Esophageal Temperature during Atrial Fibrillation Ablation Poorly Predicts Esophageal Injury: An Observational Study.

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Abstract

**Background:** Esophageal injury (EI) remains a concern when performing pulmonary vein isolation (PVI) using the high-power short duration technique (HPSD).

**Objective:** We aim to indicate that high esophageal temperature during HPSD PVI doesn’t correlate with positive esophageal endoscopy (EGD) findings.

**Methods:** A retrospective observational study was performed on 43 patients undergoing PVI using HPSD (50 W for 6 to 7 seconds per lesion) at Tulane Medical Center from July 2020 to January 2021. Esophageal temperature was monitored throughout the procedure using a temperature probe and patients underwent EGD the following day. Small ulcers, non-bleeding erosions, erythema and/or esophagitis were considered positive EGD findings.

**Results:** Mean age was 64.9 years old, 46.5% of the patients were female. Eleven patients had positive EGD findings (group 1), and 32 patients had normal EGD (group 2). There was no statistical difference in mean esophageal peak temperature between group 1 and group 2 (43.9 +/- 2.9 °C and 42.5 +/- 2.3 °C, respectively (p=0.17)). There was no association between positive EGD results and esophageal temperature during PVI. Mean baseline esophageal temperature was similar in both groups (36.1°C, p=0.78). Average contact force (p=0.53), ablation time (p=0.67), age (p=0.3096), sex (p=0.4), BMI (p=0.14) and other comorbidities didn’t correlate with positive endoscopy results. We found positive correlation between the distance of the left atrium (LA)-to-esophagus and positive EGD (p=0.0001).

**Conclusion:** EI during HPSD PVI doesn’t correlate to esophageal temperature changes during ablation. However, esophageal injury does correlate to a shorter proximity of the esophagus to the LA.

**Key Words:** Atrial fibrillation – Pulmonary vein isolation – Esophageal injury – Catheter ablation – Esophageal temperature – Left atrium.
Introduction

High power short duration (HPSD) application of radiofrequency (RF) current for pulmonary vein isolation (PVI) is a safe and effective technique with increasing utilization (1-3) for the treatment of atrial fibrillation (AF). The advantages of HPSD RF PVI include, improved resistive heating, reduced thermal latency, and conductive collateral tissue injury (4, 5). Factors such as conductive heating, local inflammation, and post-ablation reflux mechanisms play significant roles in causing EI. Atrio-esophageal fistula (AEF) is a rare esophageal complication (incidence rate of 0.1% to 0.25%) associated with this procedure. However, its mortality rate has been reported to be as high as 80% (6). Thus, in order to prevent AEF, an established method has been to avoid conducting cardiac ablations near to the esophagus. Given the anatomical position of the esophagus and its proximity to the posterior atrial wall and the right lower pulmonary vein, ablation around this region is often necessary to achieve a successful outcome (7).

Deep tissue heating during catheter ablation can be controlled via different approaches. Essentially, the energy delivered can be calculated as the amount of power delivered to the tissue multiplied by time. Compared to the conventional low power, longer duration (LPLD) approach, HPSD offers more accurate therapeutic lesions and a decreased depth penetration secondary to thermal latency reduction (1-6).

Currently, adequate evidence linking esophageal thermal injury to HPSD ablation procedures is lacking and should be investigated further. Esophageal temperature monitoring is one way to reduce the risk of thermal injury intraoperatively (8). However, this method has mostly been researched using LPLD ablation procedures (7, 9, 10). Thus, the means by which HPSD may result in EI remains unclear.

For this reason, our observational study evaluated the correlation between esophageal lesions seen during esophageal endoscopy post-PVI and compared it to intraoperative esophageal temperatures achieved during HPSD PVI. We also took into consideration other factors that could increase the risk of injury e.g. average force used, power and total time of procedure, and compared it with any observed esophageal lesions. In addition, a separate
analysis measuring the distance between the LA and the esophagus (LA-esophageal) was also performed on a subset of patients.

Methods

Study design: This retrospective observational study aimed to associate positive EGD findings after HPSD ablation when esophageal temperatures could be high.

Patient population: Between July 2020 to January 2021, 43 AF patients (paroxysmal or persistent type) who underwent a first time AF ablation with next-day EGD were included in this study. Demographic information, clinical history and imaging data were all collected from the Tulane Research Innovation for Arrhythmia Discoveries (TRIAD) database, a registry that includes AF patients undergoing cardiac ablation at Tulane Medical Center, New Orleans, LA. On December 13, 2019, the Tulane University Biomedical IRB provided an expedited review and approval determination for the initial submission of this minimal risk study. Patients consent was waived due to the use of retrospective and de-identified data. The review was provided in accordance with the appropriate research regulations. The research reported in this paper adhered to the Helsinki Declaration guidelines.

Ablation procedure: Patients undergoing catheter ablation for AF were placed on anticoagulant therapy at least 3 weeks prior to their procedure. Signed informed consent forms were also obtained prior to cardiac ablation.

All patients included in the study underwent a radiofrequency ablation procedure in accordance with the latest guidelines (11). The procedure was performed using a 3-dimensional electroanatomic mapping system (CARTO: Biosense Webster, CA). After achieving transeptal access, patients received 10000 UI of heparin and had Activated Clotting Time (ACT) monitored every 15 minutes to maintain it between 300 and 350 seconds.

The ablation consisted of isolating the pulmonary veins first, followed by creating an ablation line at the roofline which connects both left and right sided lesions. Finally, fibrosis targeted ablation was performed in all patients, mainly on the posterior atrial wall, guided by
magnetic resonance imaging (MRI) images or mapping images. Radiofrequency energy was delivered using an irrigated RF ablation catheter (Thermo Cool Smart-Touch; Biosense Webster) at a distance of 10 mm from the pulmonary vein (PV) ostia using high power short duration ablation technique (50 W for 5 to 7 seconds per lesion, temperature 50 degree Celsius). PVI was assessed continuously in all pulmonary veins using the CARTO® PENTARAY™ NAV eco Catheter (Biosense Webster). Target contact force was between 7g and 15g for all the lesions created. The endpoint of the PVI ablation was the presence of a bidirectional block confirmed by a PENTARAY mapping catheter.

**Temperature monitoring:** Throughout the procedure, esophageal temperature was monitored using the CIRCA S-CATH Esophageal Temperature Probe. This probe contained 12 temperature sensors and provided temperature monitoring at a rate of 20 measurements per second. An automated alarm system notified the operator each time the esophageal temperature increased to more than 40 degrees Celsius. Since our ablation lesions were for short duration (7 sec), we did not stop ablating even if temperature increased to > 40 degrees Celsius.

**MRI imaging:** Prior to cardiac ablation, 11 patients underwent a cardiac MRI for LA structure and LA shape assessment. In addition, the anatomical location and distance of the LA relative to the esophagus was assessed. A LA fibrosis score and its distribution was also obtained from the MRI images in order to guide the therapeutic lesions during cardiac ablation. For those unable to receive a cardiac MRI, a cardiac and pulmonary veins CT scan was conducted instead.

**Esophageal endoscopy:** All patients had an esophagogastroduodenoscopy (EGD) the day after ablation to look for and evaluate any esophageal injury that may have been caused during cardiac ablation. Esophageal injury was defined as any lesion in the esophagus that had close contact to the LA wall. These lesions were defined as an erythema, ulcer, esophageal bleeding, perforation, or fistula. EGD was performed under moderate anesthesia by an experienced gastroenterologist/endoscopist. Patients with positive endoscopy findings were started on a high dose proton pump inhibitor (PPI) for 8 weeks (pantoprazole
40 mg twice daily). Patients with negative endoscopy were discharged on a low dose PPI (pantoprazole 40 mg daily).

**Statistical analysis:** Unless otherwise specified, continuous measurements are summarized as mean (SD), with categorical variables denoted as frequency counts and percentages of the respective endoscopy result group. Missing values were omitted. Measurements and frequency counts were divided according to endoscopy result. Continuous measurements were tested for equality of central tendency. Both groups’ measurements were tested for normality via the Shapiro-Wilk test. If both did not significantly depart from normality, they were tested for equality of means via an independent two-sample t-test; otherwise, a two-sample Wilcoxon rank-sum test was used. Proportionality of categorical variables was tested using Fisher’s Exact Test, as some expected cell counts were less than 5.
Results

Baseline Demographics

A total of forty-three patients were included in the study. Mean age was 64.9 years. 46.5% of the patients were females. 62.7% had paroxysmal AF, while the remainder had persistent AF. 32.5% of the study population had a history of coronary artery disease and 11.6% had a history of stroke.

EGD findings

Out of 43 patients, 32 (74%) patients had normal EGD findings (Group 1) post-ablation whereas, 11 (26%) patients had positive findings on EGD following ablation (Group 2). EGD findings are shown in Figure 1 and Figure 2. Five lesions were identified as ulcers/erosions of the esophageal mucosa (Figure 1) and five other lesions were of an erythematous nature (Figure 2). All ulcers were noted to be smaller than 5 mm in diameter and all erythematous lesions were localized. One patient showed esophageal mucosal changes suspicious for Barrett esophagus and presented with a bleeding vessel in the mid-esophagus.

Sociodemographic characteristics were similar in both groups: Age (66.6 ±/− 7.4 and 60.1 ±/− 11.1 years old in Group 1 and Group 2 respectively, p=0.095), sex (p=0.29) and body mass index (BMI) 35.8 (SD) and 33.6 (SD) respectively (p=0.47). There was no difference in terms of AF type (persistent or paroxysmal) in both groups (p=0.49). Co-morbidities were statistically similar in both groups such as, hypertension (p=1), diabetes (p=0.71), previous stroke (p=0.40), heart failure (p=0.09) and coronary artery disease (p=0.46). All clinical characteristics are summarized in Table 1.

Correlation between temperature and EGD findings

The mean esophageal temperature and the highest temperature recorded during ablation were analyzed for each patient. The distribution of both mean temperature and peak temperature are visualized as box plots for both Group 1 and Group 2 patients (Figure 3). There was no significant difference in mean baseline temperature between both groups (36.1 ±/− 0.5 °Cand 36.1 ±/− 0.4 °Cin EGD- negative and EGD- positive, respectively, p= 0.95). The peak temperature was also similar in both EGD- negative and EGD- positive patients: 42.5 ±/− 2.3 °Cand 43.9 ±/− 2.9 °C, respectively (p=0.17). Therefore, we can deduce that there
is no significant correlation between the temperatures recorded in the esophagus during ablation and EI post catheter ablation.

**Ablation Parameters**

All lesions were created using a high power (50W) short duration (7 seconds) technique. There was no significant difference in both groups regarding total ablation time (1205 +/- 373 seconds and 1254 +/- 240 seconds in Group 1 and Group 2 patients respectively, p=0.67). In addition, no significant difference was noted regarding the contact force used in both groups (16.2 +/- 3.9 g in Group 1 and 15.3 +/- 3.7 g in Group 2 patients, p= 0.53). The correlation between ablation time (A) and contact force (B) in the two cohorts is shown in Figure 4.

**Magnetic Resonance Imaging and CT scan Findings**

Out of the forty-three subjects, eleven patients received a cardiac MRI prior to catheter ablation. The remaining 25 patients underwent cardiac and PV CT scans. Data summarizing the left atrial volume, left posterior wall volume and fibrosis for both groups is shown in Table 2. No significant difference was found between patients without EI and in patients who had positive EGD findings in terms of their fibrosis score (20.9 %; 95% CI 14.7-24.3; and 23 %; 95% CI 21.8-25.5, respectively; p=0.56), left atrial volume (114.1 cm3; 95% CI 79.3-181.2; and 76.8 cm3; 95% CI 62.2-91.4, p=0.29) and posterior wall volume (4.3 cm3; 95% CI 3.3-5.8; and 2.8 cm3, 95% 2.5-3.2, p=0.19).

Cardiac MRI and CT scans were used to approximate the distance between the left atrial posterior wall and the esophageal wall. Differences in distance are outlined in Table 2. We observed a significantly smaller esophageal-atrial distance in patients with esophageal anomalies on EGD compared to healthy subjects (p=0.0001). In fact, an average distance of 2.47 mm was found in the EGD- positive group (95% CI 1.69-3.25) compared to 4.1 mm in the EGD- negative group (95% CI 2.9-5.4). This significantly smaller distance separating the wall of the left atrium and the esophagus could possibly be associated with a higher incidence of esophageal injury after catheter ablation. An example of distance measurement on cardiac MRI is shown in Figure 5.
Discussion

In this study of 43 patients who underwent HPSD ablation for AF, we demonstrated that the incidence of developing an EI is independent of the highest esophageal temperature reached during ablation. Also, despite a smaller population sample, we observed a strong correlation between the LA-esophagus distance and the occurrence of EI.

Temperature and ETI

The percentage post-ablation ETI in our study (26%) was similar to previous findings (12). Studies have shown discrepancies on whether temperature is correlated with EI or not. On one hand, Sommer et al. showed that EI depended on the esophageal position and temperature, but not on BMI (13). On the other hand, a randomized control trial demonstrated that intraoesophageal temperature monitoring does not affect the probability of developing EI.

Relationship of Power and Duration with ETI

High-Power short duration (HPSD) is a new trend in catheter ablation. Some HPSD benefits include a decrease in fluoroscopy time compared to conventional methods (14, 15). It also results in less collateral damage to extra-cardiac structures due to reduced resistive heating (16). Feasibility and safety of the HSPD procedure has been previously demonstrated in several studies (17). In a study that included over 10,000 patients (Winkle et al), it showed that HPSD ablations had lower complication rates and shorter procedural times compared to other conventional methods (18). Leshem et al echoed this finding by demonstrating that HSPD actually improved lesion-to-lesion uniformity, linear contiguity, and transmurality compared to conventional ablation while maintaining a similar safety profile (19). With specific regard to esophageal injuries, a study conducted by Baher et al exhibited similar EI rates and patterns in HPSD compared to LPLD ablations when assessed during same-day late gadolinium enhancement MRI (20). Kaneshiro et al also showed that while HPSD ablations resulted in higher rates of gastric hypomobility, the prevalence of esophageal lesions as assessed by endoscopy were similar compared to conventional ablation parameters (21).
A suggestive limitation of HSPD is that it can result in significantly higher temperatures in both the left atrium and esophageal wall (22). However, the correlation as to whether a higher esophageal temperature leads to esophageal injury is not well established thus, supplying the necessity of our research study.

In our study, we set the ablation time to 7 seconds per lesion to all our patients with no exception. A lesion point appears on our Carto map whenever 7 seconds of ablation are reached. We did not stop ablating even if the temperature increased to > 40 degrees Celsius. The reason behind this is to demonstrate that this approach, and this specific ablation time are safe and feasible and do not really correlate with esophageal injury secondary to high esophageal temperature. Future prospective studies should be conducted comparing two arms: the first one with patients to whom we stopped ablating when the temperature reaches > 40 degrees, the second arm with patients to whom we did not stop ablating.

**ETI in RF ablation: Characteristics and Prevention strategies**

Esophageal injury during RF ablation is not a rare occurrence. A recent study showed that the incidence of EI, which included erosions and ulcers after ablation was 1.3% for each type of lesion respectively (23). EI can range from simple esophageal erosions to the more sinister atrio-esophageal (AE) fistula. EI findings may include gastric erosions (22%), esophageal erythema (21%), gastroparesis (17%), hiatal hernia (16%), reflux esophagitis (12%), thermal esophageal lesion (11%), and suspected Barrett esophagus (5%).

Symptoms of EI include chest pain with symptoms of gastroesophageal reflux, hematemesis, fever, hypotension, septic shock, and neurologic symptoms. Currently, there are no clinical guidelines establishing how to prevent EI during catheter ablation procedures. Proton pump inhibitors are routinely given post-ablation to reduce the risk of an AE fistula developing by decreasing gastric acidity and gastroesophageal reflux.

Of the many techniques designed to prevent EI, luminal esophageal temperature (LET) monitoring is most commonly used. While earlier studies showed that LET could help potentially reduce EI rates (24), more recent investigations have highlighted its limitations.
In several independent studies, Ha et al (25), Halbfass et al (26), Nakagawa et al (27), and Kadado et al (28), they all found that LET monitoring was not associated with a reduction in EI rates. Furthermore, two other studies analyzed whether EI rates differed when either a multi-thermocouple or a single-sensor probe was used (29, 30). They found that although the multi-thermocouple probe had a more sensitive temperature detection, there was ultimately no EI rate difference between the use of the two probe types. Barbhaiya et al emphasized LET's major limitation is the necessity for the temperature probe to be within 20mm of the ablation location (31). If not kept at that distance, temperature measurements would be considered highly unreliable. Also, other studies have also shown that there is a significant variation in transient thermal response among the various commercially available esophageal temperature probes. Thus, different strategies may lead to an underestimation of luminal esophageal temperature (32).

Multiple other strategies have been designed to protect the esophagus during catheter ablation and very few have shown reliable efficacy. A meta-analysis published by Leung et al demonstrated esophageal cooling during AF ablation may play a role in reducing the severity of the lesions produced (33). The IMPACT trial showed that thermal protection of the esophageal lumen reduces ablation-related thermal injury compared to standard care (34). However, the IMPACT trial did not provide any evidence that esophageal cooling could in fact protect against AE fistula development. This shows that the mechanism underlying EI and AE fistula post-ablation is not only limited to thermal injury. Bhardwaj et al used an esophageal balloon retractor to mechanically deviate the esophagus during ablation (35). This technique is feasible however, it carries a high risk of mechanical trauma to the esophagus. Multiple studies suggested several anatomical characteristics that could harm the esophagus during ablation and ways to prevent this damage. Sandhu et al. showed that esophageal confinement may be a risk factor for atrioesophageal fistula. In addition, Lu et al. proposed that modified posterior-inferior line could serve as a favorable alternative in linear ablation for left atrial posterior wall isolation (36).

The pathophysiology underlying EI after ablation remains unclear. Several etiologies include, gastric acid-reflux, infection and ischemic injury (37). Damage to the esophageal artery during ablation (and therefore, ischemic injury) may constitute as one of the primary
mechanisms of EI, more so than the likelihood of thermal injury being the cause. This could also explain why AE fistulae presents as a delayed complication post-ablation.

Although several studies have indicated thermal injury as one of the most important predictors for the development of EI including AE fistula formation, our investigation indicates no significant correlation between thermal injury and EI. In fact, we found that the most important factor in the development of EI after RF ablation is based on the proximity and anatomic distance between the LA and esophagus. Thus, in case a shorter LA-esophagus distance was found, less energy (<50W) should be delivered when ablating to an area near the esophagus. Also, the use of an esophageal retractor during the procedure is a feasible and promising technique that may be helpful in avoiding esophageal injury.

Bahnson et al found that heat transfer during RF ablation depended on the interaction of a multitude of factors, including but not limited to, the thickness of the atrial wall, connective tissue and esophagus, specifically at the “contact-patch” (38). These interactions are further complicated by intraoperative esophageal and left atrial movements, making an objective and accurate clinical evaluation more difficult. Despite these complexities, Martinek et al found several risk factors for esophageal ulcerations (39). This included patients that had persistent atrial fibrillation, those that received additional lines of ablation at the roofline, LA isthmus, and coronary sinus, as well as those with LA enlargement. Specifically, patients with LA enlargement are believed to be at higher risk due to their existing closer contact between the posterior LA wall and the anterior esophageal wall. The mean thickness of these structures measured 2.2±0.9 mm and 3.6±1.7 mm respectively (39). A discontinuous layer of fat lied between the two structures but its thickness was not found to affect ETI rates (40). Furthermore, Aupperle et al found that unipolar RF ablations often produced more intensive and deeper esophageal lesions compared to cryoablation or bipolar RF ablation (41).

Clinically, our study implicates that when esophageal monitoring was applied, no correlation was seen between esophageal injury during PVI ablation and esophageal temperature changes. Larger prospective studies are needed to determine the exact correlation between
thermal injury and esophageal lesions, as well as the underlying pathophysiology of lesions’ formation.

**Limitations**

Our study has a few limitations. Firstly, the sample study population was small although it had a power of 0.89. Secondly, as a retrospective study, this may have limited some of the overall power and precision of this observational study. Therefore, by conducting this study prospectively and on a larger scale would provide a more precise correlation between esophageal temperature and esophageal lesions post-ablation. A randomized control trial with two arms: one with esophageal temperature monitoring and one without temperature monitoring should be conducted. The incidence of esophageal injury in both arms should be tested to determine if esophageal monitoring during ablation is necessary.

Second, not all the patients were able to receive a cardiac MRI or a CT scan before the procedure. This limited our pre-assessment of the anatomical relations between the LA and the esophagus, as well as determining the differences in LA volume and posterior wall surface.

**Conclusion**

The mechanisms underlying esophageal lesion formation remain to be the result of a multitude of factors. In our study, we determined that during high-power (50 W) short-duration RF ablation, high esophageal temperatures did not directly correlate to a patient developing any type of EI.

What we did discover, however, is having a shorter distance between the LA and the esophagus directly correlates to an increased probability of developing esophageal injury during cardiac ablation.
Funding Sources
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Disclosures
Dr. Marrouche reports receiving grant support and consulting fees from Abbott, Medtronic, Biosense Webster, Boston Scientific, and Siemens, receiving consulting fees from Preventice, and holding equity in Cardiac Design. All other authors have no conflicts of interest associated with the content of this manuscript.

Authorship
All authors attest they meet the current ICMJE criteria for authorship.

Patient Consent
Patients consent was waived due to the use of retrospective and de-identified data.

Ethics Statement
On December 13, 2019, the Tulane University Biomedical IRB provided an expedited review and approval determination for the initial submission of this minimal risk study. The review was provided in accordance with the appropriate research regulations. The research reported in this paper adhered to the Helsinki Declaration guidelines.

Data Availability:
The data that support the findings of this study are available from the corresponding author, NM, upon reasonable request.
References


### Tables

#### Table 1: Clinical characteristics of EGD- Negative Patients and EGD- Positive Patients. EGD: Esophagogastroduodenoscopy; N: number of patients; HF: Heart Failure; CAD: coronary artery disease; AF: atrial Fibrillation.

<table>
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<th>EGD-Negative</th>
<th>EGD-Positive</th>
<th>p-value</th>
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<td>N</td>
<td>32</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
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<tr>
<td>BMI (kg/m²)</td>
<td>35.8 (10.3)</td>
<td>33.6 (7.7)</td>
<td>0.4722</td>
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<tr>
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<td>Male</td>
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<td>Hypertension (%)</td>
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<tr>
<td>Male</td>
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<td>9 (81.8%)</td>
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<tr>
<td>Diabetes (%)</td>
<td>9 (28.1%)</td>
<td>4 (36.4%)</td>
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<tr>
<td>Stroke (%)</td>
<td>3 (9.4%)</td>
<td>2 (18.2%)</td>
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<tr>
<td>HF (%)</td>
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<td>0 (0.0%)</td>
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<tr>
<td>CAD (%)</td>
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<td>Persistent</td>
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#### Table 2: MRI/CT Findings of EGD- Negative Patients and EGD- Positive Patients. EGD: Esophagogastroduodenoscopy; N: number of patients; LA: Left atrium.

<table>
<thead>
<tr>
<th>MRI/CT Findings</th>
<th>EGD- Negative</th>
<th>EGD- Positive</th>
<th>p-value</th>
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<td>Esophageal-LA Distance (N=36)</td>
<td>4.10 (2.9, 5.4)</td>
<td>2.47 (1.69, 3.25)</td>
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<td>Fibrosis Score (N =11)</td>
<td>20.9 (14.7, 24.3)</td>
<td>23.7 (21.8, 25.5)</td>
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<td>LA Volume (N=11)</td>
<td>114.1 (79.3, 181.2)</td>
<td>76.8 (62.2, 91.4)</td>
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<td>LA Posterior Wall Volume (N=11)</td>
<td>4.3 (3.3, 5.8)</td>
<td>2.8 (2.5, 3.2)</td>
<td>0.1949</td>
</tr>
</tbody>
</table>
Legends

**Figure 1:** Esophageal ulcer seen on EGD.

**Figure 2:** Esophageal erythema seen on EGD.

**Figure 3:** Box plot summarizing the distribution of baseline temperature (left) and peak temperature (right) in both EGD- Negative and EGD- positive patients. EGD: Esophagogastroduodenoscopy.

**Figure 4:** Box plots summarizing the distribution of ablation duration (left) and power (right) in both EGD- Negative and EGD- positive patients. EGD: Esophagogastroduodenoscopy. S= seconds. W= Watt.

**Figure 5:** Example of left atrial-esophageal distance measurement based on cardiac MRI.
Figure 1:

Figure 2:
Figure 3:

![Baseline Temperature by Endoscopy Result](image1)

![Peak Temperature by Endoscopy Result](image2)

Figure 4:

![Ablation Duration by Endoscopy Result](image3)

![Ablation Force and Endoscopy Result](image4)
Figure 5:
Key findings

- When monitoring was applied, no correlation was seen between esophageal injury during PVI ablation and esophageal temperature changes.
- The lack of an increase in temperature does not guarantee esophageal protection.
- A small distance between the left atrium and the esophagus is the main risk factor for esophageal injury after atrial fibrillation ablation.