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ORIGINAL ARTICLE

Findings and outcomes of emergent endoscopies after cardiovascular surgery

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Author contributions: Takeshi Okamoto developed the concept, designed the study, conducted chart reviews to collect data, analyzed and interpreted the data, and wrote the manuscript. Kazuki Yamamoto, Ayaka Takasu, Yuichiro Suzuki, Takashi Ikeya, Shuhei Okuyama, and Koichi Takagi contributed to data analysis and interpretation and critically reviewed the manuscript. Nobuko Fujita, Hiroyasu Misumi, and Katsuyuki Fukuda supervised the study, contributed to contributed to data interpretation, and critically reviewed the manuscript. All authors approved the final version of the manuscript.

Abstract

Aims: Studies detailing endoscopic findings and hemostatic interventions for upper gastrointestinal bleeding after cardiovascular surgery are scarce. We conducted this study to determine the frequency and findings of emergent esophagogastroduodenoscopy (EGD) after cardiovascular surgery and the effect of bleeding requiring hemostatic intervention on clinical outcomes.
Methods and Results: We retrospectively reviewed records of emergent EGD examinations conducted within 30 days after cardiovascular surgery at a tertiary referral center in Japan from April 2011 to March 2020. Of 1625 patients undergoing cardiovascular surgery, 47 underwent emergent EGD. Sources of bleeding were identified in 30 cases, including transesophageal echocardiogram (TEE)-related injuries (8 patients), gastric ulcers (7 patients), and duodenal ulcers (7 patients). Patients who required endoscopic hemostatic intervention had more TEE-related injuries (43% vs 3%, $P = 0.005$), gastric ulcers (35% vs 6%, $P = 0.018$), or ulcers in the first part of the duodenum (29% vs 0%, $P = 0.006$) than those who did not. Intraoperative TEE did not increase the need for endoscopic intervention (71% vs 64%, $P = 0.435$). Intraoperative TEE and the need for endoscopic intervention did not affect length of stay or all-cause mortality. Only one death was associated with gastrointestinal bleeding.
Conclusion: Despite the potential severity of bleeding after cardiovascular surgery, most cases can be managed endoscopically with no increase in hospital stay or mortality.

Introduction

Gastrointestinal complications arise 0.8–4.6% of cases after cardiac surgery.[1–3] Of these, postoperative ileus is the most common, and mesenteric ischemia is associated with the highest mortality.[1] Gastrointestinal bleeding occurs in about 0.5% of cases and has a mortality rate of about 18%. Upper gastrointestinal bleeding (UGIB) occurs at similar rates in cardiac and vascular surgery patients.[4] Duodenal ulcers are the most common cause of UGIB after cardiac surgery.[5] Splanchnic hypoperfusion is a major contributor to gastrointestinal complications after cardiac surgery and may result from hypovolemia, inflammation, emboli, or medications.[6–8]

Intraoperative transesophageal echocardiography (TEE) has become an indispensable aid in many types of cardiovascular surgeries. As it is inserted blindly after intubation and applies continuous pressure on the esophagus for a prolonged period of time, it can cause gastrointestinal complications in 0.1–1.4% of cases.[9–11] Hemorrhage and perforation resulting from TEE-related injury are rare, estimated at 0.03% and 0.01–0.09%, respectively.[9] Both may sometimes be managed endoscopically, but surgery is often required, particularly for perforations.[12–15]

While there are various studies on the incidence, risk factors, and outcomes of gastrointestinal complications after cardiac surgery, those detailing endoscopic characteristics and hemostatic interventions are scarce. We hypothesized that endoscopic examinations are conducted more frequently after cardiovascular surgery in Japan due to the low hurdle for endoscopy, which may lead to earlier discovery or the identification of less life-

threatening causes of UGIB. We conducted this study to determine the frequency of emergent endoscopies after various types of cardiovascular surgery and to elucidate the endoscopic findings and outcomes of such emergent endoscopies at a tertiary care center in Japan.

Methods

We retrospectively reviewed records of all patients who underwent emergent esophagogastroduodenoscopy (EGD) examinations within 30 days after cardiovascular surgery at St. Luke's International Hospital from 1 April 2011 to 31 March 2020. Patients were excluded if they underwent EGD for nonemergent reasons, such as for scheduled screening or follow-up, which were unrelated to the cardiac surgery. Patients with acute indications who had already been discharged when undergoing EGD were also excluded.

EGDs were performed by gastroenterology residents (supervised by staff physicians), clinical fellows, or staff physicians of the Department of Gastroenterology at St. Luke's International Hospital. The GIF-260J esophagogastroduodenoscope (Olympus Corp., Tokyo, Japan), equipped with a water jet function, was used in most cases. Data on operating time, use of intraoperative TEE, and use of the cardiopulmonary bypass machine were based on the anesthesiology report. Specifics on TEE such as duration, problems with insertion, and whether or not evaluations included the deep gastric view were not available. Reports and images from previous or subsequent EGDs on each patient were confirmed if bleeding precluded an adequate evaluation of the gastric mucosa during the emergent EGD. Data on hemoglobin levels and blood transfusions were collected but were not used in analyses because they were heavily affected by various factors unrelated to UGIB, including the surgery itself.

Emergent EGD was defined as EGD performed within 24 h after a consultation to the gastroenterology department due to symptoms suggestive of UGIB (hematemesis, coffee grounds emesis, bloody nasogastric tube aspirate, hematochezia, or tarry stools), a sudden drop in the hemoglobin level, signs of UGIB on imaging studies, or severe thoracoabdominal pain. TEE-related injury was defined as longitudinal tears in the esophagus or upper gastric body, including the gastroesophageal junction. If not indicated on the endoscopy report, one of the authors (TO) reviewed endoscopic images to determine whether the gastroesophageal junction lesion appeared to be the result of TEE or Mallory–Weiss syndrome, based on the nature and location of the injury (Fig. 1).

A total of 1625 patients underwent cardiovascular surgery over the 9-year study period. Of these, 521 had coronary bypass surgery, 493 had valve surgery, 290 had open aortic surgery, 126 had endovascular therapy for thoracic or abdominal aortic aneurysms, 120 had transcatheter aortic valve insertion, and 75 had other cardiovascular surgeries (such as resections of

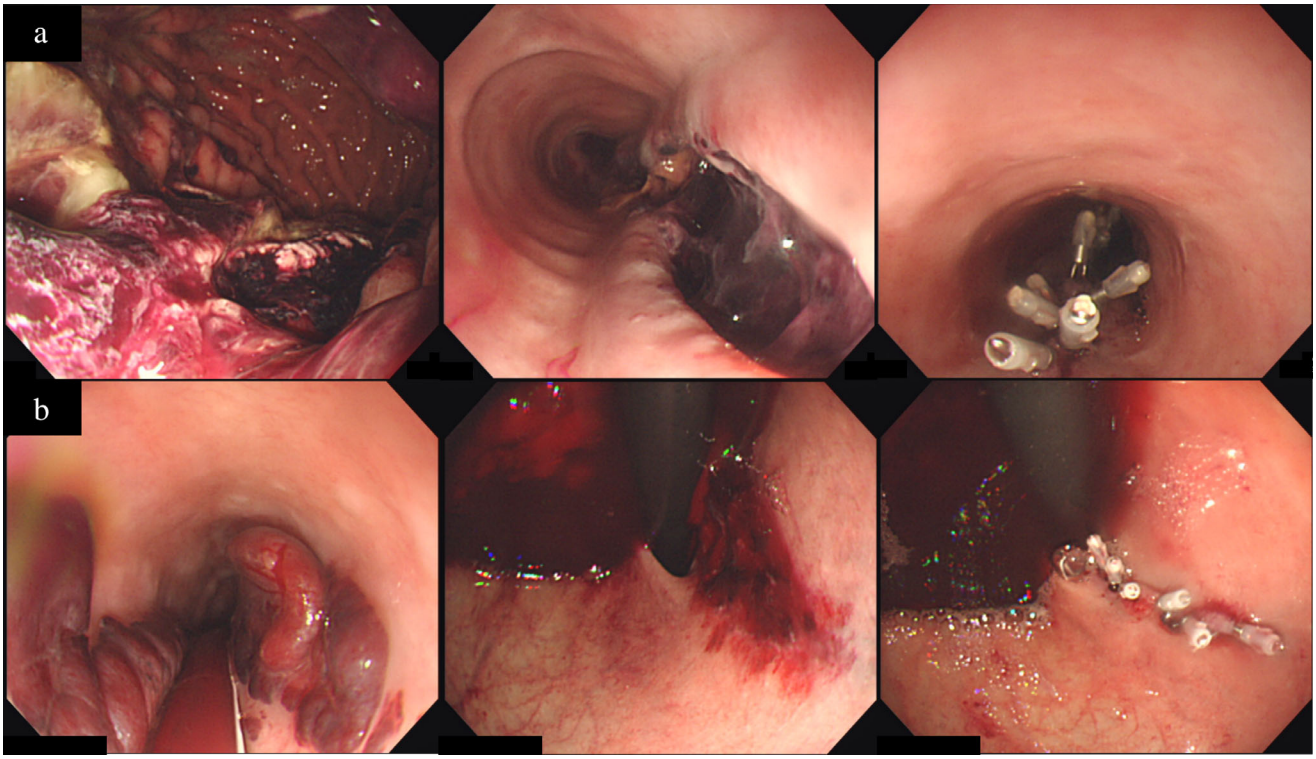

Figure 1 Transesophageal echocardiography–related injury. (a) Deep, longitudinal lacerations in the upper gastric body and esophagus treated with hemoclips. Friability, mucosal discoloration, and ulceration consistent with ischemia were also observed. (b) Longitudinal hematomas, blood-filled nasogastric tube, and longitudinal injury to the upper gastric body treated with hemoclips. While the spear-shaped mucosal injury and esophageal findings are suggestive of traumatic transesophageal echocardiography–related injury, differentiation from Mallory–Weiss syndrome can be difficult.

cardiac tumors or vegetations and pulmonary thromboendarterectomy). Those who underwent emergent EGD within 30 days after surgery were included in the analysis.

Data on demographics, clinical variables, surgical and endoscopic findings, medications, and clinical outcomes were extracted for analysis. This observational study was conducted in accordance with the Declaration of Helsinki. Consent for surgery and the subsequent endoscopy was obtained from all patients. The study was approved by the ethics committee at St. Luke's International Hospital (20-R128). Patient consent for participation in the study was waived due to the retrospective study design. The study was publicized on the official website of St. Luke's International Hospital to allow patients to opt out of the study without any consequences on their future care.

Statistical analyses were conducted using Pearson's chi-square test or Fisher's exact test for categorical variables and the Mann–Whitney U-test for continuous variables. Cox regression analysis was conducted to identify factors affecting length of stay. *P*-values <0.05 were considered statistically significant. All statistical analyses were conducted using IBM SPSS Statistics ver. 25.0 (IBM Corp., Armonk, NY, USA).

Results

Of the 1625 patients (median age: 71 years) who underwent cardiovascular surgery during the 9-year study period, a total of 47 patients underwent emergent EGDs within 30 days after cardiovascular surgery (Table 1). Emergent EGDs were performed less often after heart surgery than after aortic surgery, endovascular therapy, or transcatheter aortic valve insertion (2% vs 4%, hazard ratio [confidence interval]: 2.12 [1.16–3.87], $P = 0.012$). However, bleeding rates were similar between the two groups (1.7% vs 2.1%).

Of the 47 included patients, 26 patients underwent open heart surgery (coronary bypass or valve surgery), while 21 patients underwent aortic surgery, pulmonary endarterectomy, transcatheter aortic valve implantation, or endovascular therapy. The open heart surgery patients had higher median body mass indexes (24.2 vs 22.1, $P < 0.001$), shorter median operating times (185 vs 334 min, $P = 0.031$), and less frequent use of TEE (50% vs 86%, $P = 0.011$) than vascular surgery patients. Intraoperative TEE was performed in 31 cases, and the cardiopulmonary bypass machine was used in 25 cases. Almost all patients were taking acid blocking medications and had a history of diabetes mellitus. Forty cases received antiplatelet therapy, anticoagulants, or both after surgery (Table 2).

A total of 81 EGDs were performed, with 18 patients undergoing multiple (range: 2–12) EGDs (Table 3). Sources of UGIB were identified in 30 cases (64%). Major causes of bleeding were TEE-related injury (8 patients), gastric ulcer (7 patients), and duodenal ulcers (7 patients). Four and six patients had ulcers in the first and second parts of the duodenum, respectively (three had both). Other causes included Mallory–Weiss syndrome and ischemic gastritis.

Endoscopic hemostatic intervention was performed in 14 patients (30%). Ten patients were treated with hemoclips, three with heater probe thermocoagulation, and one with hemoclips and epinephrine injection. Rebleeding was observed in two patients. One had multiple gastric and duodenal ulcers and experienced rebleeding 7 days after endoscopic intervention. The other had TEE-related injury and experienced three rebleeding episodes, each time treated with hemoclips and/or epinephrine injections. There were no other complications from endoscopic treatment, and no patients required surgery.

Table 2 Patient characteristics

	All patients ($n = 47$)	
Male, *n* (%)	31	66.0%
Age, median (range)	78	(35–92)
Body mass index, median (range)	22.9	(16.5–35.0)
Medical history, *n* (%)		
Diabetes mellitus	45	95.7%
Antiplatelet or anticoagulant therapy	40	85.1%
Use of proton pump inhibitors or H2 blockers	46	97.9%
Use of steroids or nonsteroidal anti-inflammatory drugs	15	31.9%
Surgery		
Open heart surgery, *n* (%)	26	55.3%
Operating time, min (range)	286	(68–919)
Use of cardiopulmonary bypass machine, *n* (%)	25	53.2%
Use of TEE, *n* (%)	31	66.0%
EGD-related, *n* (%)		
Indication (upper gastrointestinal bleeding vs other), *n* (%)	30	63.8%
Days from surgery to first EGD, median (range)	6	(0–28)

EGD, esophagogastroduodenoscopy; TEE, transesophageal echocardiography.

Table 1 Emergent endoscopies performed after cardiovascular surgery

	Surgery performed	Emergent endoscopy	% of total
Coronary artery bypass grafting	521	10	1.9%
Valve surgery	493	11	2.2%
Aortic surgery	290	12	4.1%
Endovascular treatment (thoracic or abdominal aorta)	126	6	4.8%
Transcatheter aortic valve insertion	120	5	4.2%
Other	75	3	4.0%
Total	1625	47	2.9%

Table 3 Characteristics and outcomes based on the need for endoscopic intervention

	Endoscopic intervention				
	Yes		No		
	($n = 14$)		($n = 33$)		*P*-value
Male, *n* (%)	7	50.0%	24	72.7%	0.122
Age, median (range)	75.5	(60–87)	79	(35–92)	0.837
Body mass index, median (range)	23.3	(16.5–31.2)	22.9	(18.2–35.0)	0.362
Medical history, *n* (%)					
Diabetes mellitus	12	85.7%	33	100.0%	0.084
Antiplatelet or anticoagulant therapy	14	100.0%	26	78.8%	0.068
Use of proton pump inhibitors or H2 blockers	14	100.0%	32	97.0%	0.702
Use of steroids or nonsteroidal anti-inflammatory drugs	7	50.0%	8	24.2%	0.084
Surgery					
Open heart surgery, *n* (%)	6	42.9%	20	60.6%	0.212
Operating time, min (range)	258	(153–732)	288	(68–919)	0.733
Use of cardiopulmonary bypass machine, *n* (%)	8	57.1%	17	51.5%	0.488
Use of TEE, *n* (%)	10	71.4%	21	63.6%	0.435
EGD-related, *n* (%)					
Indication (upper gastrointestinal bleeding vs other), *n* (%)	13	92.9%	17	51.5%	0.006
Days from surgery to first EGD, median (range)	5	(0–20)	8	(1–28)	0.452
Number of EGDs performed, median (range)	2	(1–12)	1	(1, 2)	0.001
EGD findings					
Transesophageal echocardiogram-related injury	6	42.9%	2	6.1%	0.005
Gastric ulcer	5	35.7%	2	6.1%	0.018
Duodenal ulcer (first part)	4	28.6%	0	0.0%	0.006
Duodenal ulcer (second part)	3	21.4%	3	9.1%	0.241
Outcomes					
Length of stay, days (range)	28	(2–58)	22	(2–287)	0.454
All-cause in-hospital mortality, *n* (%)	1	7.1%	3	9.1%	0.658

EGD, esophagogastroduodenoscopy; TEE, transesophageal echocardiography.

Table 4 Factors affecting length of stay

	Linear regression		
	Beta coefficient	95% CI	*P*-value
Age			0.089
Male			0.684
Body mass index			0.083
Medical history, *n* (%)			
Diabetes mellitus			0.371
Antiplatelet or anticoagulant therapy			0.818
Use of proton pump inhibitors or H2 blockers			0.629
Use of steroids or nonsteroidal anti-inflammatory drugs			0.434
Surgery			
Open heart surgery, *n* (%)			0.550
Operating time, min (range)	0.627	0.567~0.687	< 0.001
Use of cardiopulmonary bypass machine, *n* (%)			0.188
Use of TEE, *n* (%)			0.743
EGD-related, *n* (%)			
Indication (upper gastrointestinal bleeding vs other), *n* (%)			0.537
Days from surgery to first EGD, median (range)			0.383
Number of EGDs performed, median (range)			0.710
Endoscopic intervention performed			0.454
Transesophageal echocardiogram-related esophageal injury			0.258

CI, confidence interval; EGD, esophagogastroduodenoscopy; TEE, transesophageal echocardiography.

The 14 patients who required endoscopic hemostatic intervention more frequently underwent emergent EGD for clear signs of gastrointestinal bleeding (hematemesis, melena, or blood from nasogastric tube) than other indications such as progression of anemia or abdominal pain than those who did not (93% vs 51%, $P = 0.006$). They were more likely to have TEE-related injury (43% vs 3%, $P = 0.005$), gastric ulcers (35% vs 6%, $P = 0.018$), or ulcers in the first part of the duodenum (29% vs 0%, $P = 0.006$). Use of TEE did not significantly increase the need for endoscopic hemostasis (71% vs 64%, $P = 0.435$). There were four deaths, of which only one resulted from UGIB. Neither use of intraoperative TEE nor the need for endoscopic intervention affected length of stay or all-cause in-hospital mortality.

The 31 patients who underwent intraoperative TEE were less likely to have open heart surgery (42% vs 81%, $P = 0.011$) and had longer operating times (323 vs 181 min, $P = 0.028$) than those who did not. TEE-related injury was observed in 26% of patients in the TEE group. There were no other significant differences in endoscopic findings or clinical outcomes between the TEE and non-TEE groups.

Early UGIB occurring within 7 days after surgery tended to present more often with hematemesis or melena than UGIB occurring later on (76% vs 50%, $P = 0.061$). The type of surgery, operating time, and use of TEE had no impact on the timing of bleeding. There were also no differences in endoscopic findings, length of stay, or mortality between early and late bleeders.

Median length of stay after surgery was 26 (range: 2–287) days. Four patients died during admission, of which three deaths were unrelated to gastrointestinal bleeding. One death resulted from hemorrhagic shock from gastrointestinal bleeding after TEE-related esophageal injury, which was complicated by mesenteric ischemia and sepsis. Operating time was the only factor affecting length of stay in regression analysis (Table 4). Younger age and higher body mass index had a tendency to prolong length of stay ($P = 0.089$ and 0.083, respectively), but these differences were not significant. Notably, use of antithrombotic agents or acid blockers, type of surgery, timing of UGIB after surgery, use of TEE, and need for endoscopic intervention had not significant impact on length of stay.

Discussion/conclusion

In this study, we found that emergent EGDs were performed less often after heart surgery than after aortic surgery, endovascular therapy, or transcatheter aortic valve insertion. While gastrointestinal bleeding after cardiovascular surgery patients often requires endoscopic intervention, the need for endoscopic intervention and use of intraoperative TEE did not affect length of stay or all-cause in-hospital mortality. Mortality due to UGIB was lower than suggested by previous reports.

UGIB has been reported to occur in 0.3–1.4% of patients undergoing cardiac surgery, with a population-based study of 182 688 patients identifying UGIB in 0.5% of cases.[1–3,5,16.] According to one report, UGIB occurs at similar rates in cardiac and vascular surgery patients, both affecting about 1% of cases.[4] In our study, which also included vascular surgery, emergent EGD was performed in 2.9% of cases. Clear sources of UGIB were identified in 1.8% of cases. The high figures in our study most likely reflected our low hurdle for emergent EGD in Japan, which allowed us to discover early UGIB and less life-threatening causes of UGIB. Previous reports may have missed UGIB cases in which spontaneous hemostasis was achieved, as blood transfusions are routinely performed after cardiovascular surgery for various reasons including the surgery itself.

While emergent EGDs were performed more frequently after aortic or endovascular surgery (4%) than after cardiac surgery (2%), bleeding rates were similar (2.1% of vascular cases and 1.7% of cardiac cases). Routine autologous blood transfusions after routine cardiac surgery can mask progression of anemia, while surgeons are more sensitive to decreases in hemoglobin levels after endovascular therapy. In addition, the more frequent use of TEE most likely led to a higher index of suspicion for UGIB in patients who underwent vascular therapy, particularly after transcatheter aortic valve implantation.[17] While old age has been identified as a preoperative risk factor for postoperative UGIB,[5] use of TEE was not associated with age or need for endoscopic intervention in our study.

Duodenal ulcers accounted for about 70% of UGIBs occurring after coronary artery bypass grafting or valve surgery in one study, with risk factors including old age, low ejection fraction, congestive heart failure, pre-existing gastrointestinal or renal disease, and use of warfarin.[5] We found that causes of UGIB were almost even split between TEE-related injury, gastric ulcers, and duodenal ulcers, all of which required endoscopic intervention in a majority of cases.

UGIB due to TEE-related injury is rare, reported to occur in less than 0.1% of patients undergoing cardiac surgery.[9,10] The frequency of UGIB may be higher after catheter-based treatments such as transcatheter aortic valve implantation.[17] A review of 17 cases of TEE-related injury resembling Mallory–Weiss syndrome revealed that 24% received endoscopic therapy, 24% had rebleeding or continued bleeding after EGD, 18% required surgery or angiography, and 24% died.[18] We found eight cases of UGIB due to TEE-related injury (0.7% of total) in our study, six of which were successfully treated endoscopically. None experienced rebleeding, required surgery or angiography, or died.

Careful endoscopic closure with numerous clips may have played an instrumental role in achieving the favorable outcomes achieved in our patients who underwent intraoperative TEE. Although endoscopic clipping is a standard technique in nonvariceal, nonulcer upper intestinal bleeding, the effectiveness of clipping for long, relatively wide lacerations resulting from TEE-related injury has not been elucidated.[19] Applying hemoclips in the narrow lumen of the esophagus can be difficult, particularly when filled with blood. Clipping in the gastroesophageal junction can be particularly difficult due to reflux of blood from the stomach and the risk of iatrogenic Mallory–Weiss syndrome when approached in the retroflexed position. Water or gel immersion and the use of rotatable clips which can be reopened after closure may help secure endoscopic view and facilitate clipping.[20,21] Effective endoscopic clipping, particularly by expert endoscopists with experience closing Mallory–Weiss tears or post-endoscopic submucosal dissection ulcers, may reduce the incidence of undesirable outcomes.

High mortality of up to 18.1% has been reported in UGIB after cardiac surgery.[5] Two studies[5,16] found higher mortality among bleeders than nonbleeders, while another[3] found no increase in mortality. We found that the need for endoscopic

intervention did not affect length of stay or all-cause mortality. Four of the 30 patients (13.3%) with proven UGIB died during admission, of which only one (3.3%) was associated with UGIB. The lower mortality relative to previous reports and the avoidance of prolonged lengths of stay despite endoscopic intervention can be most simply explained by the effectiveness of hemostatic interventions in the first endoscopic session. We only experienced rebleeding in two cases (6.7% of patients with proven UGIB), and there were no cases of rebleeding after endoscopic intervention for TEE-related UGIB.

Our strategy for emergent EGDs is to perform EGDs immediately (generally within 2 h) for severe UGIB and within 24 h even for relatively mild UGIB symptoms as well as asymptomatic, unexplained decreases in hemoglobin levels. This lower hurdle for endoscopic evaluation, our ability to rapidly perform EGDs in the operating room or intensive care unit, and our close collaboration with the cardiovascular surgery and anesthesiology teams allowed us to achieve lower mortality than previous reports and to limit deaths due to UGIB to only one of 1625 cardiovascular surgery patients (0.06%). As our patients experienced no prolonged length of stay due to UGIB, we believe the costs associated with our lower hurdle for emergent EGDs are more than justified. The precise indications for emergent EGDs must be determined on a case-by-case basis, considering the resources available at each institution.

There are several limitations to this study. The study was a retrospective study with a limited sample size at a single institution; selection bias was inevitable. Severity of bleeding based on blood loss and transfusions could not be evaluated due to frequent bleeding or transfusions for other reasons, particularly the surgery itself. Details of the TEE, including difficult insertion and whether or not the deep gastric view was attempted, were not available.

Cardiovascular surgery and intraoperative TEE may cause severe UGIB, which may rarely have fatal consequences. Most cases can be managed endoscopically. Early and effective endoscopic intervention can prevent increases in length of stay or mortality. However, given the potential severity of UGIB, studies on the utility of routine endoscopic evaluation after cardiovascular surgery may be warranted.

REFERENCES

1 Chaudhry R, Zaki J, Wegner R *et al*. Gastrointestinal complications after cardiac surgery: a nationwide population-based analysis of morbidity and mortality predictors. *J. Cardiothorac. Vasc. Anesth.* 2017; **31**: 1268–74.

2 Andersson B, Nilsson J, Brandt J, Höglund P, Andersson R. Gastrointestinal complications after cardiac surgery. *Br. J. Surg.* 2005; **92**: 326–33.

3 Haywood N, Mehaffey JH, Hawkins RB *et al*. Gastrointestinal complications after cardiac surgery: highly morbid but improving over time. *J. Surg. Res.* 2020; **254**: 306–13.

4 Jayaprakash A, McGrath C, McCullagh E, Smith F, Angelini G, Probert C. Upper gastrointestinal haemorrhage following cardiac surgery: a comparative study with vascular surgery patients from a single centre. *Eur. J. Gastroenterol. Hepatol.* 2004; **16**: 191–4.

5 Krawiec F, Maitland A, Duan Q, Faris P, Belletrutti PJ, Kent WDT. Duodenal ulcers are a major cause of gastrointestinal bleeding after cardiac surgery. *J. Thorac. Cardiovasc. Surg.* 2017; **154**: 181–8.

6 Chor CYT, Mahmood S, Khan IH, Shirke M, Harky A. Gastrointestinal complications following cardiac surgery. *Asian Cardiovasc. Thorac. Ann.* 2020; **28**: 621–32.

7 Ohri SK, Velissaris T. Gastrointestinal dysfunction following cardiac surgery. *Perfusion*. 2006; **21**: 215–23.

8 Moneta GL, Misbach GA, Ivey TD. Hypoperfusion as a possible factor in the development of gastrointestinal complications after cardiac surgery. *Am. J. Surg.* 1985; **149**: 648–50.

9 Kallmeyer IJ, Collard CD, Fox JA, Body SC, Shernan SK. The safety of intraoperative transesophageal echocardiography: a case series of 7200 cardiac surgical patients. *Anesth. Analg.* 2001; **92**: 1126–30.

10 Piercy M, McNicol L, Dinh DT, Story DA, Smith JA. Major complications related to the use of transesophageal echocardiography in cardiac surgery. *J. Cardiothorac. Vasc. Anesth.* 2009; **23**: 62–5.

11 Purza R, Ghosh S, Walker C *et al*. Transesophageal echocardiography complications in adult cardiac surgery: a retrospective cohort study. *Ann. Thorac. Surg.* 2017; **103**: 795–802.

12 Côté G, Denault A. Transesophageal echocardiography-related complications. *Can. J. Anaesth.* 2008; **55**: 622–47.

13 Sainathan S, Andaz S. A systematic review of transesophageal echocardiography-induced esophageal perforation. *Echocardiography*. 2013; **30**: 977–83.

14 Lennon MJ, Gibbs NM, Weightman WM, Leber J, Ee HC, Yusoff IF. Transesophageal echocardiography-related gastrointestinal complications in cardiac surgical patients. *J. Cardiothorac. Vasc. Anesth.* 2005; **19**: 141–5.

15 Herbold T, Chon SH, Grimminger P *et al*. Endoscopic treatment of transesophageal echocardiography-induced esophageal perforation. *J. Laparoendosc. Adv. Surg. Tech. A*. 2018; **28**: 422–8.

16 Filsoufi F, Rahmanian PB, Castillo JG, Scurlock C, Legnani PE, Adams DH. Predictors and outcome of gastrointestinal complications in patients undergoing cardiac surgery. *Ann. Surg.* 2007; **246**: 323–9.

17 Freitas-Ferraz AB, Rodés-Cabau J, Junquera Vega L *et al*. Transesophageal echocardiography complications associated with interventional cardiology procedures. *Am. Heart J.* 2020; **221**: 19–28.

18 Cappell MS, Dass K, Manickam P. Characterization of the syndrome of UGI bleeding from a Mallory-Weiss tear associated with transesophageal echocardiography. *Dig. Dis. Sci.* 2014; **59**: 2381–9.

19 Tjwa ET, Holster IL, Kuipers EJ. Endoscopic management of nonvariceal, nonulcer upper gastrointestinal bleeding. *Gastroenterol. Clin. North Am.* 2014; **43**: 707–19.

20 Yano T, Nemoto D, Ono K *et al*. Gel immersion endoscopy: a novel method to secure the visual field during endoscopy in bleeding patients (with videos). *Gastrointest. Endosc.* 2016; **83**: 809–11.

21 Wang TJ, Aihara H, Thompson AC, Schulman AR, Thompson CC, Ryou M. Choosing the right through-the-scope clip: a rigorous comparison of rotatability, whip, open/close precision, and closure strength (with videos). *Gastrointest. Endosc.* 2019; **89**: 77–86.e1.