identification of bleeding source	6/50 (12%)
in cases with presumptive or obscure identification of bleeding source	8/37 (22%)
Cause of rebleeding // surgery for primary disease	
(1) rebleeding in cases with definitive preoperative identification of bleeding source	6/50 (12%)
#1 anastomotic bleeding // transanal surgery for rectal ulcer bleeding	
#2 anastomotic bleeding // right hemicolectomy for ascending diverticular bleeding	
#3 anastomotic bleeding // right hemicolectomy for Behçet's disease	
#4 perirectal abscess bleeding // colostomy for perirectal abscess	
#5 hemorrhoid bleeding // hemorrhoid ligation for hemorrhoid bleeding	
#6 colonic diverticular bleeding // right hemicolectomy for ascending colon cancer	
(2) rebleeding in cases with presumptive or obscure preoperative identification of bleeding source	8/37 (22%)
#1 colonic diverticular bleeding// left hemicolectomy for presumptive diverticular bleeding	
#2 colonic diverticular bleeding// right hemicolectomy for presumptive diverticular bleeding	
#3 colonic diverticular bleeding// sigmoidectomy for presumptive diverticular bleeding	
#4 small bowel bleeding // small bowel segmental resection for Meckel 's diverticular bleeding	
#5 small bowel bleeding // small bowel segmental resection for multiple ulcers of the small intestine	
#6 anastomotic bleeding // sigmoidectomy for presumptive diverticular bleeding	
#7 obscure LGI bleeding // small bowel segmental resection for Meckel 's diverticular bleeding	
#8 obscure LGI bleeding // laceration reparation for rectal laceration	
Length until postoperative rebleeding (median days) (IQR)	99 (32–652)
Mortality	
Thirty-day mortality in all surgery cases	2/136 (1.5%)
Mortality during hospitalization in all surgery cases	4/136 (2.9%)

colon cancer. The causes of rebleeding in the eight cases with presumptive or obscure preoperative identification of the bleeding site were CDB in three, small bowel bleeding in two, anastomotic bleeding in one, and obscure bleeding in two (Table 2).

Thirty-day mortality rate was 1.5% (2/136) in patients who underwent surgery, and mortality during hospitalization in all surgery cases was 2.9% (4/136) (Table 2).

Assessment of associated risk factors of surgery using multivariate regression (surgery vs. non-surgery)

In a multivariate analysis, risk factors significantly associated with surgery were transfusion of six or more units (OR 2.50; 95% CI 1.58–3.95, $P < 0.001$), in-hospital rebleeding (OR 2.67; 95% CI 1.66–4.29, $p < 0.001$), small bowel bleeding (OR 7.87; 95% CI 4.07–15.2, $p < 0.001$), colorectal cancer (OR 23.2; 95% CI 12.7–42.3, $p < 0.001$), and hemorrhoids (OR 5.30; 95% CI 2.17–13.0, $p < 0.001$). On the contrary, endoscopic hemostasis (OR 0.33; 95% CI 0.16–0.68, $p = 0.003$) was the factor negatively related to surgery (Table 3).

Discussion

This study was the first to identify risk factors associated with surgery for ALGIB in a large nationwide cohort. Transfusion need ≥ 6 units, in-hospital rebleeding, small bowel bleeding, colorectal cancer, and hemorrhoids conferred significantly higher odds of surgery, whereas endoscopic hemostasis had significantly lower odds in multivariate analysis. Transfusion need ≥ 6 units and in-hospital rebleeding after primary inpatient care, including hemostatic intervention, indicate severe refractory bleeding and are understandable as a surgery-related risk. Colon cancer and hemorrhoids with overt hematochezia upon admission require consequential surgery owing to the nature of the disease. On the other hand, it is clinically noteworthy that small bowel bleeding was a significant risk factor for surgery (OR 7.87, 95% CI 4.07–15.2, $p < 0.001$). Small intestinal bleeding presents as either obscure gastrointestinal bleeding or overt bleeding with hematochezia. The latter overt small bowel bleeding was the third top cause (16.2%) for surgery in this cohort of acute hematochezia. Similarly, a recent report enrolling 87 surgery cases of 1198 ALGIB patients [10] documented that small bowel disease was the second most common cause of surgery. When small bowel bleeding was considered, the surgery rate was significantly lower ($p = 0.03$) at 2% (1/54) in patients with endoscopic hemostasis as compared with 12% (21/179) in those without endoscopic hemostasis. The test to diagnose small bowel bleeding is not available in all hospitals. Taken together, however, these results suggest that small bowel exploration is essential in acute hematochezia when the bleeding site cannot be unlocalized with standard examinations, because small bowel bleeding is a major cause of ALGIB and has a high risk of requiring surgery.

In our cohort, colonoscopy was performed in 88% with a high diagnostic yield (94.9%) [20, 21]. In 27% of colonoscopy examinations, endoscopic hemostasis was performed and conferred significantly low odds of surgery (OR, 0.32; 95% CI 0.16–0.68, $p = 0.003$). Taken together, colonoscopy to identify the bleeding source and subsequent endoscopic hemostasis have contributed to better management of ALGIB by reducing surgical intervention. Consequently, surgery was performed in only 1.2% of 10,342 acute hematochezia cases, in which colonoscopy and endoscopic hemostasis were done at high rate of 88% and 27%, respectively. Our literature review showed that surgery rates ranged from 34 to 46% between 1980 and 1999 [12–15], from 14 to 19% in the 2000s [16–18] and from 0.2 to 18% with a median of 4.8% after 2010 [6–11]. Surgery for ALGIB has been declining over time, probably due to the improvement of total medical management, including diagnosis of a bleeding source and non-surgical hemostasis. Grayer C. et al. [18] analyzed 1,112 ALGIB cases and demonstrated that endoscopic hemostatic control significantly increased from 1% in 1988–1997 to 4.4% in 1998–2006, with a corresponding decrease in surgical control from 22.6 to 16.6% in the same time periods.

Detailed data on postoperative rebleeding after surgery for ALGIB have not been reported to date, and this nationwide study was the first to focus on this issue. Postoperative rebleeding rates were 16% (14/87) in total, 22% (8/37) in patients with presumptive or obscure preoperative identification of the bleeding source, and 12% (6/50) in those with definitive identification. In 6 postoperative rebleeding cases with definitive preoperative identification, three were anastomosis bleeding and one was bleeding from primary anal lesions, meaning that only 2 of 50 cases (4%) were postoperative bleeding from sources unknown preoperatively. On the other hand, in 8 postoperative rebleeding cases with presumptive or obscure preoperative identification, seven were postoperative bleeding from sources unknown preoperatively. These results demonstrate that definitive preoperative identification of a bleeding source is pivotal for reducing postoperative rebleeding and again support the British guideline that laparotomy without localization of the source of the bleeding should be avoided.

In this cohort, total or subtotal colectomy was 6% of 136 surgical procedures, and emergency surgery for hemostasis was 14% of those, indicating that localized colectomy or segmental intestinal resection has been electively performed in most cases. A 30-day mortality rate was 1.5% in all surgery cases of the above operative profile, comparable to the rate of 0.8% in patients without surgery. In contrast, a 30-day

Table 3 Risk factors associated with surgery

Factor	Surgery ($n = 122$)	Non-surgery ($n = 10,151$)	Univariate logistic regression analysis		Multivariate logistic regression analysis	
			Odds ratio (95%CI)	P value	Odds ratio (95%CI)	*P* value
Age < 65	46 (38%)	2780 (27%)	1.61 (1.11–2.32)	0.012	0.68 (0.45–1.03)	0.067
Male	78 (64%)	6194 (61%)	1.17 (0.81–1.71)	0.40		
BMI > 25	23 (19%)	2344 (23%)	0.70 (0.44–1.12)	0.14		
Current drinker	49 (40%)	4051 (40%)	1.12 (0.76–1.65)	0.58		
Current smoker	22 (18%)	1627 (16%)	1.31 (0.82–2.08)	0.26		
PS ≥ 3	9 (7%)	539 (5%)	1.43 (0.72–2.83)	0.31		
Syncope	7 (6%)	656 (6%)	0.89 (0.41–1.91)	0.76		
Fever	31 (25%)	645 (6%)	1.62 (0.89–2.95)	0.12		
SI* > 1	19 (16%)	732 (7%)	2.37 (1.45 ~ 3.89)	0.001	1.42 (0.81–2.48)	0.22
Diarrhea	12 (10%)	1000 (10%)	1.0 (0.55–1.83)	0.99		
Abdominal pain	31 (25%)	1623 (16%)	1.81 (1.20–2.73)	0.005	1.46 (0.90–2.36)	0.13
WBC > 10,000 (/µl)	36 (30%)	1928 (19%)	1.78 (1.21–2.64)	0.004	1.25 (0.80–1.96)	0.32
Hb < 7.0 (g/dl)	12 (10%)	730 (7%)	1.41 (0.77 ~ 2.57)	0.264		
Plt ≤ 15.0 (/µl)	14 (11%)	1553 (15%)	0.72 (0.41–1.25)	0.24		
PT-INR ≥ 1.5	14 (11%)	785 (8%)	1.41 (0.80–2.47)	0.24		
Creatinine ≥ 1.5 (mg/dl)	12 (10%)	1222 (12%)	0.79 (0.43–1.44)	0.44		
Hemodialysis	1 (0.8%)	316 (3%)	0.26 (0.036–1.85)	0.18		
Albumin < 3.0 (g/dl)	31 (25%)	1068 (11%)	2.93 (1.94–4.41)	< 0.001	1.28 (0.79–2.06)	0.32
History of LGIB	26 (21%)	3033 (30%)	0.64 (0.41–0.98)	0.041	0.96 (0.57–1.60)	0.87
CCI ≥ 2	49 (40%)	3701 (36%)	1.17 (0.81–1.68)	0.40		
NSAIDs	16 (13%)	911 (9%)	1.53 (0.90–2.60)	0.12		
Low dose aspirin	17 (14%)	2029 (20%)	0.65 (0.39–1.08)	0.099		
Non-LDA antiplatelet	12 (10%)	1233 (12%)	0.66 (0.36–1.20)	0.17		
Anticoagulant	17 (14%)	1293 (13%)	1.11 (0.66–1.86)	0.69		
Extravasation on CT	16 (13%)	1121 (11%)	1.22 (0.72–2.06)	0.47		
TAE	5 (4%)	130 (13%)	3.29 (1.32–8.20)	0.01	1.22 (0.39–3.85)	0.74
Colonoscopy	109 (89%)	8889 (88%)	1.19 (0.67–2.12)	0.56		
SRH detection	26 (21%)	2759 (27%)	0.73 (0.47–1.12)	0.15		
Endoscopic hemostasis	8 (7%)	2756 (27%)	0.19 (0.092–0.39)	< 0.01	0.33 (0.16–0.68)	0.003
Transfusion ≥ 6U	46 (38%)	1210 (12%)	4.47 (3.09–6.48)	< 0.01	2.50 (1.58–3.95)	< 0.001
In-hospital rebleeding**	39 (32%)	1511 (15%)	2.69 (1.83–3.95)	< 0.01	2.67 (1.66–4.29)	< 0.001
High-volume group	71 (58%)	5508 (54%)	1.17 (0.82–1.69)	0.39		
Academic group	92 (75%)	5306 (52%)	2.8 (1.85–4.24)	< 0.01	0.68 (0.43–1.08)	0.10
Colonic diverticular bleeding	33 (24%)	6498 (64%)	0.21 (0.14–0.31)	< 0.01	0.70 (0.39–1.25)	0.22
Small bowel bleeding	22 (18%)	211 (2%)	10.4 (6.40–16.8)	< 0.01	7.87 (4.07–15.2)	< 0.001
Colorectal cancer	30 (25%)	138 (2%)	22.6 (14.4–35.5)	< 0.01	23.2 (12.7–42.3)	< 0.001
Hemorrhoid	7 (6%)	176 (1%)	3.45 (1.59–7.51)	< 0.01	5.30 (2.17–13.0)	< 0.001
Inflammatory bowel disease	6 (5%)	203 (2%)	2.54 (1.10–5.83)	0.03	2.09 (0.77–5.70)	0.15
Intestinal ischemia	5 (4%)	933 (9%)	0.51 (0.22–1.16)	0.11		
Rectal ulcer	3 (2%)	252 (3%)	1.33 (0.49–3.64)	0.58		
Post-endoscopic therapy bleeding	1 (1%)	443 (4%)	0.18 (0.03–1.30)	0.089		
Others	8 (7%)	657 (6%)	1.01 (0.49–2.09)	0.97		

*Shock index (SI) was calculated by dividing the heart rate (HR) by the systolic blood pressure (SBP)

**In-hospital rebleeding in surgery group was defined as preoperative rebleeding mortality rate was higher at 12.2% in a recent cohort of 1614 emergency surgery cases; of those, total or subtotal colectomy was 24% [11]. As shown in the British guideline [25], emergency total or subtotal colectomy for ALGIB has a high 30-day mortality even in recent years and should be avoided by extensive exploration of bleeding source and non-surgical hemostasis.

The present study has shown that the fourth cause for surgery was complications of diagnostic and therapeutic intervention (7%). The rate of TAE-related complications requiring surgery in this study was 2.1% (3/143), while the rates were previously reported from 3.6 to 13% [26–28], showing that surgery could be indicated due to TAE-related complications at a certain unignorable percentage. The rate of colonoscopy-related perforation requiring surgery in this study was 0.054% (6/11056, 5.4 per 10,000 colonoscopies) in total, 0.040% (3/7486) in diagnostic colonoscopy, and 0.084% (3/3570) in endoscopic hemostasis. The recent systematic review [29] demonstrated that the pooled rate of perforations among 10,328,360 colonoscopies was 5.8 per 10,000 colonoscopies (95% CI, 5.7–6.0). The perforation rate in this study was below the lower value of 95% CI shown in the systemic review, suggesting that colonoscopy could be performed in ALGIB without the increase in perforation risk. The perforation rate of endoscopic hemostasis in this study was 0.084%, considerably lower than the rate of TAE-related perforation (2.1%). Given together with the benefit in the significant reduction of surgery needs and the relatively low risk of perforation, endoscopic hemostasis can be selected as the first-line hemostasis.

The present study had some limitations. First, because of the retrospective design of this study, there could have been missing data and the possibility of bias. However, no missing data were available concerning diagnosis, procedures, interventions, or outcomes, and items with missing values and their rates in our cohort were comparably low, as shown previously [20, 21]. After efforts were made to minimize missing data, multivariate analysis was performed using complete-case analysis. Second, this was a large-scale cohort collected from 49 hospitals, but there may be some bias regarding region, hospital size, and the nature of the institution. Third, we cannot present the exact number of small bowel bleeding cases diagnosed with balloon-assisted endoscopy or capsule endoscopy because we did not collect this information. Fourth, the multivariate analysis on surgery-related risk factors, the possible presence of potential confounders other than those statistically analyzed, and the setting of cut-off values for the risk factors may alter the results.

Conclusions

Our large-scale cohort study has comprehensively elucidated the characteristics, outcomes, and risk factors of surgery for acute hematochezia. Extensive exploration including the small bowel to identify the source of bleeding and endoscopic hemostasis may reduce unnecessary or high-risk surgery and improve the management of ALGIB.

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Author contributions NN was the principal investigator in this study. JO and MK designed and conducted the study, performed statistical analysis, and wrote the paper. NN and TA mainly edited the paper and advised the statistical analysis. KK, AY, AY, TI, TA, NT, YS, TK, NI, TS, MM, AT, KM, KK, SF, TU, MF, HS, SS, TN, JH, TF, YK, AM, SK, TM, RG, HF, YF, TH, YT, KN, NM, KN, TK, YS, SF, KK, TM, YK, KM, KW, OG, and KI designed the study, made decisions and definitions of survey items, and interpreted the data. All the authors have read and approved the submitted version of the manuscript.

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Declarations

Conflict of interest The authors declare no conflicts of interest relevant to this article.

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Consent for publication Not applicable.

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