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Safety of Transesophageal Echocardiography to Guide Structural Cardiac Interventions

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ABSTRACT

BACKGROUND Despite the widespread use of transesophageal echocardiography (TEE) to guide structural cardiac interventions, studies evaluating safety in this context are lacking.

OBJECTIVES This study sought to determine the incidence, types of complications, and factors associated with esophageal or gastric lesions following TEE manipulation during structural cardiac interventions.

METHODS This was a prospective study including 50 patients undergoing structural cardiac interventions in which TEE played a central role in guiding the procedure (mitral and tricuspid valve repair, left atrial appendage closure, and paravalvular leak closure). An esophagogastroduodenoscopy (EGD) was performed before and immediately after the procedure to look for new injuries that might have arisen during the course of the intervention. Patients were divided in 2 cohorts according to the type of injury: complex lesions (intramural hematoma, mucosal laceration) and minor lesions (petechiae, ecchymosis). The factors associated with an increased risk of complications were assessed.

RESULTS Post-procedural EGD showed a new injury in 86% (n = 43 of 50) of patients, with complex lesions accounting for 40% (n = 20 of 50) of cases. Patients with complex lesions presented more frequently with an abnormal baseline EGD (70% vs. 37%; p = 0.04) and had a higher incidence of post-procedural dysphagia or odynophagia (40% vs. 10%; p = 0.02). Independent factors associated with an increased risk of complex lesions were a longer procedural time under TEE manipulation (for each 10-min increment in imaging time, odds ratio: 1.27; 95% confidence interval: 1.01 to 1.59) and poor or suboptimal image quality (odds ratio: 4.93; 95% confidence interval: 1.10 to 22.02).

CONCLUSIONS Most patients undergoing structural cardiac interventions showed some form of injury associated with TEE, with longer procedural time and poor or suboptimal image quality determining an increased risk. Imaging experts performing this technique should be aware of the nature of potential complications, to take the necessary precautions to prevent their occurrence and facilitate early diagnosis and treatment.
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Transesophageal echocardiography (TEE) has become an invaluable monitoring adjunct for operative and percutaneous interventions by providing real-time information to help guide and assess procedural results (1). Despite being considered to have a good safety profile, this semi-invasive technique has been associated with severe complications, some of which can be life-threatening (2–6). Notably, in the field of cardiac transcatheter-based interventions in which TEE plays a central role in guiding the procedure (e.g., mitral valve repair), the incidence of major TEE-related complications seems to be higher than what has been previously reported during the ambulatory and operative setting: 3.3% (7) versus 0.2% to 1.4% (3,6,8,9). The need for constant probe manipulation to optimize the image and guide the interventionalist throughout the duration of the procedure appears to account for part of this higher injury rate. However, despite the widespread application of this technique that parallels the rapidly expanding field of structural heart interventions, most data on TEE safety come from the surgical literature. Hence, it is important to understand and be familiar with the potential complications associated with TEE in this context, in order to better identify patients at risk, implement preventive measures, and allow for a prompt diagnosis and management. Thus, the goal of the present study was to prospectively determine the incidence, types of complications, and factors associated with anatomic lesions related to TEE probe manipulation to guide structural cardiac interventions.

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METHODS

PATIENT POPULATION. A cohort of 50 patients undergoing cardiac structural interventions with an intraprocedural TEE between November 2018 and November 2019 at our institution were included. All patients had an intervention in which TEE played a central role in guiding the procedure during the study period: edge-to-edge mitral valve repair (n = 20) (MitraClip, Abbott Vascular, Chicago, Illinois), tricuspid valve repair (n = 2) (FORMA device, Edwards Lifesciences, Irvine, California), left atrial appendage closure (n = 24) (WATCHMAN, Boston Scientific, Marlborough, Massachusetts), and paravalvular leak closure (n = 4) (Amplatzer Vascular Plug, Abbott Vascular). The study was performed as part of an evaluation of the quality of medical care following an episode of a major life-threatening esophageal complication related to TEE during a transcatheter structural heart disease intervention. All patients provided signed informed consent for the procedures and the recording and scientific use of baseline, procedural, and follow-up data. Ethics committee approval was obtained for data collection and analysis.

PRE-PROCEDURAL AND INTRAPROCEDURAL ANTICOAGULATION. Patients receiving warfarin were asked to interrupt the treatment 5 days before the procedure, and bridging with low-molecular-weight heparin at a dose of 1 mg/kg twice daily was started once the international normalized ratio decreased below 2 (10). For patients taking a direct oral anticoagulant (DOAC), the treatment was discontinued 2 days prior to the procedure, without bridging (10). Intraprocedurally, patients received a bolus of 100 IU/kg of intravenous heparin after transseptal puncture, and further doses were adjusted to achieve and maintain a target activated clotting time >250 s. Activated clotting time levels were checked every 30 min throughout all procedures.

ABBREVIATIONS AND ACRONYMS

AF = atrial fibrillation

DOAC = direct oral anticoagulant

EGD = esophagogastroduodenoscopy

GA = general anesthesia

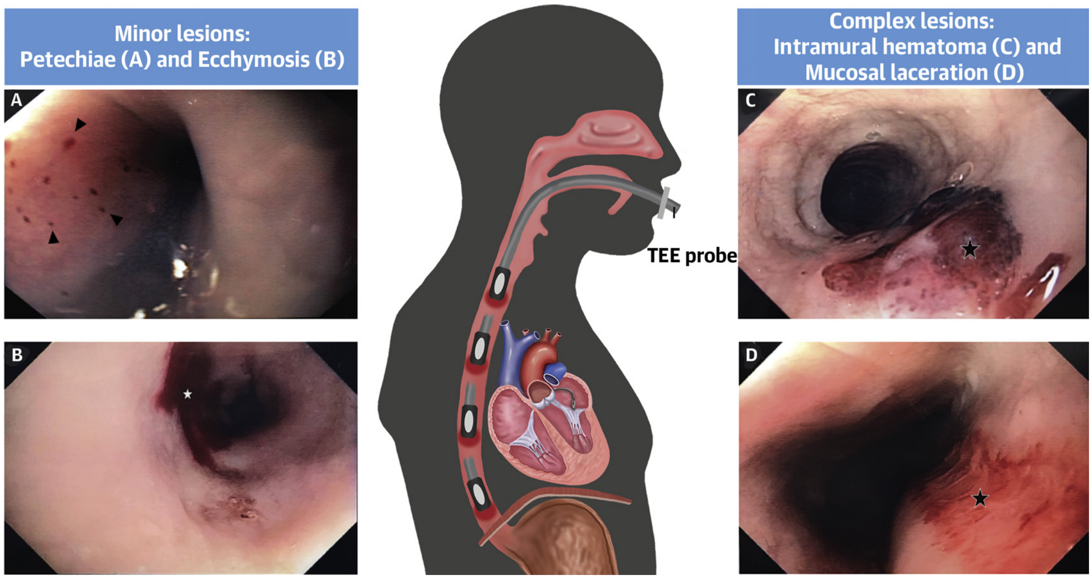
IQR = interquartile range

TEE = transesophageal echocardiography

ECHOCARDIOGRAPHIC STUDY. All intraprocedural TEE examinations were performed by an experienced cardiologist after the induction of general anesthesia (GA) and endotracheal intubation. Following adequate lubrication, the probe was blindly inserted with the help of a jaw-thrust maneuver, and a mouth guard was inserted. A multiplane adult TEE probe from GE Vivid E9 (6VT-D) (GE Healthcare, Milwaukee, Wisconsin) and Philips EPIQ 7 (X8-2t) (Philips Healthcare, Best, the Netherlands) was used, and the maximal temperature registered by the probe was noted. A digital stopwatch was used to time the intervention. The stopwatch was started each time image acquisition was ongoing and stopped when the probe was not being used, at which point the image was frozen to prevent overheating. Image quality (2-dimensional and 3-dimensional) was graded on a scale of good, suboptimal and poor. The image was considered to have a good quality if we were able to clearly identify all the relevant anatomical details and devices being used with minimal probe manipulation. Image quality was graded as poor if it had a low temporal or spatial resolution that resulted in a lower diagnostic quality requiring significant probe manipulation (anteflexion or retroflexion) to optimize the image. Cases in which the image resolution was lower but neither interfered with the ability to guide the procedure nor required significant probe manipulation were rated as suboptimal.

ESOPHAGOGASTRODUODENOSCOPY. All esophagogastroduodenoscopy (EGD) examinations were performed by a thoracic surgeon with extensive

CENTRAL ILLUSTRATION Types of Lesions Associated With TEE Manipulation During Structural Cardiac Interventions



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Post-procedural esophagogastroduodenoscopy (EGD) showed a new injury in the vast majority of patients undergoing transesophageal echocardiography (TEE). Lesions were considered to be minor if they only affected the mucosa and complex if the damage extended into the submucosal layer. Minor lesions included **(A)** petechiae **(black arrowheads)** and **(B)** ecchymosis **(white star)**. Complex lesions accounted for 40% of cases and included **(C)** intramural hematomas **(black star)** and **(D)** mucosal lacerations **(black star)**.

experience in endoscopic procedures. Patients underwent a first EGD after endotracheal intubation, just before TEE probe placement. The distance from the incisor teeth to the squamocolumnar junction (Z-line) was recorded, along with any anatomical abnormalities or injuries encountered prior to the start of the procedure. A second EGD was performed at the end of the procedure, after the removal of the TEE probe but before endotracheal extubation, to thoroughly look for new injuries that might have arisen during the course of the intervention.

DEFINITIONS. Pharyngeal, esophageal, and gastric lesions were classified as minor (superficial) lesions, or complex lesions if the damage extended into the submucosal layer. Minor lesions included petechiae and ecchymosis. Hematomas and mucosal lacerations were considered to be complex lesions. Examples of each lesion type are shown in the Central Illustration. Petechiae were defined as small (pinpoint) red-purple, nonraised (macular), circular lesions, and ecchymosis as larger confluent petechial lesions. An intramural hematoma was defined as a collection of blood in the submucosa causing a circumscribed elevated lesion. A laceration or abrasion was defined as a defect of the mucosal surface.

FOLLOW-UP. Patients were followed at 30 days by phone calls or clinical visits made after discharge as part of a standardized in-hospital protocol following structural interventional procedures.

STATISTICAL ANALYSIS. Given the paucity of data examining complications related to TEE guidance during structural cardiac interventions, the sample size was empirically estimated at 50 patients. Because the prevalence of TEE-related injuries found in previous studies with systematic endoscopic evaluation was relatively high (30% to 64%) (11,12), it was considered that this sample size would allow for an appropriate description of the type of lesions associated with TEE manipulation.

Categorical variables were expressed as a number (percentage), and comparisons were performed with the chi-square or Fisher exact test. Owing to the relatively small sample size, continuous variables were expressed as median (interquartile range [IQR]), and comparisons were performed using the nonparametric Wilcoxon rank sum test. A logistic

TABLE 1 Baseline Clinical Demographics of the Study Population, Overall and According to the Occurrence of TEE-Related Complex Lesions

	Overall Population (N = 50)	Complex Lesions (n = 20)	Minor/No Lesions (n = 30)	p Value
Baseline characteristics				
Age, yrs	76.8 (70.0–82.0)	76.1 (70.9–80.5)	77.5 (70.0–83.0)	0.820
Female	16 (32.0)	8 (40.0)	8 (26.7)	0.366
Weight, kg	77.2 (67.0–82.0)	75.5 (66.0–86.0)	74.0 (68.0–80.0)	0.714
BMI, kg/m^2	26.3 (23.8–29.0)	27.1 (23.1–32.7)	25.8 (23.8–28.4)	0.586
Comorbidities				
Hypertension	45 (90.0)	19 (95.0)	26 (86.7)	0.636
Diabetes mellitus	19 (38.0)	8 (40.0)	11 (36.7)	0.812
Dyslipidemia	38 (76.0)	16 (80.0)	22 (73.3)	0.589
Smokers	10 (20.0)	6 (30.0)	4 (13.3)	0.171
Previous PAD	7 (14.0)	2 (10.0)	5 (16.7)	0.687
Chronic kidney disease (eGFR <60 ml/min/1.73 m^2)	29 (58.0)	14 (70.0)	15 (50.0)	0.243
Previous open-heart surgery	24 (48.0)	9 (45.0)	15 (50.0)	0.779
Heart failure	19 (38.0)	8 (40.0)	11 (36.7)	0.812
LVEF, %	50.0 (37.0–60.0)	47.5 (32.5–60.0)	50.0 (40.0–58.0)	0.789
CVA/TIA	13 (26.0)	4 (20.0)	9 (30.0)	0.522
Prior bleeding	23 (46.0)	7 (35.0)	16 (53.3)	0.254
Previous GI bleeding	13 (26.0)	5 (25.0)	8 (26.7)	0.895
Prior chest RT	5 (10.0)	1 (5.0)	4 (13.3)	0.636
Prior AF/flutter	39 (78.0)	14 (70.0)	25 (83.3)	0.311
Previous treatment				
ASA	22 (44.0)	11 (55.0)	11 (36.7)	0.251
Clopidogrel	7 (14.0)	2 (10.0)	5 (16.7)	0.687
Dual antiplatelet therapy	5 (10.0)	1 (5.0)	4 (13.3)	0.636
Anticoagulant therapy	30 (60.0)	12 (60.0)	18 (60.0)	1.000
Warfarin	14 (28.0)	6 (30.0)	8 (26.7)	0.797
DOACs	16 (32.0)	6 (30.0)	10 (33.3)	0.804
PPI	40 (80.0)	17 (85.0)	23 (76.7)	0.720
Immunosuppressors	3 (6.0)	1 (5.0)	2 (6.7)	0.808

Values are median (interquartile range) or n (%).

AF = atrial fibrillation; ASA = acetylsalicylic acid; BMI = body mass index; CVA = cerebrovascular accident; DOACs = direct oral anticoagulants; eGFR = estimated glomerular filtration rate; GI = gastrointestinal; LVEF = left ventricular ejection fraction; PAD = peripheral artery disease; PPI = proton pump inhibitor; RT = radiotherapy; TIA = transient ischemic attack.

regression analysis was performed to determine the independent predictors of TEE-related complex lesions. Those variables from the univariable analysis with a p value <0.05 were entered into a multivariable regression analysis. Owing to a low event per variable ratio, the logistic regression model was penalized using the Firth bias correction (13). Analyses were performed using STATA version 14.2 (StataCorp, College Station, Texas).

RESULTS

Baseline clinical demographics of the study population are summarized in Table 1. The median age of the overall cohort was 77 years (IQR: 70 to 82 years), 32% of patients were women, and the median left ventricular ejection fraction was 50% (IQR: 37% to 60%). Patients exhibited a high prevalence of comorbidities such as hypertension (90%) and chronic kidney disease (58%). Sixty percent of patients were under anticoagulation therapy (warfarin: 28%, DOAC: 32%), 44% under antiplatelet therapy with aspirin, and 80% were treated with a proton pump inhibitor. The main procedural characteristics and in-hospital outcomes are displayed in Table 2. Difficult endotracheal intubation was noted in 1 (2%) patient, and difficult probe placement was noted in 4 (8%). The overall median procedural time was 48 min (IQR: 35 to 80 min), and image quality was considered to be poor or suboptimal in 11 (22%) cases. The longest procedural time was seen in patients undergoing the MitraClip procedure (80 min [IQR: 65 to 89 min]), followed by tricuspid valve repair (75 min [IQR: 60 to 90 min]), paravalvular leak closure (57 min [IQR: 27 to 76 min]), and left atrial appendage closure (35 min [IQR: 31 to 42 min]). Median hospital stay was 1 day (IQR: 1 to 1 day), and there was 1 hospital death unrelated to a TEE complication.

TABLE 2 Procedural Characteristics and In-Hospital Outcomes of the Study Population, Overall and According to the Occurrence of TEE-Related Complex Lesions

	Overall Population (N = 50)	Complex Lesions (n = 20)	Minor/No Lesions (n = 30)	p Value
Procedural characteristics				
Difficult ET intubation	1 (2.0)	0 (0.0)	1 (3.3)	0.409
Difficult probe insertion	4 (8.0)	2 (10.0)	2 (6.7)	0.670
Abnormal pre-EGD	25 (50.0)	14 (70.0)	11 (36.7)	0.042
SAP, mm Hg	115 (110–120)	110 (108–128)	115 (110–120)	0.888
DAP, mm Hg	55 (50–60)	55 (50–63)	55 (50–60)	0.663
MAP, mm Hg	75 (67–80)	77 (67–81)	74 (68–80)	0.662
TU-TEE manipulation, min	48.0 (35.0–80.0)	66.5 (44.0–87.0)	42.0 (32.0–69.0)	0.019
Maximal probe temperature, °C	39.0 (38.7–39.3)	39.2 (38.8–39.8)	39.0 (38.6–39.2)	0.116
Poor/suboptimal image quality	11 (22.0)	8 (40.0)	3 (10.0)	0.017
Types of procedures				
LAAC	24 (48.0)	7 (35.0)	17 (56.7)	0.133
Mitral valve repair (MitraClip)	19 (38.0)	10 (50.0)	9 (30.0)	0.153
PVLC	4 (8.0)	0 (0.0)	4 (13.3)	0.140
Tricuspid valve repair (FORMA device)	2 (4.0)	2 (10.0)	0 (0.0)	0.155
MitraClip + LAAC	1 (2.0)	1 (5.0)	0 (0.0)	0.400
In-hospital outcomes				
Hospital stay, days	1 (1–1)	1 (1–1)	1 (1–1)	0.181
In-hospital death*	1 (2.0)	0 (0.0)	1 (3.3)	0.409
Post-procedural dysphagia/odynophagia	11 (22.0)	8 (40.0)	3 (10.0)	0.017
Moderate/severe	3 (6.0)	3 (15.0)	0 (0.0)	0.058

Values are n (%) or median (interquartile range). *Death unrelated to a TEE complication.

DAP = diastolic arterial pressure; EGD = esophagogastroduodenoscopy; ET = endotracheal; LAAC = left atrial appendage closure; MAP = mean arterial pressure; PVLC = paravalvular leak closure; SAP = systolic arterial pressure; TU-TEE = time under transesophageal echocardiography.

TEE-RELATED COMPLICATIONS. Pre-procedural EGD revealed anatomic abnormalities in 25 (50%) cases, which included Barrett's esophagus (n = 7), hiatal hernia (n = 7), esophageal dilation suspicious of achalasia (n = 2), esophageal diverticulum (n = 3), esophageal varices grade I (n = 2), gastric hyperplastic polyp (n = 2), gastritis (n = 1), and chronic radiation-induced esophagitis (n = 1). In 3 patients in which a TEE was performed within the prior 2 weeks, EGD revealed the presence of old abrasions with fibrin crusts and ecchymosis.

Post-procedural EGD showed a new injury in 86% (n = 43 of 50) of patients, with complex lesions accounting for 40% (n = 20 of 50) of cases (**Central Illustration**). A detailed summary of individual cases presenting with complications are shown in Supplemental Table 1, and additional visual examples of complications are depicted in Supplemental Figure 1. Complex lesions included 14 (28%) esophageal hematomas, 1 (2%) soft palate hematoma, 12 (24%) cases of laceration or abrasions, and 1 (2%) stomach laceration. Compared with patients exhibiting no or minor lesions, those with complex injuries had also more frequently an abnormal baseline EGD (70% vs. 37%; p = 0.04), underwent more prolonged procedures (66 min [IQR: 44 to 87 min] vs. 42 min [IQR: 32 to 69 min]), had image quality that was more frequently considered to be poor or suboptimal (40% vs. 10%; p = 0.02), and had a higher incidence of post-procedural odynophagia or dysphagia (40% vs. 10%; p = 0.01). All patients were managed conservatively with analgesics, proton pump inhibitors, bowel rest, or cessation of anticoagulation. In 1 patient in whom a difficult probe insertion was noted (case number 9, Supplemental Appendix), the EGD revealed a large soft palate hematoma and arytenoid edema that required discontinuation of anticoagulation, cessation of oral intake, nonsteroidal anti-inflammatory drugs to manage severe odynophagia, and a repeat endoscopy using a flexible laryngoscopy to make sure that the hematoma was stable and that there was no airway obstruction. In another patient (case number 14, Supplemental Appendix), post-procedural EGD showed 2 large hematomas and a laceration that the thoracic surgeon performing the endoscopic procedure deemed severe enough to require a prolonged hospital stay to monitor the patient. In this case, management was also conservative and comprised analgesia and cessation of oral intake, followed by a gradual reintroduction of liquid and soft diet.

TABLE 3 Predictors of Complex Lesions

	Univariate Model		Multivariate Model	
	OR (95% CI)	p Value	OR (95% CI)	p Value
Clinical variables				
Age (per 1-yr increments)	1.00 (0.93–1.08)	0.999	–	–
Female	1.83 (0.55–6.12)	0.325	–	–
Weight (per 1-kg increments)	1.01 (0.97–1.04)	0.650	–	–
BMI (per 1-kg/m^2 increments)	1.03 (0.93–1.15)	0.568	–	–
Comorbidities				
Hypertension	2.92 (0.30–28.29)	0.354	–	–
Diabetes mellitus	1.15 (0.36–3.68)	0.812	–	–
Dyslipidemia	1.45 (0.37–5.68)	0.590	–	–
Smokers	2.79 (0.67–11.55)	0.158	–	–
Previous PAD	0.55 (0.10–3.19)	0.510	–	–
Chronic kidney disease (eGFR <60 ml/min/1.73 m^2)	2.33 (0.71–7.70)	0.164	–	–
Previous open-heart surgery	0.82 (0.26–2.54)	0.729	–	–
Heart failure	1.15 (0.36–3.68)	0.812	–	–
LVEF (per 5% increments)	0.94 (0.75–1.17)	0.552	–	–
CVA/TIA	0.58 (0.15–2.24)	0.432	–	–
Prior bleeding	0.47 (0.15–1.5)	0.206	–	–
Previous GI bleeding	0.92 (0.25–3.25)	0.895	–	–
Prior chest RT	0.34 (0.03–3.31)	0.354	–	–
Prior AF/flutter	0.47 (0.12–1.81)	0.270	–	–
Previous treatment				
ASA	2.11 (0.67–6.68)	0.204	–	–
Clopidogrel	0.56 (0.10–3.19)	0.510	–	–
Dual antiplatelet therapy	0.34 (0.03–3.31)	0.354	–	–
Anticoagulant therapy	1.00 (0.31–3.17)	1.00	–	–
Warfarin	1.18 (0.34–4.12)	0.797	–	–
DOACs	0.86 (0.25–2.91)	0.805	–	–
PPI	1.72 (0.39–7.66)	0.474	–	–
Immunosuppressors	0.74 (0.06–8.71)	0.809	–	–
Procedural characteristics				
SAP (per 5-mm Hg increments)	1.04 (0.85–1.27)	0.716	–	–
DAP (per 5-mm Hg increments)	1.01 (0.95–1.08)	0.726	–	–
MAP (per 5-mm Hg increments)	1.07 (0.78–1.47)	0.674	–	–
TU-TEE manipulation (per 10-min increments in imaging time)	1.27 (1.01–1.58)	0.037	1.27 (1.01–1.59)	0.039
Maximal probe temperature (per 1°C increments)	2.14 (0.57–8.07)	0.260	–	–
Poor/suboptimal image quality	6.00 (1.35–26.65)	0.019	4.93 (1.10–22.02)	0.037
Abnormal pre-EGD	4.03 (1.20–13.53)	0.024	2.77 (0.77–9.96)	0.120

Abbreviations as in Tables 1 and 2.

The main clinical and procedural factors associated with complex lesions are summarized in Table 3. In the multivariable analysis, independent features associated with an increased risk of complex lesions were a longer imaging time under active probe manipulation (for each 10-min increment, odds ratio: 1.27; 95% confidence interval: 1.01 to 1.59) and having a poor or suboptimal image quality (odds ratio: 4.93; 95% confidence interval: 1.10 to 22.02).

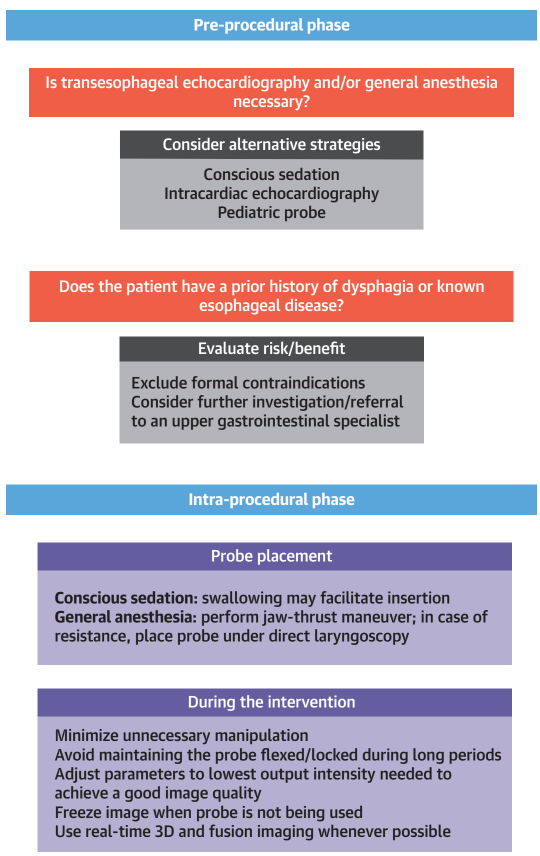
The median follow-up period was 45 days (IQR: 28 to 56 days). There were no deaths, readmissions, or complications related to the use of TEE during follow-up.

DISCUSSION

The results of the present study showed that some form of TEE-associated injury was present in the vast majority of patients undergoing structural cardiac interventions, with more complex lesions (hematoma or laceration) accounting for 40% of cases. A longer procedural time under TEE manipulation and a suboptimal or poor image quality were associated with an increased risk of complex lesions.

The growing prevalence of valvular heart diseases, an aging population with frequent comorbidities, and patients opting for less invasive therapies has given

FIGURE 1 General Considerations and Recommendations to Potentially Reduce the Risk of Transesophageal Echocardiography-Related Complications



Key concepts and recommendations to help reducing complications associated with transesophageal echocardiography probe manipulation in patients undergoing structural cardiac interventions. 3D = 3-dimensional.

rise to advances in percutaneous transcatheter technologies and a growing number of increasingly complex interventions being performed (14,15). To guide these procedures, TEE plays an instrumental role by monitoring the procedural steps in order to improve results and minimize complications (16). However, despite the extensive use of this technique, there is a paucity of data concerning the safety of TEE to guide transcatheter heart interventions, and most of the available information comes from the surgical literature (2,3,6,8,9). Some of the factors found to be associated with esophageal injury in surgical series, such as advanced age, administration of peri-operative anticoagulation, the complexity and duration of the procedure, and undergoing GA (3,5,6,8,9), seem to also play a role in the mechanisms responsible for TEE-related complications in patients undergoing structural cardiac procedures. Similar to the cardiac surgery setting, these patients also receive systemic anticoagulation and undergo GA. In patients undergoing GA, probe placement and manipulation poses a slightly different risk profile. Patients are unable to swallow to facilitate probe insertion and cannot respond to potentially harmful manipulations by indicating pain or discomfort, which may also mask symptoms and delay the diagnosis in case of a complication. Interestingly, Di Biase et al. (17) showed that patients undergoing ablation for atrial fibrillation (AF) under GA had a higher incidence of esophageal injury detected by capsule endoscopy as compared with conscious sedation. The authors suggested that the abolition of spontaneous deglutition and a decrease in peristalsis may prevent physiological cooling and, in our study, a similar mechanism may have facilitated heat transfer from the probe to the esophagus.

In line with surgical series, we have also found that a prolonged procedure was associated with an increased risk of TEE complications, a finding that has also been replicated in the setting of patients undergoing AF ablation with TEE (11). Moreover, in a recently published retrospective study, we observed that the duration of active TEE imaging increased the risk of injury and was associated with higher rates of major TEE-related morbidity in patients undergoing procedures requiring active probe manipulation compared with transaortic valve replacement, in which the use of TEE is more limited and resembles the operative setting (7). Indeed, in the current cohort, we detected a noticeably higher incidence of TEE-related complications (86%) compared with what has been previously reported in the literature, and there might be several explanations for these discrepant observations.

First, even though some of the studies performed in the operative setting included a large number of patients (3,6,8), the majority were retrospective and prone to underestimate the true incidence of TEE-related injuries because outcomes were mainly based on symptoms and methods to detect complications have been inconsistent. In our study, a significant proportion of patients were asymptomatic or had self-limiting symptoms that might have gone underdiagnosed in the absence of a systematic esophageal and gastric evaluation. In fact, a pediatric series in which an endoscopic evaluation was performed following congenital heart surgery also found a high incidence (64%) of esophageal lesions (12). In a more recent study, Kumar et al. (11) evaluated the risk of TEE imaging during AF ablation using capsule endoscopy prior to and within 24 h following the procedure. Akin to our findings, Kumar et al. (11) observed a high prevalence (37%) of pre-procedural esophageal abnormalities. After the procedure, new lesions were detected in 30% of patients who had a TEE in place during pulmonary vein isolation, in 0% of those who underwent ablation without TEE guidance, and in 22% of those that underwent a TEE but had no left atrial ablation (11). It is important to note that, in patients undergoing left atrial ablation, there are some differentiating aspects regarding the mechanisms leading to esophageal lesions, such as thermal injury caused by radiofrequency per se and the fact that the TEE probe may act as an antenna that draws radiofrequency energy into the esophagus. However, the fact that a significant number of esophageal lesions were also identified in patients undergoing TEE without ablation indicates that the TEE probe was the likely cause in at least some of the cases. The second reason that may account for the higher incidence of esophageal damage seen in the present study is the different risk profile of patients undergoing structural cardiac interventions. Compared with the baseline characteristics of patients enrolled in previous studies, patients in our cohort were older and had a higher prevalence of comorbidities, which might in turn predispose them to the development of complications. Last, in contrast with the operative and AF ablation settings, in which image acquisition typically lasts short periods of time, TEE used to guide interventional procedures requires constant probe manipulation throughout the course of the intervention.

Several mechanisms for esophageal injury caused by TEE have been reported. Direct mechanical trauma might be related to blind insertion and advancement of an improperly placed probe or with forced manipulation of a well-placed one, which is sometimes required to achieve certain views needed for procedural guidance (5,8). A high surface contact pressure exerted at the mucosal-probe interface has also been postulated as a potential mechanism that could lead to injury and necrosis, although this theory is not clearly supported by animal and human studies (5,18,19). Finally, thermal injury caused by the heat or ultrasound energy produced by the TEE probe, especially in patients with severe atherosclerosis, might play a contributory role (20). In the context of transcatheter cardiac interventions, direct mechanical trauma caused by the probe in patients under "intensive" heparin anticoagulation is likely to be one of the main mechanisms responsible for the injuries. In the current study, a longer procedure and a poor or suboptimal image were associated with an increased risk of developing an intramural hematoma or mucosal laceration. It is not unusual for TEE to be in some cases technically more challenging, with poor image quality requiring forced manipulation to optimize the image. However, it is of note that even though patients had a high incidence of TEE-related injuries, all complications were managed conservatively, the majority of dysphagia or odynophagia episodes were self-limited, and there were no cases of perforation or death related to a TEE complication. In general, patients with mild symptoms and minor or small complex lesions were treated with analgesics, proton pump inhibitors, and a soft diet. In cases in which the EGD revealed a large hematoma, if symptoms were severe, patients were successfully managed with cessation of oral intake and temporary interruption of anticoagulation (if previously prescribed).

An abnormal baseline EGD was also associated with an increased risk of developing a complex lesion post-procedure. It is well established that esophageal injury is more likely in patients with pre-existing diseases or abnormalities than in those with a normal esophagus (5,21).

CLINICAL IMPLICATIONS. Given the results of our study, operators may consider the following measures in order to potentially reduce the risk of TEE-related complications (**Figure 1**):

First, during the evaluation phase of patient suitability for structural cardiac procedures, it may be important to question the need of using TEE and GA. Alternative strategies to consider include doing the procedure under conscious sedation and adopting alternative imaging tools such as intracardiac echocardiography or using pediatric probes, which are less traumatic but have the downside of not supporting 3-dimensionality and having an inferior image quality compared with the standard adult probe (22).

Second, considering that the majority of complications were managed conservatively and that most patients were asymptomatic or had self-limiting symptoms, we believe that a routine endoscopic investigation would not be cost-effective and should not be recommended in all patients. In those patients with known esophageal disease, the potential benefits of performing a TEE should be balanced against the potential risks and, if in doubt, a clearance from an upper gastrointestinal specialist should be obtained prior to the examination (23). Also, because formal contraindications for TEE usually include a past history of dysphagia, a careful patient evaluation for swallowing difficulties may help identify patients at an increased risk that might benefit from further evaluation.

Third, in patients under conscious sedation, asking the patient to swallow during probe advancement may minimize excessive force. In those under GA, the probe should be inserted under direct laryngoscopy if a blind insertion is not readily accomplished.

Fourth, during the course of the intervention, operators should try to minimize unnecessary manipulation, avoid maintaining the probe flexed or locked during long periods of time, freeze the image when the probe is not being used to prevent it from overheating, and always consider the need to terminate a procedure with a low expected success rate based on a long TEE imaging time.

Last, the routine implementation of relatively new technologies such as real-time 3-dimensional spatial visualization and fusion imaging, which superimpose live TEE or pre-acquired computed tomography scan images onto the fluoroscopic images, have shown to increase procedural success rate and lead to safer and shorter procedures (24,25).

STUDY LIMITATIONS. Data regarding TEE complications were recorded without an event adjudication committee, and the lack of a standardized injury scale to report lesions may partially limit the external validity of the study. Additionally, the relatively small number of patients limits the statistical power for identifying predictors of complications.

CONCLUSIONS

The use of TEE for guiding structural heart disease interventions was associated with some degree of esophageal or gastric injury in the vast majority of cases, with a longer procedural time, suboptimal TEE image quality, and prior esophageal disease being associated with an increased risk of a more complex injury (hematoma, mucosal laceration). These results highlight the clinical relevance of being aware of predisposing factors and the nature of potential TEE complications during structural cardiac interventions, in order to improve their prevention, prompt diagnosis, and optimize management strategies.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: Despite the relative safety of TEE, injuries related to this type of imaging occur in the vast majority of patients undergoing structural cardiac interventions. Pre-existing esophageal or gastric disease, suboptimal image quality, and a longer imaging time are associated with more complex injuries, including intramural hematoma or mucosal laceration.

TRANSLATIONAL OUTLOOK: Further efforts are needed to clarify the mechanisms and factors predisposing to TEE complications in patients with structural heart disease.

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APPENDIX For a supplemental figure and table, please see the online version of this paper.