Mechanical Esophageal Displacement During Catheter Ablation for Atrial Fibrillation

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Esophageal Deviation in AF Ablation. Objective: To determine the feasibility and safety of esophageal displacement during atrial fibrillation (AF) ablation, to prevent thermal injury.

Background: Patients undergoing AF ablation are at risk of esophageal thermal injury, which ranges from superficial ulceration, to gastroparesis, to the rare but catastrophic atrioesophageal fistula. A common approach to avoid damage is luminal esophageal temperature (LET) monitoring; however, (1) temperature rises mandate interruptions in energy delivery that interrupt workflow and potentially decrease procedural efficacy, and (2) esophageal fistulas have been reported even with LET monitoring.

Methods: A cohort of 20 consecutive patients undergoing radiofrequency (RF) (16 patients) or laser balloon (4 patients) ablation of AF under general anesthesia. After barium instillation, the esophagus was deviated using an endotracheal stylet placed within a thoracic chest tube. LET monitoring was used during catheter ablation. Upper GI endoscopy was performed prior to discharge.

Results: At the pulmonary vein level, leftward deviation measured 2.8 ± 1.6 cm (range: 0.4–5.7) and rightward deviation 2.8 ± 1.8 cm (range: 0.5–4.9). The temperature rose to >38.5 °C in 3/20 (15%) patients. In these 3 patients, there was an average of 2 applications/patient that recorded temperatures >38.5 °C. No patient had a temperature rise >40 °C. Endoscopy revealed no esophageal ulceration from thermal injury in 18/19 (95%) patients; the sole patient with a thermally mediated ulceration had an unusual esophageal diverticulum fully across the posterior left atrium. Twelve patients (63%) exhibited trauma related to instrumentation with no clinical sequelae.

Conclusions: Mechanical esophageal deviation is feasible and allows for uninterrupted energy delivery along the posterior wall during catheter ablation of AF. (J Cardiovasc Electrophysiol, Vol. 23, pp. 147-154, February 2012)

atrial fibrillation, catheter ablation, esophagus, esophageal temperature monitoring, pulmonary vein isolation

Introduction

Catheter ablation of atrial fibrillation (AF) is increasingly employed in the management of symptomatic AF. The overall complication rates for AF ablation have declined, but the development of atrioesophageal fistula remains one of its most feared complications due to the potentially catastrophic outcome. Several strategies have been described to help prevent or reduce gastroesophageal injury during AF ablation. These include luminal esophageal temperature (LET) monitoring, determination of the anatomical relationship of the esophagus to the posterior LA with preprocedural or real-time imaging, and modulation of power and duration of radiofrequency lesions. These approaches, even when applied in combination, have failed to prevent atrioesophageal fistula formation. Moreover, these strategies do not address the need to reduce other forms of injury such as gastroesophageal motility disorders that originate from injury to vagal nerves that surround the esophagus. In addition, LET monitoring focuses on the early detection of thermal injury and often results in modification of the lesion sets, i.e., by directing the encircling lesions to be either more ostial or further midline in order to avoid temperature rises. Such modifications increase the risk of pulmonary vein (PV) stenosis and “gaps” that may affect the long-term clinical success of the ablation procedure. Frequent premature lesion terminations and power reductions may also compromise chronic PV isolation rates, an endpoint critical to the long-term outcomes of AF ablation.

On the other hand, there have been 2 reports on the use of either an endoscope or transesophageal echocardiographic (TEE) probe to mechanically displace the esophagus laterally away from the point of endocardial ablation along the posterior left atrium (LA). This approach is unique in that it has the potential to reduce gastroesophageal injury by actively displacing the primary organ at risk, i.e., the esophagus. Because of the logistical difficulties attendant with these
approaches, we sought to evaluate the feasibility safety and efficacy of a strategy of mechanical esophageal deviation during AF ablation using “off-the-shelf” equipment.

Methods
Consecutive patients were approached for participation as part of a quality improvement initiative at Mount Sinai Medical Center, NY, USA, between September 2010 and November 2010. Patients were approached if they were undergoing a first-ever AF ablation procedure for drug-refractory AF using a heat-based ablation energy source (radiofrequency or laser balloon ablation). Patients were excluded if they were undergoing cryoballoon ablation, had a prior history of esophageal ulcers/strictures, severe esophagitis/gastroesophageal reflux disease or esophageal surgery. Detailed verbal and written informed consent was obtained from all patients. Patients who underwent laser ablation (Endoscopic Ablation System with Adaptive Contact (CardioFocus, Inc., Marlborough, MA, USA) were part of a FDA approved non-randomized phase II IDE trial (NCT00971204) approved by the Mount Sinai School of Medicine (MSSM) Institutional Review Board (IRB). Data collection and case review were approved by MSSM IRB.

To assess the safety of the approach, postprocedure esophagogastroduodenoscopy (EGD) was performed in all patients prior to discharge regardless of symptoms. The EGD was used to evaluate for potential esophageal trauma induced by esophageal deviation and to assess for ablation-related thermal injury.

Procedural Details
As per our usual practice, all patients arrived for the ablation procedure with a planned strategy of uninterrupted Warfarin anticoagulation. All procedures were performed under general anesthesia using a thermal-based energy source (radiofrequency or laser energy). Ablation procedures were performed by operators with experience with the above techniques (AD, SD, and VR). Patients underwent computed tomographic imaging of the LA. Double transseptal punctures were performed in all patients. Intravenous unfractionated heparin was administered to maintain an activated clotting time of 250–350 seconds. For RF cases, an electroanatomic map was created with the NavX navigation system (St. Jude Medical). RF pulses were delivered circumferentially around each vein pair, approximately 1 cm from each PV ostium using a 3.5 mm externally irrigated catheter (Thermocool, Biosense Webster) and a steerable sheath (Agilis, St. Jude Medical, St. Paul, MN, USA). Initially, the RF generator (Stockert, Biosense Webster) was set to deliver RF energy of up to 35 W/40 °C in all LA sites including the posterior wall. However, after an esophageal ulceration was noted in one patient, the strategy was modified to use power settings of a maximum of 25 W while ablating on the posterior wall.

The laser balloon catheter has been previously described. The dosing regimen used for PV isolation was between 5.5 and 16 W for 20–30 seconds.

Esophageal Protection Strategy
The deviation procedure was performed at the time of posterior wall lesion placement by the anesthesiologist. A standard orogastric tube was inserted. The tip was positioned at the distal end of the esophagus, and 20–30 mL of oral barium sulfate contrast (Liquid E-Z-Paque, E-Z-EM Canada Inc., Lake Success, NY, USA) was injected to allow the contrast to fill the mid and distal esophagus. A 9F single thermocouple esophageal temperature probe (Mon-a-therm®, Tyco Healthcare Group) was then inserted into the esophagus. Next, a 32Fr flexible PVC thoracic catheter (e.g., Atrium Medical Corporation) was inserted into the esophagus. The tip was positioned a few centimeters below the level of the PV. A 14 Fr aluminum intubation stylet encased in plastic was inserted into the lumen of the thoracic catheter to create a curve in the distal half. The proximal end of this stylet was then manipulated (applying clockwise/counterclockwise torque) to laterally displace the esophagus (Fig. 1).

Maximal deviation of the barium-filled esophagus was determined fluoroscopically (Fig. 2, Panels B and C and Data Supplement 1, video loops 1, 2, and 3). Deviation was maintained during posterior wall ablation and confirmed with intermittent fluoroscopy.

Prior to onset of ablation, the temperature probe was manipulated to ensure that it was positioned lateral to the thoracic tube and closest to the ablation catheter in the horizontal plane. The probe was adjusted in a craniocaudal fashion before application of all lesions, irrespective of the extent of deviation performed. This was felt to be important, to ensure detection of thermal injury in cases of unrecognized suboptimal deviation. All RF and laser applications were terminated if LET exceeded 38.5 °C. Peak LET was recorded for all temperature rises.

Figure 1. Diagrammatic representation of esophageal deviation: Panel (A) baseline esophageal position with intraluminal thoracic catheter. Panel (B) endotracheal stylet placed within the thoracic catheter. Panel (C) esophageal deviation being performed to the right of the patient for contralateral ablation.
Esophageal Evaluation and Follow-Up

Postprocedure endoscopy was performed under conscious sedation by 2 experienced gastroenterologists. Using video endoscopes (Olympus GIF-H180), complete endoscopy of the esophagus, stomach, and duodenum was performed. In addition to the initial assessment of the EGD results, post hoc offline review of all lesions was performed in all but 2 patients due to technical limitations. Lesions were attributed to AF ablation if they were located on the anterior wall in the middle third of the esophagus (approximately 25–35 cm from the incisors) over the area of cardiac pulsations. All other acute findings were classified as indicative of esophageal instrumentation. Lesions were classified by severity (mild, moderate, and severe) and lesion type (petechiae, erosion, and ulceration). Linear lesions were considered separate if they involved more than a third of the length of the esophagus. All patients with lesions were treated with high-dose proton-pump inhibitor therapy for at least 1 week. Follow-up was scheduled at the discretion of the electrophysiologist. Typically, the day after the procedure, patients were discharged on Warfarin anticoagulation for at least 3 months after ablation.

Statistical Analysis

Continuous variables were reported as mean ± SD, and distribution of discrete variables were reported as percentages for each group. Means of continuous variables were compared with the Student t-test. Probability values < 0.05 were considered significant. All authors had full access to the data and take responsibility for its integrity. All authors have read and agree to the manuscript as written.

Results

Patient Characteristics

All 20 consecutive patients approached for participation in this series gave informed consent. After ablation, 19 of these patients underwent EGD evaluation; one patient withdrew consent for the EGD after the ablation procedure. The mean age of the cohort was 59 ± 13 years, 75% were male, 50% had paroxysmal AF, and the other 50% had persistent AF. The mean ejection fraction and LA cross-sectional area were 56 ± 9% and 23 ± 5 mm², respectively. Six patients had a history of dilated cardiomyopathy and 3 patients had a history of reflux disease. All patients had failed at least one antiarrhythmic agent and were undergoing their first AF ablation procedure.

Procedural Characteristics

All procedures were performed under general anesthesia. RF was used in 16 (80%) patients and laser in 4 (20%). LET monitoring was used in all patients. The patient characteristics are described in Table 1. There were no significant differences between the RF or laser ablation groups at baseline, except that patients undergoing laser ablation had a higher proportion of paroxysmal AF (100%) versus only 58% in the RF group.

Esophageal Deviation

Cine-fluoroscopic images in the straight anteroposterior view were recorded to identify the baseline esophageal position at the time of barium instillation and during maximal

<table>
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<th>TABLE 1</th>
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<td>Clinical Characteristics of Patients Undergoing Esophageal Deviation</td>
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<td>-------------------------------------------------</td>
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<tr>
<td>Clinical Characteristics: n (%)</td>
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<tr>
<td>Total patients: 20</td>
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<tr>
<td>Age (years, mean ± SD): 59.4 ± 13.4</td>
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<tr>
<td>Male: 15 (75%)</td>
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<td>Paroxysmal AF: 10 (50%)</td>
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<td>Persistent AF (%): 10 (50%)</td>
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<td>EF (%: mean ± SD): 55.9 ± 8.9</td>
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<tr>
<td>LA area (mm²: mean ± SD): 22.8 ± 4.9</td>
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<tr>
<td>Cardiomyopathy (%): 6 (30%)</td>
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<td>Hx of gastroesophageal reflux disease (%): 3 (15%)</td>
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<td>Antiarrhythmic agents: n (%)</td>
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<td>Amlodipine: 4 (20%)</td>
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<td>Dronedarone: 6 (30%)</td>
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<td>Sotalol: 3 (15%)</td>
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<td>Propafenone: 1 (5%)</td>
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<td>Pilsicainide: 1 (5%)</td>
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<td>Betablockers: 17 (85%)</td>
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<td>Calcium channel blockers: 5 (25%)</td>
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<td>Proton pump inhibitors or H2 receptor antagonists: 3 (15%)</td>
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<tr>
<td>Procedural details: n (%)</td>
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<tr>
<td>General anesthesia (%): 20 (100%)</td>
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<tr>
<td>Redo ablation (%): 0 (0%)</td>
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<tr>
<td>Radiofrequency (%): 16 (80%)</td>
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<td>Laser balloon ablation (%): 4 (20%)</td>
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leftward and rightward esophageal displacement that could be successfully maintained during ablation. One patient’s images were not retrievable due to technical issues related to the x-ray storage system and thus were not analyzed. The patient characteristics are described in Table 2. The initial course of the esophagus was leftward in 10 patients, rightward in 7 patients, and midline in 2 patients. The mean esophageal width at baseline was 2.9 ± 0.8 cm (range 13.4–43).

Deviation was measured at the level of the PVs using digital calipers relative to the baseline esophageal position, using the lateral borders of the vertebral body as a fixed reference. A total of 19 patients and 38 deviation attempts were analyzed. Deviation was not required and therefore not performed in 2 patients due to the presence of markedly leftward and rightward positions of the esophagus at baseline, allowing for contralateral PV isolation without risk for thermal injury. The extent of deviations were noted to be 2.8 ± 1.6 cm (range: 0.4–5.7) and 2.8 ± 1.8 cm (range: 0.5–4.9) for leftward and rightward deviation, respectively. Of the 36 deviations, 6 (17%) deviations demonstrated differential displacement of the right and left borders of the esophagus with one border deviating < 50% of the other. In terms of magnitude of maximal deviation achieved, 9 of 36 (25%) measured < 1 cm. One patient with a leftward esophagus underwent suboptimal rightward deviation and required further leftward deviation to allow for left-sided PV isolation. Another patient was noted to have a mid-esophageal propulsion diverticulum upon barium instillation that extended across the posterior LA wall.

During esophageal deviation, there were mild distortions of the LA electroanatomic map adjacent to the esophagus due to changes in the local impedance field that is utilized by the NavX navigation system that were induced by air within the thoracic tube used for deviation. However, with the esophagus deviated away from the site of ablation, the local distortion seen in the LA anatomy was distant from the site of ablation and therefore without clinical consequence. There were no acute complications.

**Esophageal Temperature**

LET rises > 38.5°C occurred in 3 of 20 (15%) patients. No patient had a temperature rise >40°C. Of these 3 patients, 2 underwent RF, and 1 laser ablation. All temperature rises noted were observed during left-sided PV isolation. The number of RF or laser applications in each patient that were associated with a temperature rise >38.5°C was 1, 1, and 4 (mean of 2). The maximum temperatures achieved in these 3 patients were 38.9°C, 38.5°C, and 39.5°C, respectively.

For comparison, we retrospectively evaluated a separate cohort of 20 consecutive patients (Table 3) at our institution who underwent AF ablation using either RF or laser ablation (80% and 20%, respectively) without esophageal deviation. The distribution of paroxysmal AF and persistent AF was 55% and 45%. All patients underwent LET monitoring. There was a 90% (18/20) incidence of temperature rises >38.5°C (Fig. 3) with a mean of 6.15 lesions per patient. Temperature rises >38.5°C were observed in significantly fewer (P < 0.05) patients in the deviation group than in the comparison group.

**Endoscopic Evaluation**

Endoscopy was performed within 24 hours in 16 of 19 patients and within 72 hours in the remaining 3 patients. There were no esophageal mucosal tears related to instrumentation. Overall, 12 patients (63%) demonstrated a total of 18 lesions consistent with esophageal instrumentation-related trauma. Nine of these patients had injury patterns that were classified as mild and 3 as moderate intensity. The percentage distribution of these lesions were petechiae (single or multiple) 44%, erythema 11%, superficial erosion 39%, and ulceration 6% (Fig. 4). Only one patient developed a lesion consistent with thermal injury, i.e., a moderately severe ulcer on the anterior wall (27 cm from the incisors) (Fig. 5). No active bleeding was noted in any patient. Other incidental findings noted on endoscopy included 3 cases of abnormal squamo-columnar junction suggestive of gastroesophageal reflux disease, 4 cases of mild antral gastritis, one case of mild duodenitis, and one gastric polyp.

**Other Adverse Events**

All patients reported a transient sore throat. One patient developed moderate to severe sore throat with transient dysphagia after the procedure that resolved prior to discharge; this was felt to be related to the effects of manipulation. Thereafter, the approach to the deviation technique was modified. Originally, the endotracheal stilet was given a gradual curve along its entire length. Subsequently, the curve on the endotracheal stilet was restricted to the distal half of the stilet. The straight course of the stilet at the proximal (oral) end restricted the lateral motion to the distal esophagus to...
avoid excessive pressure in the pharynx. After implementing this change, no further cases of significant throat pain occurred. One patient developed a retroperitoneal bleed related to femoral arterial access that required blood transfusion. One other patient who underwent simultaneous LA appendage occlusion using LARIAT™ suture delivery device developed significant pericarditis that resolved with NSAIDs. No evidence of gastrointestinal bleeding occurred in any patient.

**Follow-Up**

The mean follow-up was 40.6 days. No patient developed dysphagia or gastrointestinal bleeding. Two patients with persistent AF developed early AF recurrence requiring cardioversion.

**Discussion**

**Main Finding**

Esophageal deviation can be successfully performed and maintained during AF ablation under general anesthesia, allowing for uninterrupted energy delivery along the posterior wall in virtually all patients. A mean deviation of 2.8 cm was achieved during both leftward and rightward deviation. In terms of magnitude of deviation, the maximum leftward and rightward deviations achieved were 5.7 and 4.9 cm, respectively. Only a minority of deviations measured < 1 cm (9/36 = 25%). Esophageal temperature rises > 38.5 °C occurred in 3 of 20 (15%) patients. Only one (5.3%) patient developed evidence of thermal injury of the esophagus on endoscopy.

**Esophageal Deviation**

Autopsy studies have shown the presence of loose areolar tissue between the anterior wall of the esophagus and the parietal pericardium. Additionally, a post-mortem study demonstrated that the esophagus could be displaced up to 7 cm relative to the LA. In addition, after instillation of barium contrast into the esophagus during AF ablation procedures, spontaneous movements of the esophagus have been readily observed during the procedure. These studies all support the feasibility of esophageal displacement from an anatomic perspective.

**Comparison with Other Studies**

Mechanical displacement of the esophagus along the posterior LA as an esophageal protective strategy has been previously described using an endoscope or a TEE probe. Widespread application of these techniques has not been realized in clinical practice due to limitations. In the strategy using the endoscope, the esophagus could not be deviated in 2 of 12 patients; more importantly, the deviation could...
not be maintained in 7 patients to allow lesion delivery. This report was also limited because (i) the approach required the participation of a gastroenterologist, and (ii) the true extent of deviation achieved was unclear given the lack of barium contrast—thus, one cannot verify that there was merely tenting of the esophagus instead of actual displacement. Our technique differs in that we achieved a greater degree of displacement (2.8 vs 2.4 cm and 2.8 vs 2.1 cm for left and right deviation, respectively) and a higher percentage success of deviation (90% vs 83%). Moreover, we demonstrated that deviation could be maintained during ablation, allowing for uninterrupted ablation. In the strategy using the TEE probe, although all 3 patients underwent displacement that was maintained during ablation, LET monitoring and postprocedure endoscopy were not performed. Our study also differs from both these earlier studies in that we systematically investigated our approach in a larger series of patients with postprocedure endoscopic follow-up.

Of all the deviations performed, a total of 9/36 (25%) deviations resulted in esophageal displacements of < 1 cm in magnitude. But even in these patients with esophageal deviations measuring < 1 cm, successful uninterrupted contralateral PV isolation was performed in all patients. However, LET rises occurred in 2 of these 9 patients.

A review of the fluoroscopic and preprocedural CT images on these 9 deviations suggested that the markedly leftward or rightward esophageal position at baseline was likely responsible for the reduced deviation in 7 of these 9 deviations (Fig. 3). In the remaining 2 deviations, baseline esophageal position could not explain the reduced extent of deviation. There were no obvious anatomic variations in their posterior mediastinal anatomy that could explain this finding. Other factors related to intra- and interoperator variation in the use of the technique of esophageal deviation could have played a role.

Other limitations of mechanical displacement include the capacity of the esophagus to stretch (that is, tenting) which could cause displacement of one border and not the other. While barium was instilled in every patient, we cannot rule out the possibility that we underestimated the degree of displacement because of variation in the consistency of barium filling of the entire width of the dynamically contracting esophagus throughout the course of the procedure.

Esophageal Temperature Monitoring

Studies have demonstrated that the odds of esophageal thermal injury increase with rise in endoluminal temperature. Other studies have demonstrated the absence of esophageal lesions in patients with a maximal LET below 41 °C, emphasizing the link between temperature rises and thermal esophageal injury. Despite the uniform and diligent use of the LET probe in all cases in our study, the one patient who developed thermal injury had no LET rise. The absence of a temperature rise may be related to the fact that the LET probe was not within the esophageal diverticulum that was noted in this patient.

This lack of LET temperature rise validates a shortcoming of LET monitoring, i.e., that they are not 100% sensitive in predicting injury. However, the percentage reduction in LET rises > 38.5 °C in our study from 90% (comparison group) to 15% (deviation group) (P < 0.05) suggests a lower propensity for thermal injury with esophageal deviation. The 90% incidence of LET rises > 38.5 °C seen in the comparison
group compares to other recent studies. With respect to the extent of esophageal deviation achieved, of the 3 patients that experienced temperature rises during left-sided PV ablation, 2 patients underwent RF ablation on the posterior wall using a power of 35 W. Both these AF ablations were performed prior to the index case of esophageal ulceration that led to the modification of power delivery from 35 W to 25 W on the posterior wall. In addition, one patient also had a maximal rightward esophageal deviation of <1 cm that may explain the temperature rise. The third patient (laser ablation) had adequate deviation; however, the level of isolation by the laser balloon was relatively proximal at the PV ostium, and therefore closer to the esophagus. None exhibited signs of esophageal injury on endoscopy.

**Esophageal Injury**

The incidence of thermal injury during AF ablation has been reported to be between 2.2%–48%. This can occur in the form of esophageal erythema, erosions, ulceration, gastroesophageal motility disorders, or rarely atrioesophageal fistulas. The degree of variation is likely accounted for by differences in the frequency of use of temperature monitoring probes, general anesthesia versus conscious sedation, power, duration and contract force of posterior wall lesions, and the method of assessment of esophageal injury. The incidence of atrioesophageal fistula is much lower, at around 0.04%. This condition can be fatal if not diagnosed early in its course, a scenario that occurs due to the often nonspecific nature of the symptoms. The mechanism of esophageal injury is not completely understood; however, thermal and/or ischemic injuries are the proposed mechanisms.

The single thermal injury-related ulcer in this series occurred during RF energy-based PV isolation and without documented rises in temperature. While it is difficult to conclude with certainty why thermal injury occurred in this patient, a retrospective review of the cine-fluoroscopic images suggests several potential explanations. The extent of rightward deviation during left PV isolation was limited to 1.2 cm. This was at the lower end of the range of all rightward deviations achieved (0.5–4.9 cm). Moreover, this patient had a dilated esophagus (43 cm width at the level of the PVs) and a mid-esophageal propulsion diverticulum (Fig. 6). Both these factors potentially increased the risk of thermal injury.

It is important to note that some esophageal lesions were related to the manipulation process itself. These lesions caused by esophageal instrumentation were superficial and asymptomatic in the majority of patients but resulted in significant dysphagia and throat pain in one patient. Even in this one patient, symptoms resolved prior to discharge and we cannot exclude the possibility that the discomfort experienced by the patient was not simply related to endotracheal intubation for administration of general anesthesia.

The strengths of this study include its moderate size (largest study of esophageal deviation to date); the simple but effective approach; and the systematic evaluation including barium instillation, LET monitoring, and endoscopic evaluation.

**Limitations**

This was an observational nonrandomized study in a limited number of patients. “Off-the-shelf” equipment was employed for performing deviation and is associated with a learning curve. The lack of a dedicated device impacts the ease and reproducibility of this technique. The deviation procedure that is described can be performed only in patients under general anesthesia. Caution must be exercised in extrapolating the reduction in thermal injury to that of reduction in risk of atrioesophageal fistula formation, as the precise mechanism of this rare complication remains undefined. However, as the frequency of atrioesophageal fistula is <1% it is quite difficult to definitively prove that any strategy reduces this rare complication; thus, most investigations into atrioesophageal fistula formation have employed esophageal mucosal injury as a surrogate. Other limitations include the lack of preprocedural endoscopy, the possibility of increasing the risk of thermal injury from mechanical trauma to the anterior esophageal wall from the deviation maneuver itself.

**Conclusions**

The clinical spectrum of esophageal injury includes atrioesophageal fistula formation, esophageal and gastric motility disorders, gastroesophageal reflux, and possibly other unknown long-term effects. These adverse effects continue to contribute toward the morbidity of this increasingly performed procedure. This manuscript demonstrates the feasibility and safety of a novel technique of esophageal deviation that permits uninterrupted energy delivery to the posterior wall during AF ablation in a series of 20 consecutive patients with endoscopic follow-up. The feasibility and safety of this technique offer the potential to enhance the success of gastroesophageal protection during AF ablation. However, further improvements in the tools and techniques for esophageal deviation together with evaluation of this promising strategy...
in a prospective, randomized study comparing the strategy of esophageal deviation to LET monitoring are warranted.

References


Supporting Information

Additional Supporting Information may be found in the online version of this article:

Data Supplemental File: Loop 1: Barium instillation at baseline, Loop 2: Rightward deviation of esophagus, Loop 3: Leftward deviation.

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