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Approaches to the Diagnosis and Management of Atrial-Esophageal Fistula After Catheter Ablation for Atrial Arrhythmias

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Abstract

Purpose of Review Catheter ablation has become a cornerstone of therapy in the management of patients with atrial fibrillation (AF). Thermal energy generated in the left atrium (LA) during ablation has the potential to damage adjacent structures. The most feared and rare complication in these ablations is atrial-esophageal fistula (AEF) result from the thermal injury to the esophagus due to the proximity to the LA, with potential catastrophic outcome. This review focuses on the diagnosis and management of AEF after catheter ablation for AF, including preventive measures to avoid esophageal lesions.

Recent Findings Symptoms of AEF are often vague and nonspecific, sometimes asymptomatic until they present with fistula or perforation, making the diagnosis somewhat challenging. The esophagogastroduodenoscopy is the gold standard for early detection of esophageal lesions related to AF ablation. Chest CT with oral and intravenous contrast is preferred when there is suspicion of perforation. The use of an esophageal temperature probe during ablation to monitoring esophageal temperature, associated with mechanical displacement of the esophagus, may be feasible to prevent thermal esophageal lesions and enabling adequate energy delivery to the posterior wall of the LA. Prophylactic use of proton pump inhibitors after AF ablation is accepted to be effective and justified as preventive treatment.

Summary AEF is an unpredictable complication. Be aware of these complications in the follow-up of patients after AF ablation can lead to the early recognition to start treatment, including surgical repair, as soon as possible to prevent the fatal outcome.

Keywords Atrial fibrillation · Catheter ablation · Pulmonary vein isolation · Esophageal injury · Atrial-esophageal fistula

Abbreviations

AEF	Atrial-esophageal fistula
AF	Atrial fibrillation
CT	Computer tomography
EGD	Esophagogastroduodenoscopy
LA	Left atrium
MR	Magnetic resonance
NPO	*Nir* per os
PPIs	Proton pump inhibitors
PV	Pulmonary vein
RF	Radiofrequency

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Introduction

Atrial fibrillation (AF) is the most prevalent arrhythmia and the treatment by catheter ablation has become a cornerstone of therapy in the management of patients with AF. Since Haïssaguerre and coworkers described the role of pulmonary veins, the increasing operator experience and the advances in technology over the past decade have led to a dramatic rise in the number of ablation procedures worldwide for treatment of symptomatic or drug-refractory patients with AF, becoming now the most commonly performed catheter ablation procedure [1, 2••]. This procedure involves isolation of the pulmonary vein (PV) ostia and other common triggers of AF in the left atrium (LA) including the posterior wall. Thermal energy generated in the LA during ablation has the potential to damage adjacent structures. Thus, despite catheter ablation of AF being typically known as a minimally invasive procedure, it is not without risk. Cardiac tamponade, stroke, PV stenosis, phrenic palsy, gastroparesis, and stiff LA syndrome are some of the complications of AF ablation, but the most feared is

atrial-esophageal fistula (AEF) that results from the thermal injury of the esophagus due to the proximity to the LA and has a potential catastrophic outcome.

Atrial-esophageal fistula is a rare complication, currently, estimated to occur in 0.1 to 0.25% of the AF ablation procedure. The risk is lower than reported in the first cases reported in 2004–2005 when the risk of AEF was first described and before the introduction of several preventive measures [3–5]. A recent study involving eight centers in Brazil identified ten cases of AEF (0.116%) in 8500 procedures in the period of 2004 to 2015 [6•]. In agreement with findings from prior reports, two cases that represent an incidence of 0.5% occurred in 2003 and 2004. During this time period, the ablation strategy what changed from isolation of the pulmonary veins (PV) to antral PV isolation. Atrial-esophageal fistula was still not recognized as a significant risk of catheter ablation and no preventive measures were used. Eight of the ten cases occurred from 2005 to 2015, after preventive measures, were introduced, which represents an incidence of 0.1%. However, four cases occurred in the last 2 years of observation (2014 and 2015) when the new technology to perform deeper lesion was introduced, raising an incidence to 0.23%, higher than in previous years (Fig. 1). So, the risk of AEF still persists in the current practice, and the knowledge of preventive measures and management are essential to prevent the lethal consequences.

In this review, we will focus on the diagnosis and management of AEF after catheter ablation for atrial arrhythmias, including preventive measures to avoid esophageal lesions.

Pathophysiology of Esophageal Injury and Fistula Formation

The posterior wall of the LA maintains an intimal anatomical relationship with the anterior esophagus wall; in some cases, it can be just a few millimeters from the LA endocardium, less than 5 mm in 40% of population, although it is highly variable between patients [7]. The esophagus usually is located more distant from the right superior PV, but it can be close to any of the others. It may be even more complex by the ability of esophagus to move, even during ablation, up to 2–4 cm in the lateral dimension [8]. Therefore, the displacement of the ablation lines from the PV ostia to the posterior wall of the LA moves the isolation line toward the esophagus, whose walls may be thermally damaged by contiguity (Fig. 2). Multiple studies have shown that esophageal injury can occur despite the energy source used for ablation including RF, cryoenergy, or high-energy ultrasound ablation [9, 10]. Contreras-Valdes et al. reported that 37.4% of the patients had luminal esophageal temperatures above 39 °C, in which 10% patients had esophageal injury [11]. Di Biase and colleagues demonstrated that 17% of the patients had esophageal mucosal injury on capsule endoscopy [12]. The endoscopic finding could be mucosal erosion or an ulcer that can progress, worsened by gastroesophageal reflux, and rarely leading to fistula formation toward the LA [13].

In general, the esophageal injuries can be broadly divided into anatomical lesions such as mucosal erythema, erosions, and ulceration. The esophageal ulceration seems to be the initial lesion that leads to AEF formation and is probably

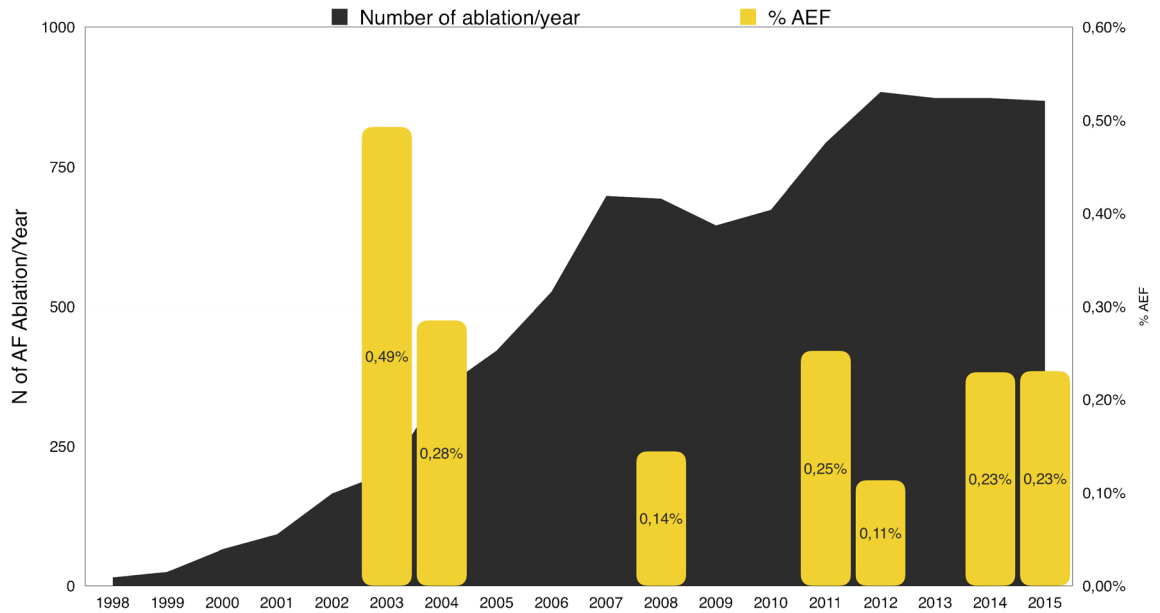

Fig. 1 Incidence of atrio-esophageal fistula occurrence in Brazil from 1998 and 2015. Yellow bars showing the percentage of AEF cases each year and black shadow behind showing the evolution of AF ablation cases in the 8 centers of Brazil who presented AEF. Adapted from Medeiros De Vasconcelos JT et al. [6]

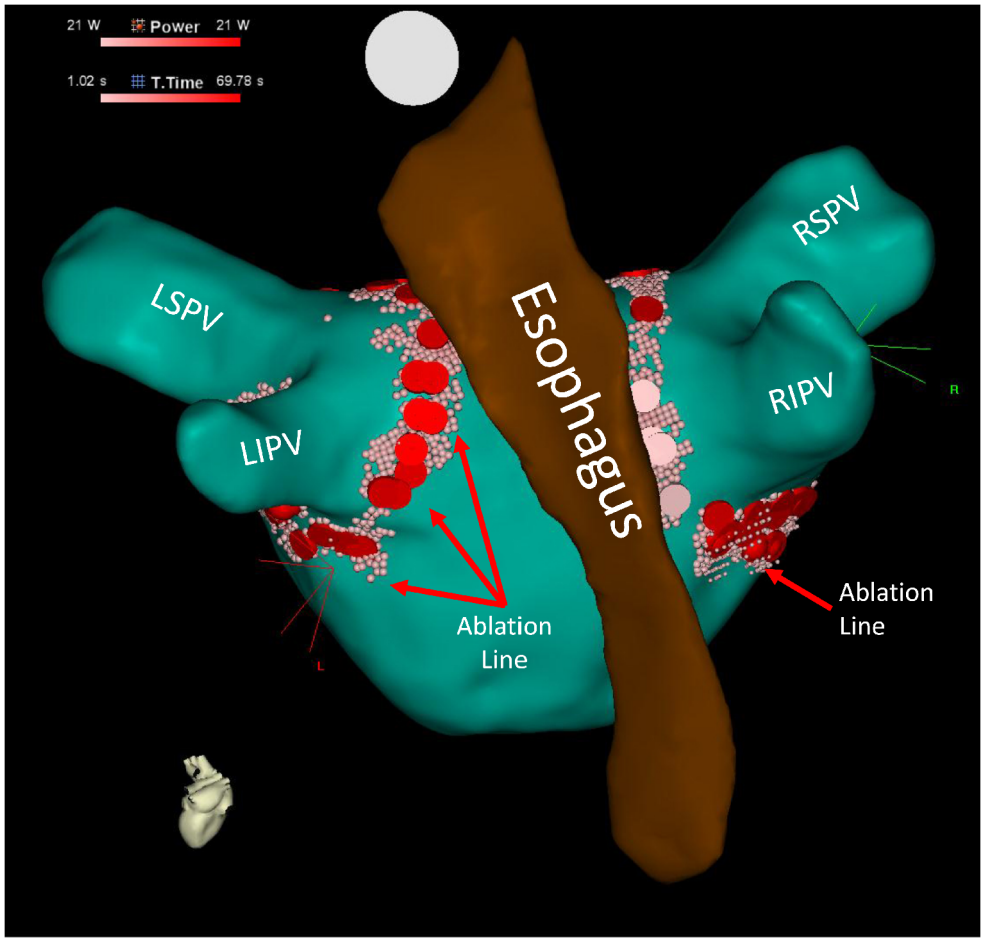

Fig. 2 Anatomical relationship between LA posterior wall, esophagus, and RF ablation sets. In this case, there is esophageal proximity with left superior and right inferior pulmonary vein

present within hours to days of the ablation. Yarlagadda et al. recently evaluated in a systematic review the temporal relationship between various types of esophageal lesions, their progression, and clinical outcome [14•]. Of the 4473 patients, 3921 underwent esophagogastroduodenoscopy (EGD) within 1 week after the procedure. The esophageal lesions were classified into 3 types using the Kansas City classification, an anatomical classification proposed by the authors: type 1, erythema; type 2a, superficial ulcers involving the mucosa alone; type 2b, deep ulcers involving up to the muscularis externa; type 3a, perforation without communication with the atria; and type 3b, perforation with AEF. The incidence of esophageal injury was 15%; 206 type 1 lesions (36%), 222 type 2a lesions (39%), and 142 type 2b lesions (25%). All type 1 and type 2a and most type 2b lesions resolved with conservative management with a median time to resolution of 2–4 weeks. Six of 142 type 2b lesions (4.2%) progressed further to type 3 on follow-up computer tomography (CT) scans, of which, 5 were type 3a and 1 was type 3b. So, it seems that the initial insult on esophageal wall needs to reach the esophageal mucosa or be a transmural lesion, and the process that ultimately results in esophageal LA fistula formation would progress from the esophageal mucosa to esophageal adventitia, with fistulization occurring from the esophagus toward the LA wall (Fig. 3). The exacerbation of acid reflux may occur via ablation-induced damage to vagal fibers leading to decreased esophageal sphincter tone and esophageal dysmotility [15, 16]. Other mechanisms of esophageal injury like ischemic injury through thermal occlusion of an arteriole and infection from the lumen were proposed, but not yet completely understood [3].

Diagnosis and Clinical Course of Atrial-Esophageal Fistula

The initial symptoms of AEF classically develop between 2 to 4 weeks after the ablation (rarely between 5 and 6 weeks) [17–19]. These symptoms are often vague and nonspecific, seem nonthreatening, and include mild retrosternal discomfort, malaise, odynophagia, fever, and leukocytosis without an apparent cause. Some patients can be asymptomatic until fistula or perforation develops and as a consequence use of clinical symptoms to prompt early diagnosis can somewhat challenging. If the process is not diagnosed and interrupted, it progresses rapidly to hematemesis, mediastinitis, and

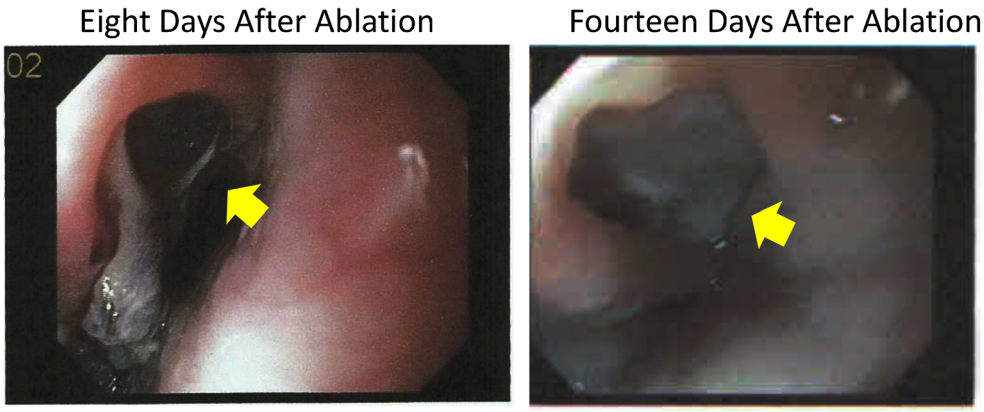

Fig. 3 A case of a patient who presented atrio-esophageal fistula with symptoms starting 24 days after ablation. Endoscopy performed on days 7 and 14 showing esophageal lesion that progressed despite medical treatment with PPI

manifestations of septicemia due to systemic and cerebral septic embolism. The presentation of AEF may mimic more common conditions such as infective endocarditis and upper gastrointestinal bleeding. Sometimes, patients who developed symptoms of AEF do not come to their electrophysiologist who performed ablation. If the emergent treating physician is not familiar with this complication, then the diagnosis of AEF is often missed or delayed [20]. This delay in diagnosis usually leads treatment in advanced stages of the disease, where complete recovery, even after reconstructive surgery of the fistula, is rare, with a high mortality. A survey that included more than 190,000 AF catheter ablation procedures reported a mortality of 79% in patients with AEF [21]. Therefore, the patients should be informed and alerted about warning symptoms of AEF to be able to recognize and contact electrophysiologist as soon the initial symptoms of AEF occur, because the awareness of these facts in the follow-up after AF ablation can lead to an early recognition, before perforation, allowing the start of the treatment as soon as possible aiming to prevent a fatal outcome.

Kim et al. described their findings from a large retrospective registry study of catheter AF ablation procedures, including 5721 patients undergoing 6724 procedures [22]. Before ablation, patients underwent either CT or magnetic resonance (MR) imaging. The investigators evaluated clinical, anatomical, and procedural characteristics of ten patients (0.15%) who developed AEF after ablation. All AEF occurred after the first ablation and 8 patients of the series died. All patients did not have any gastrointestinal symptoms at the time of discharge from ablation and the time from ablation to fistula symptom onset was 23.4 days. Older patients (64.8 ± 7.1 vs 56.6 ± 11.2; $p = 0.021$), low body weight (62.7 ± 9.1 vs 70.5 ± 11.5; $p = 0.032$), and high CHA_2DS_2-VASc score (2.6 ± 1.9 vs 1.5 ± 1.4; $p = 0.011$) were at increased risk of AEF in this series. These authors also showed that patients who presented AEF, the esophagus was close to the left inferior PV and all fistulas occurred related to this vein. The distance between LA and esophagus was also a predictor of esophageal lesion in another study with 308 patients in which an EGD was performed on the following day after ablation. The distance between LA and esophagus was significantly shorter (2.3 ± 0.6 mm vs 4.1 ± 0.9 mm; $p < 0.001$) in the injury group compared to the non-injury group [23].

Another series that analyses data from Manufacturer and User Facility Device Experience database (MAUDE) identified 78 AEF cases, in which 65 involved contact force sensing catheters; additionally, the percentage of total reports involving AEF was 5.4% for contact force sensing catheters and 0.9% for non-contact force catheters. In this series, the main presenting symptom was chest pain and 5% developed neurologic/stroke symptoms. Death occurred in 56% of the reported cases [24•].

The gold standard for early detection of esophageal thermal lesions related to AF ablation is EGD with visualization and characterization of the aspect and degree of the injury. There is no consensus about the use EGD as a routine investigation. We currently perform an EGD in all patients 24 to 72 h after the ablation, regardless of an elevation in esophageal temperature. Our objective with this approach is to identify the current incidence of esophageal lesions using new technology in our service and try to establish the circumstances in which the endoscopy is absolutely necessary.

The observations in a cohort of 425 patients, with EGD performed 1 to 3 days after ablation, in whom intraluminal esophageal temperatures were higher than 41 °C, revealed that esophageal tissue lesions occurred in 11.6% of asymptomatic patients, suggesting that asymptomatic patients could benefit from routine EGD after RF catheter ablative therapy, especially when there is an abnormal intraluminal esophageal temperature during the procedure [13]. Patients with late symptoms of dysphagia and/or fever, plus the presence of gastrointestinal bleeding or any neurological symptoms, should submit immediately to an evaluation with chest CT scan with oral and intravenous iodinated contrast (should not barium) that is the diagnostic test of choice to assess for esophageal perforations. The presence of air in the mediastinum, pericardial or LA, communication between the esophagus and pericardium or atrium, and inflammatory phlegmon between the esophagus

and the heart on CT scan are considered diagnostic of AEF. In case of suspect esophageal perforation, EGD should not be performed, because the increased pressure in the esophagus can worsen the situation, promoting the introduction of air into the LA and lead to stroke due to the systemic embolization by the infused air. Maybe in some cases, the use of CO2 instead of air for insufflation could be an alternative strategy, with minor adverse consequence [25, 26]. Unfortunately, these CT findings are usually late in the progression of AEF, demand a surgical emergency and need surgical interventions ranging from esophageal stenting, endoscopic occlusion, omental/muscle wrap to esophagectomy, depending on the clinical situation. In patients with no abnormalities on the first CT scan, it is probably safe to follow closely with repeated CT scan as necessary while manage them with conservative measures.

Management of Atrial-Esophageal Fistula

There are no defined guidelines for the management of patients with esophageal lesions following AF ablation, as well as there are no clinical studies proving the efficacy and safety of the measures that have been used. High doses of proton pump inhibitors (PPIs) for 30 days have been employed to prevent and treat ulcer erosion after ablation by majority of the electrophysiology centers. Most studies described low- and high-dose PPIs as pantoprazole or omeprazole 40 mg once a day or twice a day, respectively. PPIs are currently the most effective drug used in the treatment of gastroesophageal reflux, allowing healing esophagitis and the iatrogenic-induced ulcers due to its action in reducing the acidity of the gastric juice [27, 28]. For this reason, the prophylactic use of PPIs after AF ablation is accepted to be effective and justified as preventive treatment, even without evidences with randomized studies to determine whether PPIs reduce AEFs. Because of the low event rate of AEFs, such a study will probably not be feasible or likely be performed.

In patients with esophageal lesions (erythema, erosion, and hematoma), detected in control EGD performed after ablation, we chose to add a mucosa protective compounds such as sucralfate associated with a pureed light diet. Patients with evidence of some degree of gastroparesis in the EGD or with clinical manifestations also receive prokinetics (bromopride, domperidone, or metoclopramide) [16].

Using these measures, most of the acute lesions disappear on endoscopic evaluations performed 7 to 10 days later. Rarely, there are cases in which the lesions become worse and maintain features of an active ulcer. Close and watchful follow-up of these high-grade lesions is vital. The situation becomes more concerning if the patient presents with fever. In this condition, the patient must be admitted in hospital, remaining fasting (NPO), and monitored with leukogram, biochemical markers of inflammatory response (C-reactive protein and procalcitonin), and serial CT scans. Leukocytosis is the earliest and most sensitive markers in almost all patients with AEF [29]. Patients without evidence of infection and normal chest CT should stay in in-patient care for monitoring while receive appropriate treatment for the esophageal lesion. Patients with a suspected infectious status but without defined AEF at chest CT scan must be put on NPO with parenteral nutrition plus atropine to reduce salivary secretion and broad-spectrum antibiotic therapy. The parallel follow-up with close communication with gastroenterologist and thoracic and cardiac surgeons is advisable, because an emergency intervention may be required. The proposed management strategy for these lesions especially for an active ulcer or type 2b lesions must be aggressive, reasonable in this situation, considering the high mortality of patients with AEF associated with the understood of the underlying pathophysiology of progression of these lesions to AEF.

In the case of a detected AEF, the surgical repair of the fistula via thoracotomy, combined with LA and esophageal repair by closure of atrial aspect of AEF with pericardial patch and esophageal aspect with pleural or an intercostal muscle flap inserted in between, is necessary to prevent future recanalization of the fistula tract. The use of an esophageal T-tube has been reported in multiple cases [30–32]. Esophageal stenting is an available alternative invasive therapeutic option, which with an AEF is associated with poor outcomes, but may be used as a temporary bridge to surgical intervention or removed later after complete resolution of AEF or esophageal lesion [25, 33, 34]. Mohanty and colleagues reported that five patients who underwent esophageal stenting for AEF died within 1 week of procedure. On the other side, patients (n = 4) who underwent surgical repair were alive at median follow-up of 2.1 years [35]. In case of perforation to the mediastinum and before the fistula has performed, closure with stent or endoscopic clip can be considered [36, 37].

A conservative treatment of AEF with chest tube drainage and treatment of sepsis is associated with high mortality rate. There are a few reports on successful resolution of the fistula with stenting in patients with AEF or esophagus-pericardial fistula [38, 39]. Most studies have reported fatal outcome in the majority of patients with survival observed in only a few cases after undergoing early emergency a definitive surgical repair, a crucial point for survival in AEF. The failure of surgery may be mostly attributed to delay in the diagnosis and intervention.

Preventive Measures to Avoid Atrial-Esophageal Fistula

While operator experience may be associated with lower overall complications in any procedure, the occurrence of AEF

appears to be independent of the operator number of cases. So, it is imperative in addition to identify high-risk patients for this complication, also to determine what procedural techniques can be used to avoid and prevent this feared complication.

Many groups do not use a specific method to prevent esophageal lesions beyond reducing RF power while ablation on LA posterior wall and performing the procedure with patient in conscious sedations since the esophageal pain induced by RF application warns the electrophysiologist for the risk. Di Biase and colleagues demonstrate that the incidence of esophageal injury was higher in patients undergoing general anesthesia versus conscious sedation (48% vs 4%; $p < 0.001$) [40]. The authors suggested that reduced esophageal peristaltic movement and lack of swallowing along the fixation off esophagus due to nasogastric tube were responsible for increased incidence of esophageal injury in general anesthesia group. In contrast to Di Biase et al. findings, Martinek et al. demonstrated no significant difference in the incidence of esophageal injury with general anesthesia versus conscious sedation arm (2.7 vs 2.2, respectively; $p = 0.86$) [41].

The most frequently used method to prevent thermal esophageal lesions is the esophageal temperature monitoring with power adjustments during RF application in the posterior wall [42, 43]. The usual RF application power is 30 to 40 W. When the RF applications are directed to the posterior wall, close to the esophagus, the operator may reduce the power (20 W), application time (20 s), and avoid high contact force (10 g) to minimize the risk of esophageal lesion. In general, an increase in esophageal temperature determines prompt interruption of the RF application and reducing the power and time in subsequent applications. However, there is no agreement about the limit of the raising temperature that should RF application be interrupted, ranging from an increase in 1 to 2 °C from or to the limit of 38.5 °C or 41 °C [44]. In some circumstances, the power is reduced to 15 or 10 W, and the application is repeated when the temperature decreases. On the other hand, low power ablation precludes the creation of contiguous transmural lesions leading to reconnections and does not always prevent the increase in esophageal temperature [17, 45]. Other ways to reduce heat conduction to the esophagus have been tested. Martinek et al. compared 3 different ablation strategies with regard to esophageal lesion due to RF energy: without visualization of the esophagus, limiting power to 25 W in the posterior wall; guided by direct visualization of the esophagus using barium with a maximum power of 15 W; and guided by direct visualization, using 25 W and "short burns" (maximal 5 s) [41]. The authors found that esophageal ulcerations were rare when using a maximum of 25 W with open-irrigated tip catheters at the posterior wall. However, they did not reach any statistical significance between the randomization groups. Recently, it has been tested high-power and short-duration RF applications; this could lead to a larger superficial lesion, avoiding deeper lesions that could prevent collateral damage, although this concept still must to be proofed [46–48]. So, further prospective evaluations with larger series are still necessary to define.

In a recent HRS/ERHA/ECAS/APHRS/SOLAECE expert consensus statement on catheter and surgical ablation of AF [2], the writing group recommends that RF power should be reduced when creating lesions along the posterior wall near the esophagus (class I, LOE C-LD). The writing group also recommends that is reasonable to use an esophageal temperature probe during RF ablation procedure to monitor esophageal temperature and to help guide energy delivery (class IIa, LOE C-EO). Despite this recommendation and widespread use, with significant heterogeneity between studies with regard to ablation protocols including type of system/probe, maximum temperature/power settings, and lesion time, the esophageal temperature monitoring using discrete sensor probes does not appear to significantly reduce injury to the esophagus [49].

The use of esophageal temperature monitoring has some limitations [44]. The most used thermometer has a single linear distal electrode that is moved toward the upper and lower esophageal portions to be positioned as close as possible to the location of the ablation electrode in the posterior LA wall. Sometimes, the lateral position of the temperature probe or mapping electrode might not align with the ablation electrode, and the operator could have a false impression of safety [50]. Consequently, the absence of elevation in esophageal temperature does not necessarily mean that the esophagus is distant, failing to measure the actual temperature of the contralateral margin. A variety of esophageal temperature probe has been developed to overcome these limitations, like a multi-sensor esophageal monitoring system with a sinusoidal format, capable to cover the flat surface of the esophagus [43]. The clinical use of this multi-sensor system has shown a higher sensitivity and readiness to detect increases in esophageal temperature, but not necessary translate to lower injury rates, as showed in one randomized study with 100 patients submitted to ablation at 25–30 W using a single-sensor deflectable probe versus a multi-sensor probe with no significant difference in esophageal lesion rates between the groups (30 vs 20%; $p = 0.25$) [51]. Another nonrandomized study comparing esophageal lesion rates among 543 consecutive patients found significantly higher rates of esophageal ulceration in the group with the multi- than single-sensor probe (46 vs 29%; $p = 0.02$) [52]. Under these observations, hypothesis has been raised that multi-sensor can actually induce thermal injury due their stiff curves causing esophageal distension toward the atrium or fix the position of the esophagus preventing their displacement away from the energy source. Sometimes, the presence of metal electrodes in the thermal probe may act as an antenna inducing more current flow to the esophagus.

The demonstration of the temperature gradients in the esophagus during ablation added to the imprecision of the

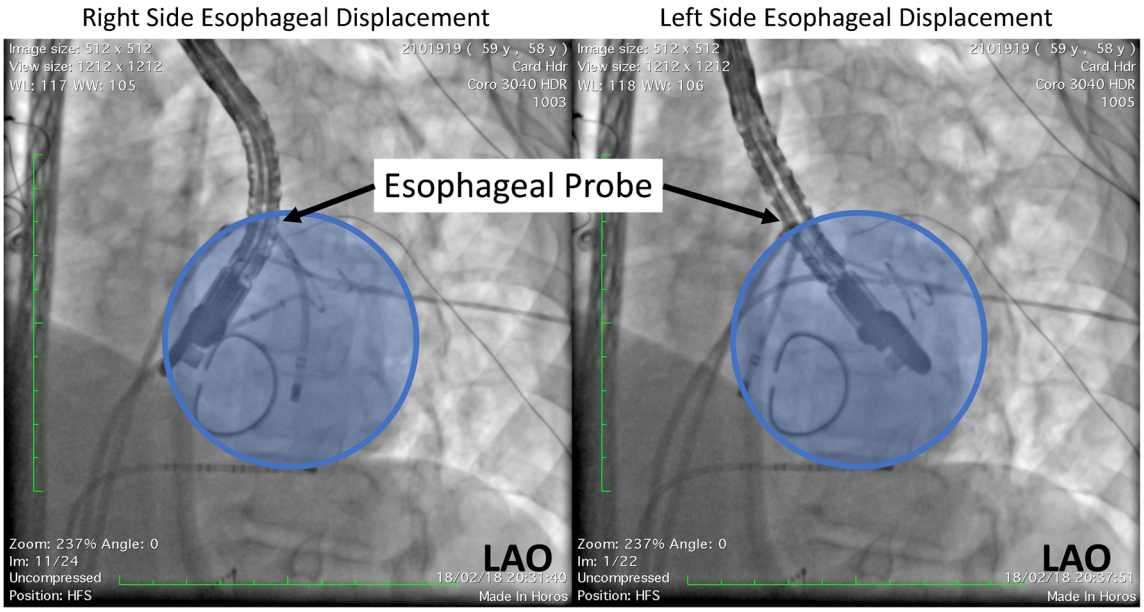

Fig. 4 Esophageal displacement using TEE probe. There is free movement of the esophagus to the left and right side of the atria, putting it away from ablation catheter

temperature record with observation of the temperature differences of > 20 °C between adjacent thermocouples, combined with the delay for the sensor to record a temperature rise due the lengthy time constants (the time taken to realize 63% of temperature change) which may not accurately reflect the intraluminal temperature and thus ongoing, real-time esophageal injury could explain the current limitation of all these probe with a finite number of discrete sensor to avoid esophageal thermal injury. More recently, a probe utilizing infrared thermography has been introduced, which provides instantaneous high-resolution map of temperature monitoring in real time while scanning the esophageal surface without having to manually move the probe. The instantaneous high-resolution temperature measurement can avoid the confounding latency of temperature reporting and spatial undersampling that is observed with discrete sensors. Real-time closed-loop use of infrared temperature data to modulate force, power, and duration appears feasible given the speed, sensitivity, and operation temperature range of the infrared system as demonstrated by HEAT-AF study (High-Resolution Esophageal Assessment of Esophageal Temperature During Atrial Fibrillation Ablation) in 63 patients submitted to PV isolation. This monitoring system allowed prediction of endoscopically detected esophageal lesion with an esophageal temperature

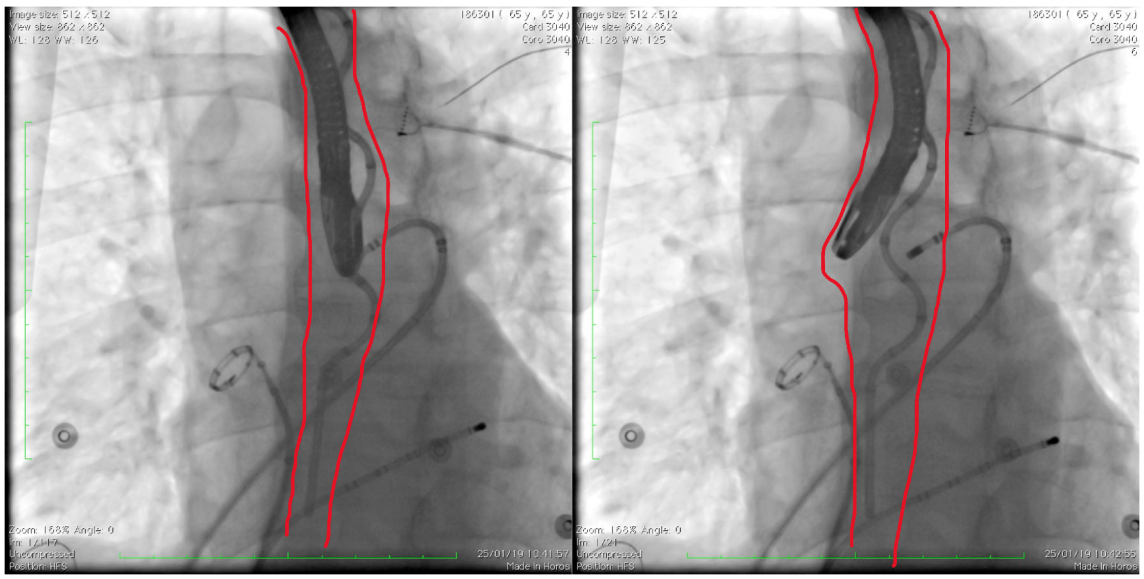

Fig. 5 Esophageal deformation despite of displacement using a TEE probe. In some patients is not possible to move the esophagus away from the ablation catheter. Red line shows the position of the esophagus based on the multieletrode probe position

cutoff of 50 °C with high accuracy, while temperatures < 50 °C predict no esophageal lesion with high-negative predictive value of > 97%. Future studies are needed to prospectively evaluate the effectiveness and the best cutoff value of this system to preventing esophageal lesion (and AEF) in patients undergoing AF ablation [53].

The mobility of the esophagus is important when considering esophagus deviation as a potential strategy to avoid thermal damage. Several devices, such as a transesophageal echocardiography probe, endoscope, and endotracheal stylet placed in the thoracic chest tube, have been reported to move esophagus away from the tip of the ablation catheter have been developed to prevent AEF. This technique appears to be promising, adds to the existing armamentarium of tools to minimize esophageal injury during AF ablation. However, none of these new devices have proved their usefulness in preventing AEF and all need additional validations [54–56]. Mateos et al. using a transesophageal echocardiography probe, with average esophageal displacement of 5.9 ± 0.8 cm, which proved to be sufficient to deliver effective lesion without esophagus overlapping (Fig. 4) [57]. However, luminal esophageal temperature monitoring was performed in only 25 patients and two patients had traumatic superficial bleeding ulcers. In addition, the probe is bulkier and stiffer, and could potentially act as a heat retainer contributing to both mechanical and thermal esophageal injury. In some patients, the esophagus could not be displaced from its original position, and difficulties in displacement depending on laxity of adjacent anatomical structures. Increased compliance of the esophageal wall resulting in distension and deformation of the esophageal lumen rather than translocation of body of the esophagus, or decrease compliance of surrounding tissues, such as the PVs and/or their antral, result in stretching and thinning of the esophageal wall in patients with relatively immobile esophagus (Fig. 5) [54, 58]. Palaniswamy et al. in a study with 114 consecutive patients determined that the extent of lateral esophageal displacement required during mechanical esophageal deviation to prevent significant esophageal heating was > 20 mm from the PV ablation line. They also demonstrated that esophageal stretching occurs during mechanical esophageal deviation, therefore highlighting the importance of identifying the trailing edge with barium allowing the correct positioning of the esophageal temperature probe to avoid an unintentional delivery of RF energy to esophagus [56]. Recently, a novel preshaped nitinol esophageal retractor (EsoSure, Northeast Scientific, Waterbury, CT) has been available for use in the USA for esophageal deviation. This device was employed in a multicenter study—the DEFLECT GUT study—which evaluated 687 patients submitted to RF ablation for AF [59]. In 209 patients, the EcoSure was used to deflect the esophagus away from the ablation site. The mechanic esophageal deviation tool was used in 61.7% of patients in which esophageal temperature rising occur and in 38.3% in which esophagus was close to the ablation line on fluoroscopy. The mean deviation of trailing edge of the esophagus with this device was 2.45 ± 0.9 cm (range 1–4.5), with a significant lower rate of rise or luminal esophageal temperature > 1 °C (3% vs 79.4%; $p < 0.001$) and the higher Δ luminal esophageal rise (0.34 ± 0.59 vs 1.6 ± 0.54; $p < 0.001$) in the esophagus deviation group than non-esophageal deviation group. In the follow-up of 3, 6, and 12 months, AF recurrence was lower in the deviation group (23.3% vs 33.3%). A limitation of this study is the absence of routine postprocedural endoscopy to evaluate for possible esophageal lesions with device use, which may help confirm the improved safety attributed to use of this device.

Conclusions

Atrial fibrillation is the most common clinically significant cardiac arrhythmia and the therapy with AF ablation is increasing every year. Esophageal injury and AEF are the most feared complication of AF ablation due to the high mortality after its occurrence. Several techniques have been implemented to reduce the risk of thermal injury, but the benefits of them are still inconclusive. So, it is imperative that physicians recognize the signs and symptoms of AEF, because the early diagnosis with appropriate treatment, including prompt surgical intervention, is crucial for survival of the in AEF occurrence.

Compliance with Ethical Standards

Conflict of Interest Tan Chen Wu, Cristiano Pisani, and Maurício Scanavacca declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. Haissaguerre M, Jais P, Shah DC, Takahashi A, Hocini M, Quiniou G, et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. N Engl J Med. 1998;339(10):659–66.
2.•• Calkins H, Hindricks G, Cappato R, Kim YH, Saad EB, Aguinaga L, et al. 2017 HRS/EHRA/ECAS/APHRS/SOLAECE expert consensus statement on catheter and surgical ablation of atrial fibrillation. Europace. 2018;20(1):e1–e160 **This expert consensus this consensus describes all possible complications in the ablation**

of AF and brings together the opinions and experiences of various services around the world, with current practices advocated and accepted in the management of complications.

3. Kapur S, Barbhaiya C, Deneke T, Michaud GF. Esophageal injury and atrioesophageal fistula caused by ablation for atrial fibrillation. Circulation. 2017;136(13):1247–55.
4. Scanavacca MI, D'Avila A, Parga J, Sosa E. Left atrial-esophageal fistula following radiofrequency catheter ablation of atrial fibrillation. J Cardiovasc Electrophysiol. 2004;15(8):960–2.
5. Pappone C, Oral H, Santinelli V, Vicedomini G, Lang CC, Manguso F, et al. Atrio-esophageal fistula as a complication of percutaneous transcatheter ablation of atrial fibrillation. Circulation. 2004;109(22):2724–6.
6.• Medeiros De Vasconcelos JT, Filho S, Atie J, Maciel W, De Souza OF, Saad EB, et al. Atrial-oesophageal fistula following percutaneous radiofrequency catheter ablation of atrial fibrillation: the risk still persists. Europace. 2017;19(2):250–8 **Brazilian series of Atrioesophageal fistula, there were 10 cases in 8863 ablation (0.113%). The incidence of AEF maintains the same over the years despite technology and knowledge.**
7. Sanchez-Quintana D, Cabrera JA, Climent V, Farre J, Mendonca MC, Ho SY. Anatomic relations between the esophagus and left atrium and relevance for ablation of atrial fibrillation. Circulation. 2005;112(10):1400–5.
8. Good E, Oral H, Lemola K, Han J, Tamirisa K, Igic P, et al. Movement of the esophagus during left atrial catheter ablation for atrial fibrillation. J Am Coll Cardiol. 2005;46(11):2107–10.
9. Miyazaki S, Nakamura H, Taniguchi H, Takagi T, Iwasawa J, Watanabe T, et al. Esophagus-related complications during second-generation cryoballoon ablation-insight from simultaneous esophageal temperature monitoring from 2 esophageal probes. J Cardiovasc Electrophysiol. 2016;27(9):1038–44.
10. Neven K, Schmidt B, Metzner A, Otomo K, Nuyens D, De Potter T, et al. Fatal end of a safety algorithm for pulmonary vein isolation with use of high-intensity focused ultrasound. Circ Arrhythm Electrophysiol. 2010;3(3):260–5.
11. Contreras-Valdes FM, Heist EK, Danik SB, Barrett CD, Blendea D, Brugge WR, et al. Severity of esophageal injury predicts time to healing after radiofrequency catheter ablation for atrial fibrillation. Heart Rhythm. 2011;8(12):1862–8.
12. Di Biase L, Dodig M, Saliba W, Siu A, Santisi J, Poe S, et al. Capsule endoscopy in examination of esophagus for lesions after radiofrequency catheter ablation: a potential tool to select patients with increased risk of complications. J Cardiovasc Electrophysiol. 2010;21(8):839–44.
13. Knopp H, Halm U, Lamberts R, Knigge I, Zachaus M, Sommer P, et al. Incidental and ablation-induced findings during upper gastrointestinal endoscopy in patients after ablation of atrial fibrillation: a retrospective study of 425 patients. Heart Rhythm. 2014;11(4):574–8.
14.• Yarlagadda B, Deneke T, Turagam M, Dar T, Paleti S, Parikh V, et al. Temporal relationships between esophageal injury type and progression in patients undergoing atrial fibrillation catheter ablation. Heart Rhythm. 2019;16(2):204–212 **This systematic review the temporal relationship between various types of esophageal lesions, their progression, and clinical outcome, helping in the understanding of the pathophysiology and evolution of esophageal lesions after ablation, determining which lesions may be the precursors of the fistula.**
15. Shah D, Dumonceau JM, Burri H, Sunthorn H, Schroft A, Gentil-Baron P, et al. Acute pyloric spasm and gastric hypomotility: an extracardiac adverse effect of percutaneous radiofrequency ablation for atrial fibrillation. J Am Coll Cardiol. 2005;46(2):327–30.
16. Pisani CF, Hachul D, Sosa E, Scanavacca M. Gastric hypomotility following epicardial vagal denervation ablation to treat atrial fibrillation. J Cardiovasc Electrophysiol. 2008;19(2):211–3.
17. Nair GM, Nery PB, Redpath CJ, Lam BK, Birnie DH. Atrioesophageal fistula in the era of atrial fibrillation ablation: a review. Can J Cardiol. 2014;30(4):388–95.
18. Scanavacca M, Hachul D, Sosa E. Atrioesophageal fistula–a dangerous complication of catheter ablation for atrial fibrillation. Nat Clin Pract Cardiovasc Med. 2007;4(11):578–9.
19. Han HC, Ha FJ, Sanders P, Spencer R, Teh AW, O'Donnell D, et al. Atrioesophageal fistula: clinical presentation, procedural characteristics, diagnostic investigations, and treatment outcomes. Circ Arrhythm Electrophysiol. 2017;10(11).
20. Thomson M, El Sakr F. Gas in the left atrium and ventricle. N Engl J Med. 2017;376(7):683.
21. Barbhaiya CR, Kumar S, Guo Y, Zhong J, John RM, Tedrow UB, et al. Global survey of esophageal injury in atrial fibrillation ablation: characteristics and outcomes of esophageal perforation and fistula. JACC Clin Electrophysiol. 2016;2(2):143–50.
22. Kim YG, Shim J, Kim DH, Choi JI, Park SW, Pak HN, et al. Characteristics of atrial fibrillation patients suffering atrioesophageal fistula after radiofrequency catheter ablation. J Cardiovasc Electrophysiol. 2018;29(10):1343–51.
23. Ito M, Yamabe H, Koyama J, Kanazawa H, Kaneko S, Kanemaru Y, et al. Analysis for the primary predictive factor for the incidence of esophageal injury after ablation of atrial fibrillation. J Cardiol. 2018;72(6):480–7.
24.• Black-Maier E, Pokorney SD, Barnett AS, Zeitler EP, Sun AY, Jackson KP, et al. Risk of atrioesophageal fistula formation with contact force-sensing catheters. Heart Rhythm. 2017;14(9):1328–33 **Data from the MAUDE report showing an increased number of reports of AEF with the contact-force catheters.**
25. Eitel C, Rolf S, Zachaus M, John S, Sommer P, Bollmann A, et al. Successful nonsurgical treatment of esophagopericardial fistulas after atrial fibrillation catheter ablation: a case series. Circ Arrhythm Electrophysiol. 2013;6(4):675–81.
26. Singh SM, d'Avila A, Singh SK, Stelzer P, Saad EB, Skanes A, et al. Clinical outcomes after repair of left atrial esophageal fistulas occurring after atrial fibrillation ablation procedures. Heart Rhythm. 2013;10(11):1591–7.
27. Kahrilas PJ. Clinical practice. Gastroesophageal reflux disease. N Engl J Med. 2008;359(16):1700–7.
28. Martinek M, Meyer C, Hassanein S, Aichinger J, Bencsik G, Schoefl R, et al. Identification of a high-risk population for esophageal injury during radiofrequency catheter ablation of atrial fibrillation: procedural and anatomical considerations. Heart Rhythm. 2010;7(9):1224–30.
29. Dagres N, Hindricks G, Kottkamp H, Sommer P, Gaspar T, Bode K, et al. Complications of atrial fibrillation ablation in a high-volume center in 1,000 procedures: still cause for concern? J Cardiovasc Electrophysiol. 2009;20(9):1014–9.
30. Sonmez B, Demirsoy E, Yagan N, Unal M, Arbatli H, Sener D, et al. A fatal complication due to radiofrequency ablation for atrial fibrillation: atrio-esophageal fistula. Ann Thorac Surg. 2003;76(1):281–3.
31. Doll N, Borger MA, Fabricius A, Stephan S, Gummert J, Mohr FW, et al. Esophageal perforation during left atrial radiofrequency ablation: is the risk too high? J Thorac Cardiovasc Surg. 2003;125(4):836–42.
32. Aupperle H, Doll N, Walther T, Kornherr P, Ullmann C, Schoon HA, et al. Ablation of atrial fibrillation and esophageal injury: effects of energy source and ablation technique. J Thorac Cardiovasc Surg. 2005;130(6):1549–54.
33. Yousuf T, Keshmiri H, Bulwa Z, Kramer J, Sharjeel Arshad HM, Issa R, et al. Management of atrio-esophageal fistula following left atrial ablation. Cardiol Res. 2016;7(1):36–45.
34. Bunch TJ, Nelson J, Foley T, Allison S, Crandall BG, Osborn JS, et al. Temporary esophageal stenting allows healing of esophageal

perforations following atrial fibrillation ablation procedures. J Cardiovasc Electrophysiol. 2006;17(4):435–9.
35. Mohanty S, Santangeli P, Mohanty P, Di Biase L, Trivedi C, Bai R, et al. Outcomes of atrioesophageal fistula following catheter ablation of atrial fibrillation treated with surgical repair versus esophageal stenting. J Cardiovasc Electrophysiol. 2014;25(6):579–84.
36. Qadeer MA, Dumot JA, Vargo JJ, Lopez AR, Rice TW. Endoscopic clips for closing esophageal perforations: case report and pooled analysis. Gastrointest Endosc. 2007;66(3):605–11.
37. Markar SR, Koehler R, Low DE, Ross A. Novel multimodality endoscopic closure of postoperative esophageal fistula. Int J Surg Case Rep. 2012;3(11):577–9.
38. Gunes MF, Gokoglan Y, DI Biase L, Gianni C, Mohanty S, Horton R, et al. Ablating the posterior heart: cardioesophageal fistula complicating radiofrequency ablation in the coronary sinus. J Cardiovasc Electrophysiol. 2015;26(12):1376–8.
39. Queneherve L, Musquer N, Leaute F, Coron E. Endoscopic management of an esophagopericardial fistula after radiofrequency ablation for atrial fibrillation. World J Gastroenterol. 2013;19(21):3352–3.
40. Di Biase L, Saenz LC, Burkhardt DJ, Vacca M, Elayi CS, Barrett CD, et al. Esophageal capsule endoscopy after radiofrequency catheter ablation for atrial fibrillation: documented higher risk of luminal esophageal damage with general anesthesia as compared with conscious sedation. Circ Arrhythm Electrophysiol. 2009;2(2):108–12.
41. Martinek M, Bencsik G, Aichinger J, Hassanein S, Schoefl R, Kuchinka P, et al. Esophageal damage during radiofrequency ablation of atrial fibrillation: impact of energy settings, lesion sets, and esophageal visualization. J Cardiovasc Electrophysiol. 2009;20(7):726–33.
42. Redfearn DP, Trim GM, Skanes AC, Petrellis B, Krahn AD, Yee R, et al. Esophageal temperature monitoring during radiofrequency ablation of atrial fibrillation. J Cardiovasc Electrophysiol. 2005;16(6):589–93.
43. Tschabrunn CM, Silverstein J, Berzin T, Ellis E, Buxton AE, Josephson ME, et al. Comparison between single and multisensor esophageal temperature probes during atrial fibrillation ablation: thermodynamic characteristics. Europace. 2015;17(6):891–7.
44. Scanavacca M, Pisani CF. Monitoring risk for oesophageal thermal injury during radiofrequency catheter ablation for atrial fibrillation: does the characteristic of the temperature probe matter? Europace. 2015;17(6):835–7.
45. Halm U, Gaspar T, Zachaus M, Sack S, Arya A, Piorkowski C, et al. Thermal esophageal lesions after radiofrequency catheter ablation of left atrial arrhythmias. Am J Gastroenterol. 2010;105(3):551–6.
46. Winkle RA, Moskovitz R, Hardwin Mead R, Engel G, Kong MH, Fleming W, et al. Atrial fibrillation ablation using very short duration 50 W ablations and contact force sensing catheters. J Interv Card Electrophysiol. 2018;52(1):1–8.
47. Ali-Ahmed F, Goyal V, Patel M, Orelaru F, Haines DE, Wong WS. High-power, low-flow, short-ablation duration-the key to avoid collateral injury? J Interv Card Electrophysiol. 2018. https://doi.org/10.1007/s10840-018-0473-5
48. Borne RT, Sauer WH, Zipse MM, Zheng L, Tzou W, Nguyen DT. Longer duration versus increasing power during radiofrequency ablation yields different ablation lesion characteristics. JACC Clin Electrophysiol. 2018;4(7):902–8.
49. Kadado AJ, Akar JG, Hummel JP. Luminal esophageal temperature monitoring to reduce esophageal thermal injury during catheter ablation for atrial fibrillation: a review. Trends Cardiovasc Med. 2018. https://doi.org/10.1016/j.tcm.2018.09.010.
50. Leite LR, Santos SN, Maia H, Henz BD, Giuseppin F, Oliverira A, et al. Luminal esophageal temperature monitoring with a deflectable esophageal temperature probe and intracardiac echocardiography may reduce esophageal injury during atrial fibrillation ablation procedures: results of a pilot study. Circ Arrhythm Electrophysiol. 2011;4(2):149–56.
51. Kuwahara T, Takahashi A, Takahashi Y, Okubo K, Takagi K, Fujino T, et al. Incidences of esophageal injury during esophageal temperature monitoring: a comparative study of a multi thermocouple temperature probe and a deflectable temperature probe in atrial fibrillation ablation. J Interv Card Electrophysiol. 2014;39(3):251–7.
52. Carroll BJ, Contreras-Valdes FM, Heist EK, Barrett CD, Danik SB, Ruskin JN, et al. Multi-sensor esophageal temperature probe used during radiofrequency ablation for atrial fibrillation is associated with increased intraluminal temperature detection and increased risk of esophageal injury compared to single-sensor probe. J Cardiovasc Electrophysiol. 2013;24(9):958–64.
53. Deneke T, Nentwich K, Berkovitz A, Sonne K, Ene E, Pavlov B, et al. High-resolution infrared thermal imaging of the esophagus during atrial fibrillation ablation as a predictor of endoscopically detected thermal lesions. Circ Arrhythm Electrophysiol. 2018;11(11):e006681. https://doi.org/10.1161/CIRCEP.118.006681.
54. Chugh A, Rubenstein J, Good E, Ebinger M, Jongnarangsin K, Fortino J, et al. Mechanical displacement of the esophagus in patients undergoing left atrial ablation of atrial fibrillation. Heart Rhythm. 2009;6(3):319–22.
55. Koruth JS, Reddy VY, Miller MA, Patel KK, Coffey JO, Fischer A, et al. Mechanical esophageal displacement during catheter ablation for atrial fibrillation. J Cardiovasc Electrophysiol. 2012;23(2):147–54.
56. Palaniswamy C, Koruth JS, Mittnacht AJ, Miller MA, Choudry S, Bhardwaj R, et al. The extent of mechanical esophageal deviation to avoid esophageal heating during catheter ablation of atrial fibrillation. JACC Clin Electrophysiol. 2017;3(10):1146–54.
57. Mateos JC, Mateos EI, Pena TG, Lobo TJ, Vargas RN, Pachon CT, et al. Simplified method for esophagus protection during radiofrequency catheter ablation of atrial fibrillation–prospective study of 704 cases. Rev Bras Cir Cardiovasc. 2015;30(2):139–47.
58. Ha FJ, Han HC, Sanders P, Teh AW, O'Donnell D, Farouque O. Prevalence and prevention of oesophageal injury during atrial fibrillation ablation: a systematc review and meta-analysis. Europace. 2019;21:80–90.
59. Parikh V, Swarup V, Hantla J, Vuddanda V, Dar T, Yarlagadda B, et al. Feasibility, safety, and efficacy of a novel preshaped nitinol esophageal deviator to successfully deflect the esophagus and ablate left atrium without esophageal temperature rise during atrial fibrillation ablation: the DEFLECT GUT study. Heart Rhythm. 2018;15(9):1321–7.