# Utility and safety of balloon-assisted enteroscopy in patients with left ventricular assist devices: a retrospective multicenter study



# $\odot$

### Authors

Badar M. Hasan<sup>1</sup>, Charles McMahon<sup>2</sup>, Rumman A. Khalid<sup>1</sup>, Yasar Colak<sup>1</sup>, Daniel C. Mayorga<sup>1</sup>, Ahmed Elkafrawy<sup>4</sup>, Kanwarpreet Tandon<sup>1</sup>, Muhammad Shafiq<sup>3</sup>, Ishtiaq Hussain<sup>1</sup>, Tolga Erim<sup>1</sup>, Fernando Castro<sup>1</sup>, Roger Charles<sup>1</sup>, Rajiv Chhabra<sup>4</sup>

## Institutions

- 1 Department of Gastroenterology, Cleveland Clinic Florida, Weston, Florida, United States
- 2 Department of Internal Medicine, Division of Gastroenterology, Loyola University Medical Center, Chicago, Illinois, United States
- 3 Department of Internal Medicine, The University of Kansas Medical Center, Kansas City, Kansas, United States
- 4 Department of Gastroenterology and Hepatology, Saint Luke's Hospital of Kansas City/University of Missouri Kansas City (UMKC), Missouri, United States

submitted 17.12.2019
accepted after revision 16.4.2020

#### Bibliography

DOI https://doi.org/10.1055/a-1181-8340 | Endoscopy International Open 2020; 08: E1002–E1008 © Georg Thieme Verlag KG Stuttgart · New York eISSN 2196-9736

### **Corresponding author**

Badar M. Hasan, MD, Department of Gastroenterology, Cleveland Clinic Florida Weston, 2950 Cleveland Clinic Boulevard, Weston, FL 33331, USA Fax: +1-954-659-6741 hasanb@ccf.org

#### ABSTRACT

**Objective and study aims** Patients with left-ventricular assist devices (LVADs) have an increased risk of gastrointestinal bleeding, especially from the small bowel, often necessitating evaluation with balloon-assisted enteroscopy (BAE). Our study aimed to assess the periprocedural safety and utility of BAE for gastrointestinal bleeding in patients with LVADs.

**Patients and methods** This was a multicenter retrospective cohort study of adults with LVADs who underwent BAE between January 2007 to December 2018.

**Results** Thirty-four patients underwent a total of 46 BAEs (9 were single-balloon enteroscopies [SBEs] and 37 were double-balloon enteroscopies [DBEs]). Mean age of patients was 66.4±8.3 years. Patients tolerated anesthesia well, without complications. There were no complications from the BAE itself. One patient required repeat BAE due to a progressive drop in hemoglobin and another patient developed paroxysmal supraventricular tachycardia. One patient died within 72 hours of the procedure due to worsening of LVAD thrombosis. Diagnostic yields were 69.6% for all procedures, 73.0% for DBE and 55.6% for SBE (P= 0.309). Therapeutic yields were 67.4% overall: 73.0% for DBE and 44.4% for SBE (P=0.102). In those that presented with overt gastrointestinal bleeding, DBE had a higher diagnostic yield compared to SBE (84.2% vs. 42.9%; P= 0.057) and a significantly higher therapeutic yield (84.2% vs. 28.6%; p=0.014).

**Conclusions** This is the largest multicenter study of patients with LVADs who underwent DBE. BAE appears to be a safe and useful modality for the evaluation of gastrointestinal bleeding in these patients.

# Introduction

In the United States, there are roughly 6.5 million adults living with congestive heart failure (CHF) and prevalence is estimated to exceed 8 million by 2030. Each year approximately 960,000 new cases of CHF are diagnosed [1,2]. In the past, the only

treatment available for CHF refractory to medical management was cardiac transplantation; however, many patients were left with inadequate options owing to the limited availability of donors. The advent of left-ventricular assist devices (LVADs) since the early 1990s has filled this gap and is now used as a bridge to cardiac transplant, as a bridge to recovery, or even as destination therapy in advanced CHF patients [3].

Unfortunately, both pulsatile-flow and continuous-flow LVADs have been associated with an increased risk of gastrointestinal bleeding [4]. Reported prevalence of gastrointestinal bleeding in LVAD patients can range between 20% and 42%, with small-bowel bleeding accounting for the majority of gastrointestinal bleeding events. Although video capsule endoscopy (VCE) can be a useful initial tool to identify the site of bleeding within the small bowel, balloon-assisted enteroscopy (BAE) has the advantage of being both diagnostic and therapeutic. The two types of BAE are double-balloon enteroscopy (DBE) and single-balloon enteroscopy (SBE). There have been limited case reports [5,6] and case series [7] that have discussed the utility and safety of BAE for the evaluation of gastrointestinal bleeding in patients with LVADs. The main objective of our study was to assess the periprocedural safety of BAE in LVAD patients, and to quantify the diagnostic and therapeutic yields of BAE in this cohort.

# Patients and methods

We performed a multicenter retrospective cohort study involving four centers: Saint Luke's Hospital of Kansas City/University of Missouri Kansas City (UMKC), Kansas University Medical Center (KUMC), Cleveland Clinic in Ohio and Weston Florida. Institutional review board approval was obtained for each center. The study included adult patients (age  $\geq$  18 years) with either pulsatile-flow or continuous-flow LVADs who underwent BAE for any indication from January 1, 2007 to December 31, 2018. Further criteria for inclusion were availability of periprocedural information for the BAE with follow-up for at least 72 hours. Patients were excluded if they had only right ventricular assist devices.

Data was collected for patient demographics, LVAD type and goal of therapy, comorbidities (chronic kidney disease, chronic liver disease/cirrhosis, and diabetes mellitus), antithrombotic medications, history of prior gastrointestinal bleeding, and previous endoscopic procedures performed. Indications for BAE were also noted, along with periprocedural details such as transfusion of blood products, American Society of Anesthesiologists (ASA) classification, method of sedation, duration of procedure, identification of culprit lesion(s), and type of therapeutic intervention(s) performed. Overt gastrointestinal bleeding was defined as melena, hematochezia or hematemesis. Diagnostic, therapeutic and procedure-related complications within 72 hours were noted including respiratory (aspiration, and hypoxia), cardiac (LVAD dysfunction, cardiac arrhythmias, hypotension, and myocardial ischemia), and gastrointestinal (nausea, vomiting, abdominal pain, pancreatitis, perforation, and uncontrolled bleeding). Death within 72 hours of the procedure was also noted from the electronic medical record.

The decision to perform either DBE or SBE was made by the endoscopist based on the clinical status of the patient, scope availability (antegrade SBE was only available at one center), and prior endoscopic evaluations.

## Outcomes

The primary outcome was to assess the periprocedural safety of BAE, based on the preanesthesia evaluation, any complications from the enteroscopy, complications from therapeutic interventions when applicable, and complications related to LVAD function.

The secondary outcome was the diagnostic and therapeutic yields of BAE (including DBE and SBE). Diagnostic yield was defined as the proportion of procedures in which the cause of bleeding was identified. Therapeutic yield was defined as the proportion of procedures in which therapeutic intervention was performed over the total number of procedures performed [8].

## Statistical analysis

Categorical variables were summarized using frequencies (n) and percentages. Continuous variables were summarized using means and standard deviations (SD). Comparisons of diagnostic and therapeutic yields between subgroups were conducted using chi-square tests of independence. When expected cell frequencies were below 5.0, Fisher's exact tests were used. P= 0.05 was used as the level of statistical significance. All analyses were performed using IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp., Armonk, New York, United States).

# Results

A total of 34 patients with LVADs who underwent 46 BAEs were identified and included in the study. The mean age of the patient population was 66.4 ± 8.3 years and were predominantly male (79.4%) (> Table 1). Thirty-two patients (94.1%) had pulsatile-type LVADs, and the majority of patients (n = 28, 82.4%) were utilizing the LVAD as a destination therapy. Approximately half of the patient population had chronic kidney disease (CKD) or diabetes mellitus. None of the patients had chronic liver disease or cirrhosis. There were 11 patients (32.4%) with a previous history of gastrointestinal bleeding from small-bowel arteriovenous malformations (AVMs). Thirty-one patients (91.2%) had a history of recent endoscopy, with both EGD and colonoscopy being more frequent than VCE which was performed in 21 patients (61.8%). Twenty patients (58.8%) were on antiplatelet therapy and 24 patients (70.6%) were on warfarin.

## **Procedure details**

Preanesthesia evaluation identified 37 patients (80.4%) with American Society of Anesthesiologists (ASA) class IV ( $\succ$  **Table 2**). General anesthesia was the predominant method (n = 34, 73.9%) of sedation in comparison to monitored anesthesia care (MAC). All procedures were performed for evaluation of gastrointestinal bleeding. Indications for performing BAE were most frequently due to acute blood loss/anemia (n = 31, 67.4%), or melena (n=19, 41.3%). A mean of 3.57±2.6 units of packed RBC transfusions were administered before the procedures ( $\succ$  **Table 3**). Most patients were admitted for more than 48 hours prior to undergoing the procedure. A

<b>Table 1</b> Baseline characteristics of patients in the study.		
Patients, n	34	
Demographics		
<ul> <li>Age, years (SD)</li> </ul>	66.4 (8.3)	
<ul> <li>Gender, n of male patients (%)</li> </ul>	27 (79.4)	
Race, n (%)		
Caucasian	28 (82.4)	
African-American	6 (17.6)	
LVAD History		
Type of LVAD, n (%)		
<ul> <li>Pulsatile-flow</li> </ul>	32 (94.1)	
Continuous-flow	2 (5.9)	
LVAD indication, n (%)		
<ul> <li>Ischemic cardiomyopathy</li> </ul>	20 (58.8)	
<ul> <li>Non-ischemic cardiomyopathy</li> </ul>	14 (41.2)	
LVAD therapy goal, n (%)		
Bridge to transplant	6(17.6)	
<ul> <li>Destination therapy</li> </ul>	28 (82.4)	
Comorbidities, n (%)		
• CKD	13 (38.2)	
Cirrhosis/chronic liver disease	0 (0.0)	
<ul> <li>Diabetes mellitus</li> </ul>	16 (47.1)	

total of 46 BAEs were performed, of which nine were antegrade SBEs and 37 were DBEs (32 antegrade, and 5 retrograde). The mean length of procedure was 52.5 (±25.2) minutes.

## Primary and secondary outcomes

The primary outcome was to assess the safety of the procedure. Patients tolerated anesthesia without any complications. In addition, there were no complications from the enteroscopy itself, such as perforation, pancreatitis or a need for surgical intervention. One patient had a progressive drop in hemoglobin following a nondiagnostic SBE and 4 days later underwent antegrade double-balloon enteroscopy (ADBE) with a finding of mid-ileal AVMs that were successfully treated with BICAP cautery and endoclips (► **Table 4**). After ADBE, one patient developed paroxysmal supraventricular tachycardia (PSVT) requiring intensive care unit (ICU) transfer and medical management. Another patient who was already diagnosed with LVAD thrombosis underwent ADBE and died within 72 hours of the procedure due to worsening of the LVAD thrombosis.

The secondary outcome was to quantify the diagnostic and therapeutic yields. The cause of bleeding was identified in 32 procedures (69.6%), with 73.0% for DBE and 55.6% for SBE (P= 0.309). Small-bowel angioectasias/AVMs were the most frequent finding accounting for 20 cases (43.5%) (**> Table 4**). A

Etiology of prior GI bleeding, n (%)	
Small-bowel AVM	11 (32.4)
Gastric/cardiac AVM	5 (14.7)
Small-bowel & gastric AVM	4 (11.8)
<ul> <li>Small-bowel &amp; gastric AVM &amp; Dieulafoy's lesion</li> </ul>	1 (2.9)
<ul> <li>Duodenal/jejunal erosion</li> </ul>	1 (2.9)
Diverticular bleeding	1 (2.9)
Negative work-up	5 (14.7)
<ul> <li>No prior gastrointestinal bleeding</li> </ul>	6 (17.6)
Previous endoscopy, n (%)	31 (91.2)
• EGD	26 (76.5)
<ul> <li>Push enteroscopy</li> </ul>	9 (26.5)
Colonoscopy	24 (70.6)
<ul> <li>VCE</li> </ul>	21 (61.8)
Antithrombotic medications, n (%)	
<ul> <li>Antiplatelet<sup>1</sup></li> </ul>	20 (58.8)
Warfarin	24 (70.6)
■ INR≤2	13 (54.2)
■ INR>2 to ≤ 3	10 (41.7)
• INR>3	1 (4.2)
<ul> <li>NOAC</li> </ul>	1 (2.9)

AVM, arteriovenous malformation; CKD, chronic kidney disease; EGD, esophagogastroduodenoscopy; LVAD, left ventricular assist device; NOAC, novel oral anticoagulant; PPI, proton pump inhibitor; SD, standard deviation; VCE, video capsule endoscopy.

<sup>1</sup> Antiplatelets include aspirin and clopidogrel.

therapeutic intervention was carried out in 67.4% of cases, 73.0% for DBE and 44.4% for SBE (P=0.102). Thermal therapy was used in the majority of procedures: argon plasma coagulation (APC) in 24 procedures (52.2%), endoclips in two (4.3%), both APC and endoclips in three procedures (6.5%), both bipolar circum-active probe (BICAP) cautery and endoclips in one procedure, and APC, BICAP and endoclip in one procedure. **Fig. 1a**, **Fig. 1b**, **Fig. 1c**, and **Fig. 1d** show therapeutic interventions performed during DBE in an LVAD patient with anemia.

Diagnostic and therapeutic yields of BAE were similar for overt gastrointestinal bleeding (73.1% and 69.2%, respectively) and anemia (65% and 65%, respectively). However, for those who presented with overt gastrointestinal bleeding, DBE had a higher diagnostic yield compared to SBE (84.2 vs. 42.9%; P = 0.057). In the same group of patients, the therapeutic yield for DBE was significantly higher compared to SBE (84.2% vs. 28.6%; P = 0.014).

► Table 2 Characteristics of anesthesia for patients undergoing balloon-assisted enteroscopy.

	Type of BA			
	SBE (n = 9)	DBE (n=37)	Total (n = 46)	
ASA classification, n (%)				
Class II	1 (11.1)	3 (8.1)	4 (8.7)	
Class III	0 (0.0)	5 (13.5)	5 (10.9)	
<ul> <li>Class IV</li> </ul>	8 (88.9)	29 (78.4)	37 (80.4)	
Type of sedation performed, n (%)				
<ul> <li>MAC<sup>1</sup></li> </ul>	5 (55.6)	7 (18.9)	12 (26.1)	
General anesthesia	4 (44.4)	30 (81.1)	34 (73.9)	
Location of procedure, n (%)				
Gastroenterology     suite	1 (11.1)	7 (18.9)	8 (17.4)	
<ul> <li>Operating room</li> </ul>	8 (88.9)	30 (81.1)	38 (82.6)	

ASA, American society of anesthesiologists; BAE, balloon-assisted enteroscopy; DBE, double-balloon enteroscopy; MAC, monitored anesthesia care; SBE, single-balloon enteroscopy.

<sup>1</sup> Involved propofol administration.

# Discussion

This is the largest multicenter study of patients with LVADs who underwent DBE for evaluation of gastrointestinal bleeding comprising 34 patients and 46 BAEs (37 DBE, 9 SBE). Our results show that BAE is a safe procedure for patients with LVADs with a good diagnostic and therapeutic yield.

The first and second-year survival benefits for advanced CHF patients on LVADs were demonstrated in the landmark RE-MATCH trial but also a 42 % incidence of gastrointestinal bleeding at 6 months of follow-up [9]. Other studies have reported incidence rates between 20% to 30% [3, 10]. As noted in our results, the most common source of bleeding is small-bowel angioectasias/AVMs [4, 11–14].

Multiple pathological mechanisms have been proposed to account for the increased incidence of gastrointestinal bleeding. Continuous impeller action and increased turbulence in the outflow and inflow cannula of the LVAD pump causes proteolysis of von Willebrand factor (vWF), thus impairing platelet mediated hemostasis [3, 10, 15]. Formation of AVMs may be due to the narrow pulse pressure generated by the LVAD, leading to decreased intraluminal pressure and dilation of the mucosal veins [16]. Depending upon the type of LVAD and comorbid conditions, patients may be on long-term anticoagulation and/or antiplatelets, predisposing them to an increased risk of gastrointestinal bleeding [11].

Apart from physiological changes induced by the LVAD, use of BAE for evaluation of gastrointestinal bleeding in patients with LVADs presents unique challenges. A multidisciplinary team approach is required, usually consisting of a gastroenterologist, cardiothoracic surgeon, cardiac anesthesia, and trans► Table 3 Procedural details for balloon-assisted enteroscopy.

	Type of BAE			
	SBE (n = 9)	DBE (n=37)	Total (n=46)	
Number of blood pro	ducts transfused	l, mean (SD)		
<ul> <li>PRBCs</li> </ul>	4.00 (1.9)	3.46 (2.7)	3.57 (2.6)	
<ul> <li>Platelets</li> </ul>	0.11 (0.3)	0.00 (0.0)	0.02 (0.1)	
<ul> <li>FFP</li> </ul>	1.78 (2.3)	0.41 (0.8)	0.67 (1.3)	
Indications for performing BAE, n (%)				
<ul> <li>Melena</li> </ul>	4 (44.4)	15 (40.5)	19 (41.3)	
<ul> <li>Hematochezia</li> </ul>	2 (22.2)	6 (16.2)	8 (17.4)	
<ul> <li>Hematemesis</li> </ul>	1 (11.1)	0 (0.0)	1 (2.2)	
<ul> <li>Acute blood loss<sup>1</sup>/ anemia</li> </ul>	5 (55.6)	26 (70.3)	31 (67.4)	
Time to procedure, n (%)				
• Within 48 hours	0 (0.0)	3 (8.1)	3 (6.5)	
<ul> <li>More than 48 hours</li> </ul>	9 (100.0)	34 (91.9)	43 (93.5)	
Type of procedure, n (%)				
<ul> <li>SBE</li> </ul>	9 (100.0)	0 (0.0)	9 (19.6)	
<ul> <li>ADBE</li> </ul>	0 (0.0)	32 (86.5)	32 (69.6)	
RDBE	0 (0.0)	5 (13.5)	5 (10.9)	
Length of procedure, mean (SD), min	36.11 (19.3)	57.23 (25.0)	52.5 (25.2)	

ADBE, antegrade double-balloon enteroscopy; BAE, balloon-assisted enteroscopy; DBE, double-balloon enteroscopy; FFP, fresh frozen plasma; PRBCs, packed red blood cells; RDBE, retrograde double-balloon enteroscopy; SBE, single-balloon enteroscopy; SD, standard deviation.

<sup>1</sup> Acute blood loss was defined as  $\geq 2 g/dL$  drop in hemoglobin from the recorded baseline value.

plant team. Patients are often intubated under general anesthesia and supported by inotropes to counter the hypotension induced by anesthetic agents. It is also imperative to avoid excess upper abdominal pressure as it can impede venous return and decrease the preload required for optimal LVAD functioning [5, 11, 17]. More importantly, data regarding the safety and utility of BAE, in particular DBE, in the LVAD population are scant.

Approximately half of our population underwent VCE initially as part of the gastrointestinal bleeding workup. VCE is a safe and practical option in patients with LVADs to diagnose small intestinal bleeding [18–21]. Once a lesion has been identified on VCE, a BAE is then necessary to access the small intestine for visualization and treatment of the culprit lesions. With use of BAE, patients can avoid exposure to more invasive testing such as mesenteric angiograms or exploratory laparotomy [11,17,22]. But major AEs related to BAE have been previously reported, including pancreatitis, perforation, aspiration pneumonia, and death [23,24]. Others have reported no AEs associated with the procedure [5,6,10]. In our study, no major AEs

► Table 4 Outcomes of balloon-assisted enteroscopy procedures.			
	Type of BAE		
	SBE (n=9)	DBE (n=37)	Total (n = 46)
Adverse events <sup>1</sup>	1	2	3
Endoscopic findings, n (%)			
<ul> <li>Small-bowel AVM</li> </ul>	4 (44.4)	16 (43.2)	20 (43.5)
<ul> <li>Gastric AVM</li> </ul>	0 (0.0)	2 (5.4)	2 (4.3)
<ul> <li>Small-bowel and astric AVMs</li> </ul>	0 (0.0)	4 (10.8)	4 (8.7)
<ul> <li>Esophagitis/gastritis</li> </ul>	0 (0.0)	1 (2.7)	1 (2.2)
<ul> <li>Dieulafoy's lesion</li> </ul>	0 (0.0)	5 (13.5)	5 (10.9)
<ul> <li>Blood clots</li> </ul>	1 (11.1)	0 (0.0)	1 (2.2)
<ul> <li>Duodenal erosions</li> </ul>	0 (0.0)	1 (2.7)	1 (2.2)
<ul> <li>Normal findings/cause not identified</li> </ul>	4 (44.4)	10 (27.0)	14 (30.4)
Interventions performed, n (%)			
<ul> <li>None</li> </ul>	5 (55.6)	10 (27.0)	15 (32.6)
<ul> <li>APC</li> </ul>	4 (44.4)	20 (54.1)	24 (52.2)
<ul> <li>Endoclip</li> </ul>	0 (0.0)	2 (5.4)	2 (4.3)
<ul> <li>BICAP cautery and endo- clip</li> </ul>	0 (0.0)	1 (2.7)	1 (2.2)
<ul> <li>APC and endoclip</li> </ul>	0 (0.0)	3 (8.1)	3 (6.5)
<ul> <li>APC, BICAP and endoclip</li> </ul>	0 (0.0)	1 (2.7)	1 (2.2)

APC, argon plasma coagulation; AVM, arteriovenous malformations; BAE, balloon-assisted enteroscopy; BICAP, bipolar circum-active probe; DBE, double-balloon enteroscopy; SBE, single-balloon enteroscopy.

<sup>1</sup> None of these events were directly related to the enteroscopy procedure itself.

were noted related to the enteroscopy procedure despite the majority of patients being classified as ASA class IV.

One patient developed an arrhythmia following the procedure, and it was medically managed in the intensive care unit (ICU). In another patient, hematocrit continued to drop following SBE, necessitating DBE that was diagnostic and therapeutic for mid-ileal AVMs. There was one death in our study population: a patient with a preexisting history of LVAD thrombosis who was admitted to the ICU with melena and acute drop in hemoglobin. The patient's international normalized ratio was supratherapeutic, thus antithrombotics (aspirin and warfarin) were held. The patient underwent esophagogastroduodenoscopy and push enteroscopy, which were both negative. The next day, DBE was performed and it was diagnostic for a Dieulafoy's lesion that was managed with argon plasma coagulation. But within a few hours of the procedure, LVAD thrombosis recurred. The patient was started on intravenous heparin and thrombolytic therapy was not administered due to the history of gastrointestinal bleeding. The patient was considered a poor candidate for LVAD exchange or urgent cardiac transplant



► Fig. 1 a In a patient with anemia and left-ventricular assist device (LVAD), antegrade double-balloon enteroscopy was performed and argon plasma coagulation (APC) was used to control a bleeding angioectasia in the jejunum. b Because the bleeding persisted after APC, three hemostatic clips were applied but the angioectasia continued to bleed. c A second round of treatment with APC was performed. d After these therapeutic interventions, hemostasis was finally achieved. due to multiple comorbidities, and after discussion with the patient and their family, palliative care was provided. The patient died 4 days after the DBE. Thrombosis is a well-known medical complication of LVADs; patients with LVAD thrombosis have higher rates of bleeding and an increased mortality rate, especially when managed medically (as was the case with our patient) versus surgically [25]. This case underscores the dilemma of balancing the fragile hemostatic state of patients with LVAD thrombosis who are on antithrombotics and present with gastrointestinal bleeding. The decision to hold antithrombotics should be made in consultation with a cardiologist in order to assess the risk of LVAD thrombosis [26].

The diagnostic yield for evaluation of gastrointestinal bleeding in patients with LVADs who underwent BAE was 69.6% in our study. This is close to the previously reported diagnostic yield of 64% to 94% for BAE performed in the setting of gastrointestinal bleeding in patients with small-bowel diseases [27]. The diagnostic yield for DBE was 73.0% in our study; this is comparable to the diagnostic yield of 69% previously reported by Edwards et al for LVAD patients undergoing DBE [7]. The diagnostic yield for SBE was 55.6% in our study; Koul et al have reported a diagnostic yield of 78% for a similar cohort of patients. The timing of the procedure has been known to influence the diagnostic yield, with shorter times increasing the yield [7]. In our study, most procedures were performed after 48 hours, however, Koul et al did not provide data on timing of the procedures and they had a relatively larger cohort of patients undergoing SBE.

We did not observe a significant difference between the diagnostic or therapeutic yields for SBE and DBE in the entire cohort. However, in the subgroup of patients that presented with gastrointestinal bleeding, DBE had a higher diagnostic yield than SBE that bordered statistical significance and reached significance for therapeutic intervention. Other studies have also reported that DBE has a higher diagnostic yield in patients with overt gastrointestinal bleeding [28, 29].

There are several limitations to this study. The study cohort was relatively small (34 patients), however, this is the only multicenter study to date and the largest cohort of LVAD patients undergoing DBE. In our study, patients were followed for 72 hours post-procedure to note any complications but it can be argued that a longer duration of follow-up might have revealed additional complications, including recurrent gastrointestinal bleeding events requiring repeat BAE. Small-bowel vascular lesions have been classified into four groups based on Yano-Yamamoto classification: angioectasias, Dieulafoy's lesions, AVMs, and unclassifiable [30]. Based on this classification, angioectasias are venous lesions that should be treated with cauterization whereas Dieulafoy's and AVM's cause arterial bleeding that is likely to require hemostatic clips. In our study, lesions could not be classified based on the Yano-Yamamoto classification because this system was not used consistently at the different study centers. Although use of this classification could affect the treatment decision, it would not alter the diagnostic or therapeutic yields which were the outcomes of this study.

# Conclusion

From our study, we can conclude that BAE in patients with LVAD is a safe and effective option in management of gastrointestinal bleeding. In patients that presented with overt gastrointestinal bleeding, DBE resulted in more therapeutic interventions than SBE. Prospective trials with larger patient populations and extended follow-up are needed.

# Acknowlegements

The authors thank the patients and their families for contributing to valuable research and the hospital staff for their hard work and dedication in improving patients' lives.

## **Competing interests**

The authors declare that they have no conflict of interest.

## References

- Benjamin EJ, Blaha MJ, Chiuve SE et al. Heart Disease and Stroke Statistics-2017 Update: A Report From the American Heart Association. Circulation 2017; 135: e146–e603
- [2] Heidenreich PA, Albert NM, Allen LA et al. Forecasting the impact of heart failure in the United States: a policy statement from the American Heart Association. Circ Heart Fail 2013; 6: 606–619
- [3] Islam S, Cevik C, Madonna R et al. Left ventricular assist devices and gastrointestinal bleeding: a narrative review of case reports and case series. Clin Cardiol 2013; 36: 190–200
- [4] Demirozu ZT, Radovancevic R, Hochman LF et al. Arteriovenous malformation and gastrointestinal bleeding in patients with the Heart-Mate II left ventricular assist device. J Heart Lung Transplant 2011; 30: 849–853
- [5] Decker GA, Miller ED, Pasha SF et al. Deep enteroscopy in patients with left ventricular assist devices: practical and technical considerations. Endoscopy 2010; 42: (Suppl. 02): E194
- [6] Kwong WT, Pearlman M, Kalmaz D. Safety of Deep enteroscopy and capsule endoscopy in lvad patients: case report and literature review. Gastroenterology Res 2015; 8: 309–312
- [7] Edwards AL, Monkemuller K, Pamboukian SV et al. Utility of doubleballoon enteroscopy in patients with left ventricular assist devices and obscure overt gastrointestinal bleeding. Endoscopy 2014; 46: 986–991
- [8] Benmassaoud A, Sasson MS, Pamphile JC et al. The use of balloon-assisted enteroscopy at a large volume centre: a retrospective analysis.
   | Can Assoc Gastroenterol 2018; 1: 33–39
- [9] Rose EA, Gelijns AC, Moskowitz AJ et al. Long-term use of a left ventricular assist device for end-stage heart failure. N Engl J Med 2001; 345: 1435–1443
- [10] Koul A, Pham DM, Nanda A et al. Safety and efficacy of single-balloon enteroscopy in management of gastrointestinal bleeding in patients with a left ventricular assist device. Endosc Int Open 2017; 5: E179– E183
- [11] Daas AY, Small MB, Pinkas H et al. Safety of conventional and wireless capsule endoscopy in patients supported with nonpulsatile axial flow Heart-Mate II left ventricular assist device. Gastrointest Endosc 2008; 68: 379–382

- [12] Shrode CW, Draper KV, Huang RJ et al. Significantly higher rates of gastrointestinal bleeding and thromboembolic events with left ventricular assist devices. Clin Gastroenterol Hepatol 2014; 12: 1461– 1467
- [13] Morgan JA, Paone G, Nemeh HW et al. Gastrointestinal bleeding with the HeartMate II left ventricular assist device. J Heart Lung Transplant 2012; 31: 715–718
- [14] Stern DR, Kazam J, Edwards P et al. Increased incidence of gastrointestinal bleeding following implantation of the HeartMate II LVAD. J Card Surg 2010; 25: 352–356
- [15] Stern DR, Kazam J, Shariff S et al. 60: Increased incidence of gastrointestinal bleeding following implantation of Heartmate II LVAD. J Heart Lung Transplant 2009; 28: S86
- [16] Sarosiek K, Bogar L, Conn MI et al. An old problem with a new therapy: gastrointestinal bleeding in ventricular assist device patients and deep overtube-assisted enteroscopy. ASAIO J 2013; 59: 384–389
- [17] Tarzia V, Dal Lin C, Bottio T et al. Occult gastrointestinal bleeding in patients with a left ventricular assist device axial flow pump: diagnostic tools and therapeutic algorithm. J Thorac Cardiovasc Surg 2012; 143: e28–31
- [18] Harris LA, Hansel SL, Rajan E et al. Capsule endoscopy in patients with implantable electromedical devices is safe. Gastroenterol Res Pract 2013; 2013: 959234
- [19] Girelli CM, Tartara P, Vitali E. Lack of reciprocal interference between capsule endoscope and left ventricular assist device. Endoscopy 2006; 38: 94–95; discussion 95
- [20] Fenkel JM, Grasso MA, Goldberg EM et al. Capsule endoscopy is safe in patients with pulsatile Novacor PC left ventricular assist device. Gastrointest Endosc 2007; 65: 559–560; author reply 560
- [21] Bechtel JF, Wellhoner P, Charitos El et al. Localizing an occult gastrointestinal bleeding by wireless PillCam SB capsule videoendoscopy in

a patient with the HeartMate II left ventricular assist device. J Thorac Cardiovasc Surg 2010; 139: e73–74

- [22] Yamamoto H, Sekine Y, Sato Y et al. Total enteroscopy with a nonsurgical steerable double-balloon method. Gastrointest Endosc 2001; 53: 216–220
- [23] Mensink PB, Haringsma J, Kucharzik T et al. Complications of double balloon enteroscopy: a multicenter survey. Endoscopy 2007; 39: 613– 615
- [24] Gerson LB, Tokar J, Chiorean M et al. Complications associated with double balloon enteroscopy at nine US centers. Clin Gastroenterol Hepatol 2009; 7: 1177–1182, 1182 e1171–1173
- [25] Luc JGY, Tchantchaleishvili V, Phan K et al. Medical Therapy as compared to surgical device exchange for left ventricular assist device thrombosis: a systematic review and meta-analysis. ASAIO J 2019; 65: 307–317
- [26] Gurvits GE, Fradkov E. Bleeding with the artificial heart: Gastrointestinal hemorrhage in CF-LVAD patients. World J Gastroenterol 2017; 23: 3945–3953
- [27] Al-Bawardy B, Piovezani RamosG, Lennon RJ et al. Outcomes of repeat balloon assisted enteroscopy in small-bowel bleeding. Endosc Int Open 2018; 6: E694–E699
- [28] Akarsu M, Akkaya Ozdinc S, Celtik A et al. Diagnostic and therapeutic efficacy of double-balloon endoscopy in patients with small intestinal diseases: single-center experience in 513 procedures. Turk J Gastroenterol 2014; 25: 374–380
- [29] Shinozaki S, Yamamoto H, Yano T et al. Long-term outcome of patients with obscure gastrointestinal bleeding investigated by doubleballoon endoscopy. Clin Gastroenterol Hepatol 2010; 8: 151–158
- [30] Yano T, Yamamoto H, Sunada K et al. Endoscopic classification of vascular lesions of the small intestine (with videos). Gastrointest Endosc 2008; 67: 169–172