Percutaneous Transatrial Access to the Pericardial Space for Epicardial Mapping and Ablation

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Background—Puncture of the atrial appendage may provide access to the pericardial space. The aim of this study was to evaluate the feasibility of epicardial mapping and ablation through an endocardial transatrial access in a swine model.

Methods and Results—An 8-F Mullins sheath was used to perforate the right (n=11) or left (n=6) atrial appendage in 17 pigs (median weight, 27.5 kg; first and third quartiles [Q1, Q3], 25.2, 30.0 kg). A 7-F ablation catheter was introduced into the pericardial space to perform epicardial mapping and deliver radiofrequency pulses on the atria. The pericardial space was entered in all 17 animals. In 15 (88%) animals, there was no hemodynamic instability (mean blood pressure monitoring, initial median, 80 mm Hg; Q1, Q3, 70, 86 mm Hg; final median, 88 mm Hg; Q1, Q3, 80, 96 mm Hg; P=0.426). In these 15, a mild hemorrhagic pericardial effusion was identified and aspirated (median, 20 mL; Q1, Q3, 15, 30 mL) during the procedure, and postmortem gross analysis revealed that the atrial perforation was closed in these animals. In 2 (12%) of the 17 animals, there was major pericardial bleeding with hemodynamic collapse. On gross examination, it was found that pericardial space was accessed through right ventricular perforation in 1 animal and the tricuspid annulus in the other. After the initial study, we used an occlusion device in 3 other animals to attempt to seal the puncture (2 at the right atrial appendage and 1 at the right ventricle). These 3 animals had no significant pericardial bleeding.

Conclusions—Transatrial endovascular right atrial appendage puncture may provide a potential alternative route for pericardial access. Further studies are needed to evaluate its safety with longer and more-complex procedures before being applied in clinical settings. (Circ Arrhythm Electrophysiol. 2011;4:331-336.)

Key Words: transvenous catheter ablation ■ epicardial mapping ■ atrial appendage ■ heart catheterization ■ pericardial effusion ■ epicardial radiofrequency ablation ■ pericardiocentesis

Subepicardial myocardial fibers may be the substrate for ventricular tachycardia in a significant portion of patients. Thus, combining endocardial and epicardial approaches may improve the success rate of ventricular tachycardia ablations.\(^1\)-\(^5\) The most common technique to access epicardial substrate is through a nonsurgical subxiphoid pericardial puncture; however, subxiphoid access is challenging for most electrophysiologists because of the significant potential risk of right ventricular (RV) puncture.\(^6\)-\(^8\)

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An alternative that uses femoral access is to perforate the heart from the endocardial side. Verrier et al\(^9\) and Waxman et al\(^10\) showed that the percutaneous approach through the right atrial appendage (RAA) provides a rapid and safe transvenous route to access the normal pericardial space. Subsequent studies have shown that RAA perforation may be useful in the delivery of a number of therapeutics, ranging from drug delivery to implantation of pacemaker leads for cardiac resynchronization therapy.\(^10\)-\(^13\) However, the feasibility of epicardial mapping and ablation through appendage perforation has not been explored. We sought to evaluate the feasibility of accessing and then maneuvering in the normal pericardial space through atrial appendage perforation. We also explored in this pilot study the possibility of using a closure device to close the puncture.

Methods

The experiments were performed according to a protocol approved by the scientific and ethical committee of our institution in accor-
dance with the guidelines for good practices for the care in the laboratory animals. Twenty pigs (median weight, 27.5 kg; first and third quartile [Q1, Q3], 25.2, 30.0 kg) were used in this study. The animals were fasted overnight and preanesthetized using an intramuscular injection of 22 mg/kg of ketamine hydrochloride and 0.3 mg/kg of midazolam. General anesthesia was performed with 10 mg/kg IV thionembutal followed by inhaled halothane or isoflurane at 1% on mechanical ventilation. Peripheral venous access was obtained in the auricular region of the animals. Arterial blood pressure was recorded through a femoral arterial line. A 7-F decapolar catheter was introduced into the coronary sinus through superior vena cava access. In addition a 7-F quadripolar catheter was temporarily placed at the His position through the femoral vein to mark His position on fluoroscopy. The quadripolar catheter was then removed for later use in the epicardium. Fluoroscopic images were obtained and recorded with a Phillips radioscopic system. Intracardiac electrograms were filtered at band-pass settings from 80 to 500 Hz and displayed simultaneously with ECG leads I, II, and III, on a multichannel recorder (EP Tracer; CardioTek; Maastricht, The Netherlands).

Transatrial Approach Without Closure
The feasibility of performing transatrial mapping and ablation without a closure device was tested in 17 animals (RAA, 16; left atrial appendage [LAA], 1). A long transseptal sheath (Preface Multipurpose; Biosense Webster; Diamond Bar, CA; or SL-1; St Jude Medical; St Paul, MN) was positioned into the RAA to access the pericardial space in 16 animals. A 7-F quadripolar catheter was placed through this long sheath at the RAA position as confirmed by pericardial fluid aspiration and contrast injection (Figure 1D). A nonirrigated ablation catheter with a 4- or 8-mm distal tip (Biosense Webster) was introduced into the pericardial space for mapping and ablation (Figure 1D). In 1 animal, the left atrium was accessed by the transseptal approach, and then left transatrial access to the pericardial space through the LAA was attempted with the same technique applied through the RAA.

With the ablation catheter, epicardial mapping was simulated by positioning the epicardial catheter in several epicardial areas of RV, left ventricle (LV), left atrium, and right atrium (RA). Next, radiofrequency (RF) applications were delivered (50 W, 60°C for 60 seconds) at the LAA or posterior-lateral wall of the RA. No ventricular ablation was performed because of concern about the high risk for ventricular fibrillation induction in swine. Arterial pressure was continuously monitored, and cardiac silhouette border movement was checked periodically to identify a possible hemopericardium. Hemodynamic instability was defined as a drop in arterial blood pressure of >20 mm Hg or if vasoactive drugs were needed to maintain blood pressure >60 mm Hg. The arterial blood pressure and heart rate at baseline and after removing the sheath from the pericardial space were recorded.

After Ablation
After ablation, the RF catheter was removed, and a 6-F pigtail catheter was introduced in the pericardial space and moved throughout the space to remove any fluid or blood. Negative pressure was maintained continuously. The 8-F long sheath was then withdrawn to the RA, and the pigtail catheter under manual negative pressure for 5 additional minutes was then removed. The arterial blood pressure and fluoroscopic cardiac border movement were monitored for 30 minutes, and then the animals were euthanized.

Transatrial Access With Closure Device
In 3 animals, we performed the same transatrial access but closed the access hole with a patent foramen ovale closure device (Premere; St Jude Medical).14 After mapping with the ablation catheter and draining fluid with the pigtail catheter, we removed the pigtail catheter but left the long sheath in the pericardium. We then placed a guidewire through the sheath into the pericardium. The sheath was withdrawn into the heart, and the patent foramen ovale closure device was placed through the guidewire as previously described for patent foramen ovale closure.14

Euthanasia
Euthanasia was performed by an intravenous infusion of 20 mL potassium chloride; the thorax was opened to allow access to the pericardial sac, and pericardial bleeding was investigated and measured. The lesions as well as the atrial punctures were documented and microscopically examined after conventional histological processing.

Statistical Analysis
All variables were tested for normality using Shapiro-Wilk test. Procedure time and initial and final heart rates presented normal distribution and were expressed as mean±SD. Weight, initial and final mean blood pressure, and amount of bleeding did not present normal distribution and were expressed as median and first and third quartiles (Q1, Q3). Nonparametric Wilcoxon signed rank test was used to compare paired variables without normal distribution. A P<0.05 was considered statistically significant.

Results
The data of all animals’ characteristics and clinical outcomes are presented in the Table.

Transatrial Approach Without Closure
All 17 animals had pericardial access, and 15 had successful simulated mapping and ablation. Mean time of procedure was...
In 15/17 (88.2%), there was no hemodynamic instability (mean blood pressure monitoring: initial median, 80 mm Hg; Q1, Q3, 70, 86 mm Hg; final median, 88 mm Hg; Q1, Q3, 80, 96 mm Hg; \( P < 0.06 \); median differences, 4 mm Hg; Q1, Q3, 0, 16 mm Hg) or visual changes in the cardiac border movements on fluoroscopy. The ablation catheter was introduced in the pericardial space; epicardial mapping and RF ablation were simulated. We performed a median of 8 (Q1, Q3, 7, 12) RF applications on the RA and left atrium of the 15 animals that did not present tamponade. There was an increase in the mean heart rate between the beginning and the end of the experiment (initial median, 100 beats/min; Q1, Q3, 90, 115 beats/min; end median, 120 beats/min; Q1, Q3, 100, 120 beats/min; \( P < 0.001 \); median difference, 20 beats/min; Q1, Q3, 0, 36 beats/min). A median of 20 mL/animal (Q1, Q3, 15, 30 mL/animal) of pericardial serohemorrhagic fluid was identified and aspirated during the procedure.

In these 15 animals, postmortem analysis detected the atrial access perforation in the RAA in 13 animals, in the right aspect of the atrial wall in 1, and in the LAA in 1. Only a median of 6 g (Q1, Q3, 2, 12 g) of blood clot was found in the 15 animals without complications. Histological analysis demonstrated a fibrin thrombus occluding the endocardial side of the puncture orifice and extending irregularly through the path, with occasional complete contact between the orifice borders that probably was due to myocardial fiber contraction around the perforation (Figure 2).

In 2 (12%) animals, there was significant pericardial bleeding and cardiac tamponade. The first occurred in animal 03. Postmortem evaluation showed 155 g of blood in the pericardial space, and atrial perforation was identified outside the RAA at the anterior aspect of the tricuspid annulus (Figure 3). The second tamponade occurred in animal 10. Postmortem evaluation revealed 201 g of blood, and perforation was identified at the RV outflow tract. Three and 4 RF applications were performed in animals 03 and 10, respectively. One interesting finding was that the weight of the animals presenting with tamponade was higher than the 75th percentile (30 and 40 kg, respectively).

**Transatrial Access With Closure Device**

The 3 procedures in which the cardiac perforation was repaired with the occlusion device were analyzed separately. The animals maintained hemodynamic stability during all procedures, with no significant intrapericardial bleeding. Postmortem evaluation showed that the puncture was performed and closure device delivered in the RA in 2 animals and RV outflow tract in 1 animal (Figure 4).

**Discussion**

In this pilot study, we have shown that epicardial mapping and ablation are possible through a transatrial puncture. In most of the cases, a mild pericardial effusion without significant hemodynamic instability was identified, although tamponade occurred in 12% the cases. In those cases, a closure device could have been useful to prevent tamponade. This

### Table. Clinical Data and Clinical Outcomes of All Procedures

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BP indicates blood pressure; HR, heart rate; LAA, left atrial appendage; RAA, right atrial appendage; RV, right ventricle; TA, tricuspid annulus; VF, ventricular fibrillation.

197.1 ± 38.0 minutes. In 15/17 (88.2%), there was no hemodynamic instability (mean blood pressure monitoring: initial median, 80 mm Hg; Q1, Q3, 70, 86 mm Hg; final median, 88 mm Hg; Q1, Q3, 80, 96 mm Hg; \( P = 0.06 \); median differences, 4 mm Hg; Q1, Q3, 0, 16 mm Hg) or visual changes in the cardiac border movements on fluoroscopy.

The ablation catheter was introduced in the pericardial space; epicardial mapping and RF ablation were simulated. We performed a median of 8 (Q1, Q3, 7, 12) RF applications on the RA and left atrium of the 15 animals that did not present tamponade. There was an increase in the mean heart rate between the beginning and the end of the experiment (initial median, 100 beats/min; Q1, Q3, 90, 105 beats/min; end median, 120 beats/min; Q1, Q3, 110, 130 beats/min; \( P < 0.001 \); median difference, 20 beats/min; Q1, Q3, 0, 36 beats/min). A median of 20 mL/animal (Q1, Q3, 15, 30 mL/animal) of pericardial serohemorrhagic fluid was identified and aspirated during the procedure.

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transvenous route might be a suitable access to map and ablate the epicardial surface of atria and ventricles for some electrophysiologists who do not feel comfortable accessing the pericardial space through the subxiphoid approach and who prefer to manipulate catheters through the transvenous access, but further studies are needed.

We suspect that the mechanism of spontaneous RAA closure is the contraction of atrial myocardial fibers around the transatrial orifice against the catheter, which avoids significant bleeding during the procedure. The hole may close up as catheters are slowly downsized. However, if this is true, patients with localized atrial scar at the access site might have continued bleeding because the scar would not contract. This fact may be important in patients with persistent atrial fibrillation or cardiomyopathies who may have large areas of atrial scar. In the present study, acute macroscopic and histological examinations showed impressive spontaneous reduction of the atria perforation orifice after catheter withdrawal that likely was due to myocardial fiber contraction located around the orifice perforation. Additionally, intramyocardial edema formed around the orifice borders complicated conditions for a stronger contact between the borders, closing tight the orifice. However, it is possible that this edema would reduce with time and that the puncture site might produce late bleeding. Microscopic evaluation also revealed a fibrin plug at the endocardial sites of the punctures that probably contributed to the absence of pericardial bleeding. These findings are in conformity with the Verrier et al.9 and Waxman et al.10 reports where a fibrin clot was observed at the endocardial site of the orifice in all of their histological samples, leading to their conclusions that this fibrin plug would be the most important mechanism to prevent pericardial bleeding after the transatrial access.

In the present study, the transatrial access failed in 2 cases when punctures were performed outside the RAA: 1 near the tricuspid annulus and 1 in the RV free wall. In both cases, we had confirmed the sheath positions in the RAA with contrast infusion before making the perforation. We suspected that those sheaths came out, dislodging from the RAA, and fell into the RV or the RA near the tricuspid annulus. Perforations at those places may not present as favorable conditions for spontaneous occlusion as the ones seen in the atrial appendages.

Interestingly, the animal in which transatrial access was achieved through the LAA did not present with pericardial bleeding. It is possible that the anatomy of the RAA and LAA
in pigs favors local thrombus formation when the catheter is downsized before being removed from the perforation. The role of intrapericardial negative pressure to avoid pericardial bleeding still is not clear. This maneuver has been performed together with downsizing the catheters in accidental atrial perforations during transseptal access to the left atrium,\textsuperscript{15–17} and it was performed in the present study.

Safety of the Transatrial Approach to the Normal Pericardial Space

Verrier and colleagues\textsuperscript{9} originally described the transatrial pericardial access concept in 1998 in an experiment involving 19 animals (6 dogs and 13 pigs). In their study, a 21-gauge hollow radiopaque needle mounted at the tip of a 4-F catheter and a soft 0.014-in guidewire were custom fabricated to perform a percutaneous approach from a femoral vein to pierce the RAA. Direct inspection after thoracotomy revealed no hemopericardium, laceration, or bleeding on catheter withdrawal.\textsuperscript{9} Their findings were confirmed in a subsequent study involving another 20 anesthetized pigs in which transatrial access was successfully accomplished within 3 minutes without significant hemopericardial bleeding after 24-hour and 2-week evaluations.\textsuperscript{10}

In the present study, despite not using customized material, the findings were similar to Verrier et al\textsuperscript{9} and Waxman et al\textsuperscript{10} when pericardial access was obtained through the atrial appendage. In comparison, we observed small pericardial effusion in 15 of 17 animals at the end of the procedure, but it did not preclude epicardial mapping and ablation. Mickelsen et al\textsuperscript{11} also observed some pericardial effusion that was hemodynamically significant in 4 of the 8 animals in which they were assessing the feasibility of inserting epicardial leads through the transatrial or transvenous (superior vena cava) route. They also used noncustomized and oversized material (8-F or 9-F sheaths) to access the pericardial space, which might have facilitated the pericardial bleeding. In their study, there was no significant pericardial effusion at necropsy, but moderate inflammatory reaction was observed in two chronic animals that had exhibited significant pericardial bleeding during the procedure. These findings bring some kind of concern because intense pericarditis and even constrictive pericarditis has been reported in association with hemorrhagic effusion.\textsuperscript{18,19} In 2 of the 17 animals in the present study, there was massive bleeding that rendered us unable to complete the procedure. However, significant pericardial bleeding also has been observed with the subxiphoid approach. It should be noted that this study represents our initial experience with this technique and reflects our learning curve. It is possible that with more experience, we will have better results.

Limitations

This preliminary study has important limitations. First it was an experimental study performed in pigs, so we cannot assume that our observations would be the same in human beings. Second, we only evaluated the feasibility of positioning the ablation catheter in different areas of the atria and ventricles and delivering a few RF applications. It is possible that longer procedure times with more aggressive sheath manipulation would cause more bleeding or larger holes. Third, we did not use IV heparin, which often is needed in combined endocardial and epicardial ventricular tachycardia ablations. Fourth, we did not perform any ablation on the ventricle, so we cannot say that we would be able to get good lesions with this approach for ventricular tachycardia ablation. Fifth, this was an acute study; a chronic survival study may show more bleeding. Sixth, we did not perform histological studies in every puncture site, which could have given us insights into how strong the spontaneous closure is. Finally, although some electrophysiologists may be more comfortable manipulating catheters from the groin, it is possible that a majority of operators will not be comfortable with intentional cardiac perforation, even if excellent data were obtained. Additionally, we did not compare the safety of a transatrial approach to a subxiphoid approach (the current standard) and, thus, can make no definite statements about the relative merits.

Conclusions

Transatrial endovascular RAA puncture may provide a potential alternative route for pericardial access. Further studies are needed to evaluate its safety with longer procedures, ability to ablate the ventricle, and the use of closure tools before being applied in clinical settings.

Sources of Funding

This study was supported by the Heart Institute (InCor), São Paulo Medical School University and the Zerbini Foundation. St Jude Medical donated the 3 devices used in this study to occlude the perforations.

Disclosures

Dr Scanavacca has received research grant support from Cordis-Biosense Webster and Johnson & Johnson Medical Brazil and honoraria from St Jude Medical and has served as consultant/advisor for Merck Sharp & Dohme. Dr Darrieux has served as consultant/advisor for Boehringer-Ingelheim and Sanofi-Aventis. Dr Mahapatra is a consultant to St Jude Medical and is a cofounder of EpiEP. Dr
Sosa has received research grant support from Cordis-Biosense Webster and Johnson & Johnson Medical Brazil.

References


**CLINICAL PERSPECTIVE**

Catheter ablation of ventricular tachycardia usually is a troublesome procedure because of the complexity of circuit’s organization, frequently encompassing subendocardial, intramyocardial, and subepicardial myocardial fibers. For this purpose, electrophysiologists have implemented many strategies for ventricular tachycardia mapping and ablation. One of them is to access the pericardial space through the percutaneous subxiphoid approach to map and ablate epicardial ventricular tachycardias. However, achieving the normal pericardial space is still a challenge for many electrophysiologists because of the potential risk of hemopericardium. In this study, we assessed the hypothesis that epicardial mapping and ablation can be performed through a vascular approach by using the femoral access to perforate the right atrium. Epicardial access was obtained in 20 pigs. Simulation of epicardial mapping and radiofrequency ablations were performed with regular electrophysiological tools without significant pericardial bleeding, even after their withdrawal, when the right atrium appendage was perforated. However, pericardial bleeding with hemodynamic collapse occurred when the puncture was performed outside the right atrial appendage (right ventricle in 1 animal and the tricuspid annulus in another). An occlusion device to seal the puncture in 3 animals (2 at right atrial appendage and 1 at the right ventricle) avoided significant pericardial bleeding. These preliminary observations suggest that transatrial endovascular right atrial appendage puncture may provide a potential route for pericardial space access. However, further studies are needed to evaluate its safety with longer and more-complex procedures before being applied in clinical settings.
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_Circ Arrhythm Electrophysiol._ 2011;4:331-336; originally published online March 23, 2011; doi: 10.1161/CIRCEP.110.960799

_Circulation: Arrhythmia and Electrophysiology_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 1941-3149. Online ISSN: 1941-3084

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