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Feasibility of Endoscopic Guidance for Non-Surgical Transthoracic Atrial and Ventricular Epicardial Ablation

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Abstract

Background—Epicardial catheter ablation via subxyphoid percutaneous access is currently employed upon failure of endocardial catheter ablation. The safety, efficacy, and applicability of epicardial catheter ablation will likely improve with direct visualization of the pericardial space.

Objective—We sought to assess the feasibility of percutaneous endoscopic guidance for identification of epicardial anatomic landmarks and epicardial catheter ablation.

Methods—Dual subxyphoid epicardial access and femoral venous and arterial access were obtained in six healthy swine. The endoscope and electrophysiology catheter were advanced to the pericardial space. Anatomic landmarks were identified via endoscopy and confirmed by multiview fluoroscopic assessment of proximity to endocardial catheters in the area of interest. Radiofrequency ablation of selected anatomic targets was performed under endoscopic guidance. Targeting of lesions was assessed by pathologic examination of the target and surrounding structures.

Results—Dual large bore subxyphoid epicardial access was obtained without complications in all animals. The coronary sinus, left anterior descending coronary artery, left atrial appendage, and pulmonary veins were easily visualized in all animals. Catheter ablation of anatomic targets including the right ventricular outflow tract, left atrial appendage, and pulmonary veins was successfully performed under direct endoscopic observation. Endoscopic guidance of point and linear lesions near coronary vessels was also assessed. Pathology revealed successful targeting of lesions.

Conclusions—Endoscopic guidance of percutaneous epicardial electrophysiology procedures is feasible. Direct visualization of epicardial structures, catheters, and lesions may improve the safety and efficacy of epicardial catheter ablation and reduce staff and patient radiation exposure.

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Keywords

Ablation; Epicardial; Endoscopy; Electrophysiology study; Pericardial

Introduction

Endocardial catheter ablation provides a cure for many focal and reentrant atrial and ventricular arrhythmias.¹ Failure of endocardial ablation often occurs if the arrhythmia focus or critical isthmus is located in the deep mid-myocardium or is epicardial in location. The technique for percutaneous epicardial mapping and ablation described by Dr Sosa and colleagues² is now widely used for treatment of patients who have failed endocardial ablation.²⁻⁷ Recently, hybrid endocardial and epicardial catheter approaches have also been proposed for treatment of atrial fibrillation refractory to standard ablation techniques^{8, 9} Subxyphoid percutaneous epicardial access and ablation, however, is currently associated with risk of injury to the epicardial coronary arteries, phrenic and recurrent laryngeal nerves, esophagus, and lungs.⁹⁻¹¹ Endoscopic visualization of intra-pericardial structures is the cornerstone of minimally invasive surgical ablation procedures^{12, 13} and would likely improve the safety and efficacy of percutaneous epicardial ablation. Recent case reports have used endoscopy to guide ventricular mapping through a small subxyphoid surgical incision,¹⁴ and to visualize the vein of Marshall.⁹ The objective of this study was to assess the feasibility of endoscopic guidance through percutaneous subxyphoid epicardial access for identification of epicardial anatomic landmarks and guidance of anatomic ablation.

Methods

The study was approved by the Johns Hopkins University Animal Care and Use Committee, and performed in six healthy swine (35–50 kg) in accordance with the *Guide for the Care and Use of Laboratory Animals* (Institute of Laboratory Animal Resources, National Academic Press, Washington DC, 1996). Anesthesia was obtained by intramuscular ketamine injection, followed by inhaled 0.8–1.5% isoflurane (Narkomed Ventilator, Draeger, Lubeck, Germany). Right and left femoral venous (8Fr × 2) and left femoral arterial (6Fr × 1) access was obtained using modified Seldinger technique. Arterial blood pressure, pulse oximetry, and end-tidal carbon dioxide levels were monitored during the entire procedure. Subxyphoid epicardial access was obtained using standard technique.² Once the first wire was positioned, a second wire was advanced through a transiently positioned sheath to then allow advancement of two large bore sheaths into the pericardium (14Fr × 1, 18Fr × 1). Electrophysiology catheters (7 Fr multipolar, steerable) were advanced sequentially to endocardial targets of interest including the coronary sinus, and pulmonary veins (via trans-septal approach). Positioning was confirmed via multiview fluoroscopy and electrogram recordings. These endocardial catheters were later used as fluoroscopic markers to confirm the position of the flexible endoscope and the epicardial ablation catheter guided solely by endoscopy.

The flexible endoscope (EB-1530T3 steerable bronchoscope, 5.3 mm diameter, 60 cm working length, Pentax, Montvale, NJ) was advanced through the 18 Fr subxyphoid sheath via endoscopic and fluoroscopic guidance. The endoscope was then retroflexed to identify the distal end of the 14 Fr sheath, thus allowing direct visualization and positioning of the standard non-irrigated radiofrequency ablation catheter (7 Fr, 4 mm tip, quadripolar, Celsius D-Type, Biosense Webster, Diamond Bar, CA). Targets of interest were localized by endoscopic guidance. Pericardial saline infusion through the endoscope significantly diminished image quality and was not used. Air insufflation through the endoscope was used when necessary to expand the pericardial space for adequate visualization of targets. If space remained limited despite air insufflation, a 20 mm inferior vena cava balloon was extended through the remaining

space in the 14 Fr epicardial sheath, positioned next to the ablation target, and expanded with saline. Coronary sinus and pulmonary vein localization by endoscopy was confirmed via multi-view fluoroscopic evaluation of proximity to catheters placed at the target using the endocardial approach. Localization of the right ventricular outflow tract, left atrial appendage, coronary vessels (left anterior descending and great cardiac vein), and pulmonary veins was confirmed by radiofrequency ablation under endoscopic visualization and follow-up pathologic confirmation.

Isolated radiofrequency lesions were delivered (using the non-irrigated 4 mm tip catheter) with a power-controlled mode at 10 W for 20 seconds (Atakr Radiofrequency Ablation System, Medtronic, Minneapolis, MN). Linear lesion sets were created by sequential delivery of 10 W for 5–10 seconds to each point along the line.

At the end of each experiment, the animals were euthanized via barbiturate overdose followed by intravascular potassium chloride injection. The pericardium, liver, and lungs were visually inspected for evidence of blunt or radiofrequency injury. The heart was excised for pathologic assessment of unintended injury to the myocardium and epicardial vessels and targeting of lesions.

Results

Dual percutaneous large bore subxyphoid epicardial access was obtained without complications in all animals. The endoscope was easily advanced into the pericardial space in all cases. The presence of two large sheaths, endoscope, and ablation catheter did not cause notable changes in blood pressure or heart rate. When trying to create additional space for visualization, filling the 20 mm inferior vena cava balloon did not result in significant hemodynamic changes. However, intra-pericardial air insufflation of greater than 50 ml routinely lowered the mean arterial pressure by at least 20 mmHg. The IVC balloon was required for adequate visualization of epicardial coronary vessels in 4 of 6 animals. Air insufflation through the endoscope was used in all cases to improve visualization.

Endoscopic Technique

The steerability and length of the endoscope allowed easy navigation throughout the pericardial space. The swine cardiac apex points toward the body midline, therefore percutaneous subxyphoid access resulted in sheath entry near the ventricular apex. This point of entry combined with the sheath length, required a retroflex approach to ventricular targets for both the endoscope and ablation catheter. Atrial targets were easier to visualize since there was no need for endoscope retroflexion. Gentle air insufflation through the endoscope improved visualization of intra-pericardial structures. Excess pericardial air and fluid was easily aspirated through the endoscope.

Target Localization

The coronary sinus and left atrial appendage were readily visualized without need for balloon expansion in all animals (Video 1). Endoscopic localization of the coronary sinus by the endoscope was confirmed by fluoroscopic assessment of the proximity of the endoscope tip to the endocardial coronary sinus catheter in all animals (Figure 1).

The lateral aspects of all 4 pulmonary veins were easily visualized by endoscopy in all animals (Figure 2) and confirmed by fluoroscopic proximity to an endocardial catheter (sequentially moved to all four pulmonary veins). Space expansion via the inferior vena cava balloon was not required for pulmonary vein visualization. However, we were unable to cannulate the oblique sinus for visualization of the medial aspect of the pulmonary veins.

The left anterior descending, circumflex, and right coronary arteries were visualized by endoscopy in all animals. Endoscopy allowed visualization of branch vessels (Figure 3 and Video 2). Adequate endoscopic visualization of epicardial coronary arteries required balloon pericardial space expansion in 4 of 6 animals. The localization of epicardial coronary vessels, right ventricular outflow tract and left atrial appendage by endoscopy was assessed by targeting of ablation lesions as described below.

Guidance of Epicardial Ablation

Catheter ablation of anatomic targets was successfully guided by endoscopy. Pathologic examination of lesions targeted by endoscopy to spare the vessels confirmed separation between the lesion center and the vessel. However, despite separation of the lesion center from the vessel, the region of secondary injury surrounding the lesion extended to involve the vessel wall in 4 of 9 lesions where separation was less than 1 cm (Figure 4).

To assess the capability of endoscopy in guiding linear lesion sets and identifying unintended acute vascular injury, a linear lesion set was created to cross a coronary vessel in two animals. Endoscopy successfully guided linear ablation across the vessel in both cases. Gross evidence of vascular injury was clearly visualized on endoscopy (Video 3). The linearity of the lesion set and vascular injury was confirmed on pathology (Figure 5).

Pathologic examination confirmed successful targeting of lesions to the right ventricular outflow tract, left atrial appendage, and lateral pulmonary veins (Figure 6) in all cases.

Discussion

The primary finding of this study is that endoscopic identification of anatomic landmarks and guidance of anatomic ablation through subxyphoid non-surgical dual epicardial access is feasible. The study builds upon previous reports regarding the potential utility of endoscopy for mapping using a subxyphoid surgical incision,¹⁴ and for visualization of the vein of Marshall for atrial fibrillation ablation.⁹

Clinical Implications for Current Procedures

Current epicardial catheter mapping and ablation procedures are primarily performed on patients who have failed previous attempts at endocardial ablation of ventricular tachycardia,²⁻⁴ atrial tachycardia,⁷ or accessory pathways.¹⁵ When ablating ventricular tachycardia from the epicardium, concomitant coronary angiography is performed to assure a safe distance from coronary arteries prior to application of ablative energy.² In the current study, epicardial coronary arteries were readily visualized by percutaneous flexible endoscopy. The capability for direct endoscopic visualization of coronary vessels will likely improve the safety of ablation and may obviate the need for concomitant coronary angiography. However, our gross pathology examination suggested that assuring separation of the radiofrequency lesion center from the artery does not ensure lack of injury. Prior studies have suggested that greater than 12 mm separation is required to assure safety specially when lesions are applied near small arteries.^{10, 16} Additionally, despite adequate visibility of coronary arteries in this study, catheter proximity to the coronary arteries may be obstructed by myocardial bridging or epicardial fat in the clinical setting. Further studies with concurrent coronary angiography to assess the relation of estimated catheter-vessel distance by angiography versus endoscopy, and the peripheral spread of radiofrequency ablation are warranted.

The risk of injury to adjacent thoracic and mediastinal structures during epicardial ablation is also likely to be limited by endoscopic visualization. As demonstrated in figure 4 and the Video 3, if adequate space exists or is created by insufflation or balloon insertion, then assuring contact

with the cardiac rather than the pericardial surface is easily achieved via endoscopic guidance. In contrast assuring contact with the cardiac epicardium rather than the pericardium and adjacent structures can be difficult with fluoroscopy, especially if ablation is being performed in a low voltage scar area where electrograms may not distinguish contact from far-field signals.

Ready endoscopic identification of anatomic landmarks such as the lateral pulmonary veins, right ventricular outflow tract, coronary sinus, and the left atrial appendage was demonstrated in this study. The ability to visualize anatomic landmarks by endoscopy may decrease procedure and radiation times of current epicardial procedures.

Clinical Implications for Future Epicardial Procedures

Given the reported success of epicardial atrial fibrillation ablation in the operating room,¹⁷ techniques for percutaneous hybrid endocardial and epicardial,¹⁸ or percutaneous entirely epicardial atrial fibrillation ablation may improve outcomes in the electrophysiology laboratory. An epicardial approach may also improve the targeting of important anatomic structures such as the vein of Marshall and autonomic ganglia,⁹ and reduce procedural stroke risk if the need for endocardial left atrial catheters is eliminated. However, the posterocranial positioning of the pulmonary veins relative to the typical subxyphoid epicardial access and the presence of pericardial reflections creating the oblique and transverse sinuses, make percutaneous catheter manipulation for epicardial atrial fibrillation ablation extremely difficult. In the current study we were able to visualize the lateral pulmonary veins thus facilitating the delivery of radiofrequency lesions to this region. It is likely that endoscopy will improve the feasibility and safety of hybrid and epicardial only percutaneous atrial fibrillation ablation techniques.

Limitations

The primary focus of the current study was proof of feasibility and safety in an animal model. Further testing in animal models, followed by initial studies with surgical support in the operating room will be required prior to clinical applicability in the electrophysiology laboratory. Moreover, long-term pericardial effects, and endoscopic guidance outcomes were not directly compared to those via current guidance techniques of fluoroscopy and/or electroanatomic mapping. Future direct comparisons of safety and efficacy of endoscopic guidance versus standard approaches are warranted.

Air insufflation through the endoscope was used in this study to expand the pericardial space for adequate visualization of targets. In the clinical setting, insufflation with carbon dioxide rather than air would likely reduce the risk of air embolization.^{19, 20}

We were unable to visualize the medial aspect of the pulmonary veins. It is possible that the larger size of the oblique and transverse sinuses may allow endoscopic access to the medial pulmonary veins in humans; however specialized equipment will likely be necessary for visualization and ablation in this region.

The specificity of scar localization via epicardial catheter voltage mapping is often limited due to presence of epicardial fat.²¹ None of the six swine in this study exhibited epicardial cardiac fat. However, the image quality from this study suggests that epicardial fat will likely be visualized thus improving the specificity of voltage mapping at scar recognition.

Conclusion

Endoscopic guidance of percutaneous epicardial electrophysiology procedures is feasible. The ability to target catheters and perform ablation via direct visualization will likely improve the

performance of percutaneous epicardial electrophysiology procedures and reduce staff and patient radiation exposure.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

The left panel is an endoscopic still image of the coronary sinus and the left atrial appendage. The right panels illustrate our technique to confirm target localization via endoscopy. Orthogonal fluoroscopic views show the proximity of the endoscope tip to an endocardial catheter placed in the coronary sinus.

Figure 2.

The figure is an endoscopic still image of the 4 mm tip ablation catheter directed to the lateral aspect of the right inferior pulmonary vein. The spark during unipolar radiofrequency ablation is also observed on the image. PV – pulmonary vein, RF – Radiofrequency, EP – Electrophysiology.

Figure 3.

The figure is an endoscopic still image of the 4 mm tip ablation catheter directed next to a diagonal branch from the left anterior descending artery. The pericardial network of vessels and a pericardial fat collection are also visualized.

Figure 4.

The figure is an image of the harvested heart after targeting of a unipolar radiofrequency lesion next to the marginal branch of the circumflex coronary artery. The vessel was 2 mm in external diameter adjacent to the site of ablation. The point ablation was performed by application of 10W for 20 seconds via the power controlled mode. The center of the ablation lesion was 8 mm away from the edge of the vessel. Separation of the lesion center from the vessel is confirmed; however secondary injury to the vessel wall is noted. RF – Radiofrequency.

Figure 5.

The figure is an image of the harvested heart after targeting of a linear lesion set across the right coronary artery. The vessel was 4 mm in diameter at the site of ablation. Linear ablation was performed by sequential delivery of 10 W for 5–10 seconds to each point along the line. Four separate radiofrequency lesions are confirmed (asterisks) coalescing to form a line (dashed line). Direct injury to the vessel is noted in the image as was observed during endoscopy (Video 3).

Figure 6.

The figure is an image of the harvested heart after targeting radiofrequency lesions to the lateral pulmonary vein ostia (10W for 20 seconds). Radiofrequency lesion targeting to the lateral aspect of the pulmonary veins was confirmed. RF – Radiofrequency.