Accessory Atrioventricular Pathways Refractory to Catheter Ablation:
The Role of Percutaneous Epicardial Approach

Running title: Scanavacca et al.; Pericardial approach in WPW ablation

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Abstract:

**Background** - Epicardial mapping and ablation of accessory pathways through a subxiphoid approach can be an alternative when endocardial or epicardial transvenous mapping has failed.

**Methods and Results** - We reviewed acute and long-term follow-up of 21 patients (14 males) referred for percutaneous epicardial accessory pathway (AP) ablation. There was a median of 2 previous failed procedures. All patients were highly symptomatic, 8 had atrial fibrillation (3 with cardiac arrest) and 13 had frequent symptomatic episodes of atrioventricular reentrant tachycardia. Six (28.5%) patients had a successful epicardial ablation. Five (23.8%) patients underwent a successful repeated endocardial mapping and ablation after epicardial mapping yielded no early activation site. Epicardial mapping was helpful in guiding endocardial ablation in 2 (9.5%) patients, showing that the earliest activation was simultaneous at the epicardium and endocardium. Four (19%) patients underwent successful open-chest surgery after failing epicardial/endocardial ablation. Two (9.5%) patients remained controlled under antiarrhythmic drugs after unsuccessful endocardial/epicardial ablation. Two patients had a coronary sinus diverticulum and one a right atrium to right ventricle diverticulum. Three patients acquired post-ablation coronary sinus stenosis. There was no major complication related to pericardial access.

**Conclusions** - Percutaneous epicardial approach is an alternative when conventional endocardial or transvenous epicardial ablation fails in the elimination of the accessory pathway. A new attempt by endocardial approach was successful in a significant number of patients. Open-chest surgery may be required in very symptomatic cases refractory to endocardial-epicardial approach.

**Key words:** Wolff-Parkinson-White syndrome, epicardial, ablation, pericardium, pericardial puncture, pericardial access
Introduction

Radiofrequency catheter ablation is currently the gold standard therapy for symptomatic patients with accessory atrioventricular pathways. A small subset of patients, however, will fail ablation procedures using a conventional endocardial approach. Percutaneous transthoracic pericardial access was originally reported for the treatment of ventricular tachycardia\(^1\)\(^-\)\(^2\) and gradually became a worldwide-accepted technique for those patients with ventricular tachycardia where the subepicardium is a component of the tachycardia circuit\(^3\)-\(^7\). Accessory pathways are epicardial structures\(^8\) that are usually accessible from a catheter positioned in the adjacent endocardium, above or beneath the valvular annulus, or from the epicardial vessels of the coronary venous system\(^9\). In some patients, however, the accessory pathway may be located further away from the annulus, out of reach from an endocardially positioned catheter. In addition, associated structural abnormalities or inability to deliver radiofrequency (RF) current may also lead to failed procedures. Clinical experience with epicardial approach for AP ablation is limited\(^10\)-\(^14\). The aim of this study is to assess the contribution of percutaneous epicardial mapping and ablation of accessory pathways refractory to conventional endocardial mapping.

Population and Methods

Study Population

The population consisted of 21 patients from 3 Institutions (Instituto do Coração, São Paulo University, São Paulo, Brazil; Biocor Instituto, Nova Lima, Brazil, and Hospital Cardiológico, Florianopolis, Santa Catarina, Brazil) with accessory atrioventricular pathways (AP) refractory to multiple endocardial attempts of catheter ablation between 2001 and 2013. All patients referred to our centers underwent a simultaneous endocardial and epicardial approach. The flowchart of the clinical-electrophysiologic decision-making process is depicted in Figure 1.
Methods

Anatomic evaluation

Coronary sinus anatomy was assessed in 16 patients by venous angiography, with multi-slice computer tomography in 3 patients. Cases 1 and 21 underwent magnetic resonance imaging to assess right atrium anatomy (Table 1 and Figure 2 and 3).

Pericardial puncture

The technique was reported elsewhere. In 19 patients, a conventional 7F sheath was introduced in the pericardial space. In two (#10 and #11), an 8.5F introducer was used with a steerable pericardial sheath (Agilis®, S Jude Medical, Minneapolis, USA). Coronary angiography was performed to check proximity of the ablation site with coronary arteries (we considered safe a minimum distance of 5 mm). A 5 Fr pigtail catheter was used to drain the accumulated pericardial fluid in case of open irrigated-tip catheter ablation. All catheters and sheaths were removed at the end of the procedure.

Electrophysiologic study, mapping and catheter ablation

Electrophysiologic study was performed with the EP Tracer System (Cardiotek BV, Maastricht, The Netherlands). In general, patients with posteroseptal and left-sided accessory pathways underwent left atrial instrumentation through transeptal puncture (13 patients), and in 2 patients a retrograde transaortic access was also used (Table 2). Percutaneous subxiphoid pericardial access was successfully performed in all patients. Assessment of the ablation target was based upon early ventricular activation mapping during sinus or atrial pacing and on earliest atrial activation site during atrioventricular reentrant tachycardia (AVRT) or ventricular pacing. Catheter ablation with an endocardial approach (including ablation inside the middle cardiac vein and coronary sinus) were performed with 4 or 8 mm ablation catheters except in 3 patients were an open
irrigated-tip catheter (Thermocool®, Biosense Webster, Diamond Bar, CA, USA) was used (Table 2). A Stockert® radiofrequency ablation generator (Biosense Webster, Johnson & Johnson, USA) was used in all cases. Coronary angiography was performed to check proximity to a major coronary artery branch before ablation.

**Surgery**

Open-chest heart surgery with cardio-pulmonary bypass and cryoablation was performed in patients with high-risk WPW-related arrhythmias after undergoing a failed endocardial-epicardial approach. In those patients with coronary sinus diverticulum, surgery consisted of diverticulum resection and cryoablation application with a probe to the diverticulum neck.

**Follow-up**

Patients underwent a transthoracic echocardiogram in the day after the procedure. Each patient returned in the outpatient clinic at least once before 3 months after the procedure. After that evaluation, the patient was referred back to the referring physician for long-term follow-up. The median follow-up was 30 months (range: 1 to 133 months).

**Statistical analysis**

All variables are presented as median and range.

**Results**

**Patient characteristics**

Twenty-one patients were included in the study. They had undergone a median of 2 previous ablation procedures (range 0 to 4). The median age was 29 years old (range 18 to 66), and 14 patients were males (66.7%). Eight of the 21 (38%) patients had atrial fibrillation with fast ventricular rate, and 3 (14%) had a cardiac arrest as the presenting arrhythmia (Patient 11 stayed 10 days into a coma and underwent 15 days of hemodialysis). Seventeen patients (81%) had
AVRT as their clinical arrhythmia (four patients had a history of AVRT and AF).

**Mapping and ablation results**

Epicardial mapping and ablation was successful in 6 (28.5%) patients, while in 7 (33%) a subsequent endocardial or epicardial transvenous mapping and ablation resulted in accessory pathway elimination. In four patients (19%), open-chest surgery was necessary for the elimination of the accessory pathway. The other four patients (19%) had a failed endocardial and epicardial ablation (Tables 1 and 2).

**Accessory pathway localization**

The most common accessory pathway position was posteroseptal in 12 (57%) patients, left free wall and left posterior in 4 (19%), right posterior or right lateral in 3 (14,2%), and anteroseptal in 2 (9,5%). Two right-lateral accessory pathways (66,7%), three posteroseptal (25%), and one left lateral (25%) were successfully ablated through percutaneous epicardial approach, while no anteroseptal pathway was epicardially ablated (p=NS).

**Anatomic evaluation:**

Case 21 had a right atrium appendage-right ventricle diverticulum with thrombi diagnosed by magnetic resonance imaging. Three patients were diagnosed with acquired post-ablation coronary sinus stenosis ranging from mild (case 4) to moderate (cases 5 and 15).

**Pericardial instrumentation access and complications**

Pericardial access via percutaneous subxiphoid puncture was accomplished in all patients. One patient (case 3) had hemopericardium diagnosed immediately after introduction of the dilator. In this patient, after draining 100 mL of blood, bleeding stopped and procedure resumed without any further bleeding. Case 19 developed acute pericarditis, which resolved with a non-steroid anti-inflammatory drug. There were no other complications related to the catheter ablation.
procedure.

**Endocardial-epicardial mapping and ablation**

Figure 1 flowchart depicts outcomes in relation to activation-mapping results. Results of activation mapping were classified in the following categories: 1) Epicardial activation earlier than endocardial-approach activation. All six patients with earliest epicardial activation underwent successful ablation from the epicardium. A likely AP potential was seen at the earliest activation site in 4 of the 6 patients (Table 1 and Figures 3 and 4, as well as Figure 1 Supplemental Material); 2) Simultaneous early activation at the epi and endocardium close to the mitral annulus was seen in three patients, and two patients were successfully ablated from the endocardium approach, guided by epicardial mapping; 3) Endocardial approach activation was earlier than epicardial (9 patients), the earliest activation in those 9 patients was found in the middle cardiac vein (3 patients), coronary sinus (2 patients), an endocardial site at the tricuspid annulus (3 patients), and at the mitral annulus (1 patient). Ablation of the accessory pathway was successful in 2 of the 3 patients in the middle cardiac vein. Both patients with earliest activation at the coronary sinus failed catheter ablation. Those 2 patients had acquired moderate coronary sinus stenosis from previous ablation attempts. In all 9 patients who underwent radiofrequency ablation attempts, the ablation sites were assessed with a coronary angiography and deemed safe (distance greater than 5 mm).

**Procedure time**

The median total procedure time in this series was 200 minutes (ranged from 110 to 375 minutes).

**Surgery**

Four patients underwent open-chest heart surgery with cardio-pulmonary bypass and
cryoablation (Table 2). Patient 16 had a giant coronary sinus diverticulum with multiple dilated epicardial vessels and coronary sinus ostium atresia. Resection of the diverticulum as well as reconstruction of the coronary sinus ostium and course was necessary in this patient (Figure 5 and 6).

**Follow-up**

None of the 17 patients who underwent successful catheter or surgical ablation had recurrence of AP conduction or symptoms. Two patients (cases 3 and 20) are under antiarrhythmic drug therapy and are asymptomatic, while one patient was referred for open irrigated-tip catheter ablation (case 17), and case 20 was lost to follow-up.

**Discussion**

The major findings of this study are: 1) percutaneous epicardial approach can be an alternative when endocardial or transvenous accessory pathway ablation fails; however, in this series, this approach was successful in only six (28.5%) patients; 2) additional endocardial or transvenous epicardial mapping was successful in 7 (33%) patients.

Four scenarios were identified: 1) The presence of a “true” epicardial accessory pathway identified by an earliest activation site at the epicardium and subsequent ablation of the accessory pathway; 2) The identification of an early epicardial activation site as a reference for successful endocardial ablation; 3) Absence of an epicardial site showing early activation, and successful ablation with further endocardial mapping; and 4) No epicardial or endocardial site with early activation to allow successful ablation was found. The scenarios 2, 3, and 4 could be explained by the epicardial fat that usually is thick and close to the AV annulus precluding accessory-pathway mapping and elimination.
Successful ablation from percutaneous epicardial instrumentation

Six patients were successfully ablated from a pericardial site. In 2 patients (cases 10 and 11), maneuverability, stability, and contact force of the catheter with the tissue were much improved using a steerable sheath (Figures 2 and 3). Both patients had an epicardial posteroseptal AP. An irrigated-tip catheter was used in 4 of 6 patients successfully ablated from the epicardium and probably played a role. Schweikert et al. reported epicardial mapping in a cohort of 10 patients with refractory APs. Only three patients (30%) that presented a right atrial appendage-right ventricle (RAA-RV) diverticulum could be ablated from the epicardium, and no other AP location had early activation or successful ablation from the epicardium. We also had 1 patient with RAA-RV diverticulum ablated from the epicardium. However, other locations like posteroseptal, left posterior, and right posterior could also be ablated from the epicardium, expanding the prospect of ablation to more patients with an AP not amenable to endocardial approach ablation. Valderrabano et al. reported epicardial ablation in 2 of 6 patients (33%), one in the right free-wall and the other in the right posteroseptal region. In some patients with diverticulum (coronary sinus or RAA-RV), with a more extensive area of contact between atrium and ventricle, multiple endocardial and epicardial radiofrequency applications might be needed to achieve a complete ablation. The “successful ablation site,” however, would be considered epicardial if the last application was delivered from that site, but contribution from endocardial applications to the final result must be acknowledged in such an instance. This happened in case 21 who received multiple endocardial and epicardial RF applications, but the epicardial site was considered the site of successful ablation.

Anatomic reason for failure of percutaneous epicardial ablation

The success of percutaneous epicardial ablation in the present series (28.5%) was similar to
previous reports by Schweikert\textsuperscript{10} and Valderrabano\textsuperscript{11}, which were 30\% and 33\%, respectively. The likely explanation for this limited success rate may be related to the anatomy of the AV groove. Becker et al.\textsuperscript{8} examined the heart of patients with accessory pathways showing that they are epicardial structures. There is a thick epicardial fat layer covering the region where accessory pathways sit, which is significant enough to be a limitation to a better performance of the percutaneous epicardial approach in most patients. Another structure that could limit the accessory pathway elimination is the coronary artery because myocardial tissue and the accessory pathway that are located underneath large epicardial arteries frequently remained intact after ablation\textsuperscript{18}.

**Epicardial mapping guiding endocardial ablation**

The concept that epicardial mapping may enhance the effectiveness of endocardial ablation was introduced during ventricular tachycardia ablation\textsuperscript{19}. The role of epicardial mapping in guiding endocardial catheter ablation was previously reported\textsuperscript{10,11}. In our series, only 3 patients had similar activation times from endocardial and epicardium. Successful endocardial ablation was achieved in 2. In Scheikert et al. series\textsuperscript{10}, 2 patients (one with left postero-septal AP and another with a right postero-lateral AP) had an epicardial-guided successful endocardial ablation. In Valderrabano et al.\textsuperscript{11} series, 4 of 6 patients had an epicardial-guided endocardial ablation (3 right free wall and 1 left postero-septal AP).

**Successful endocardial ablation unrelated to epicardial mapping**

Five of 8 patients were successfully ablated from the endocardium approach after they underwent a second round of endocardial mapping (endocardium and coronary venous system when appropriate) following epicardial mapping. Our results in those 5 patients indicate that it is not always correct to equal failure of epicardial mapping in finding an adequate early site of
activation with indication for surgery, as suggested by Valderrabano et al.\textsuperscript{11}. We cannot explain why the adequate site of ablation was not found during the initial endocardial mapping. However, after a thorough pericardial mapping without finding an adequate target, the operator was provided with critical information, which was not present before, that the endocardial approach would be the only one standing a chance of success. As a result, more emphasis and stamina were put forward in finding the spot from the endocardium.

\textit{Failure of catheter ablation of an accessory pathway in highly symptomatic patients}

A critical decision has to be made when catheter ablation is not possible. Patients referred for open-chest surgery usually underwent multiple procedures at different centers. In our series, a median of 3 procedures were performed before the percutaneous epicardial approach in the patients that underwent surgery (vs 1 without surgery). We want to stress that it is crucial to repeat endocardium mapping after making sure that no early activation was found under the subxyphoid epicardial approach. This made the difference in 24% of our patients.

Another important issue is the use of irrigated-tip technology. Irrigated-tip ablation catheter was used in only 7 patients (Table 2), and a successful ablation was achieved in 4. On the other hand, 14 patients underwent catheter ablation with regular 4mm or 8mm tip catheter, and successful ablation was attained in 9. The use of irrigated-tip ablation catheters could have improved results, particularly in patients with an AP located in the coronary sinus venous system, like patients 17 and 18, who had an accessory pathway mapped inside the middle cardiac vein (case 17 had transient disappearance of pre-excitation during RF application).

Unfortunately, we did not have the irrigated-tip technology available in all patients because some procedures were performed before this technology was available. This important issue needs to be prospectively addressed.
The presence of an associated anatomic abnormality is not *a priori* an impediment to a successful catheter ablation procedure. Successful ablation was accomplished in 1 of the 2 patients with a coronary sinus diverticulum and in the only patient with a right atrium-right ventricle diverticulum. However, coronary sinus stenosis, caused by radiofrequency applications inside the coronary sinus in previous procedures probably played a role in not achieving success in the two patients that presented moderate stenosis, in one of whom open-chest surgery was necessary. Patient 16, with a giant coronary sinus diverticulum and ostium atresia (Figures 5 and 6), is an example of the limitation of the technique: an impossible ablation. In some patients, particularly the ones with high-risk accessory pathways, open-chest surgery might be required.

**Procedure time**

Electroanatomic mapping was not usually performed during AP ablation procedures. In our series, only 1 patient underwent electroanatomic mapping (case 12). However, given the long-lasting procedure times, the use of non-fluoroscopic imaging technique to limit radiation exposure is advisable.

**Acquired post ablation decremental conduction**

Two patients (cases 11 and 21) (Table 1) showed a change in their AP electrophysiologic characteristics, which acquired slow conduction and decremental properties while losing ventriculo-atrial conduction capability. Sternick et al. 20 reported a series of patients with post-ablation decremental properties and found that posteroseptal septal AP located inside the coronary sinus venous system was at greatest risk (odds 1:6) of developing decremental properties. They suggested that in spite of the change in A-V conduction, they were still capable of being part of an arrhythmia circuit; therefore, they should be targeted for ablation. Cases 11 and 21 only had atrial fibrillation. Case 11 developed a Mahaim-like physiology after
radiofrequency current was applied in the middle cardiac vein. Atrioventricular conduction time became decremental, but the refractory period was still short and the AP was eventually ablated from the pericardial space (Figure 2). Case 21 had a right-lateral AP associated with a right atrium diverticulum and after 38 applications of RF pulses, ventricular preexcitation was only exposed during atrial pacing, ventriculo-atrial conduction was abolished and anterograde refractory period became prolonged, which was considered a valid end-point. This patient was asymptomatic in the long-term follow-up, without ventricular preexcitation at the ECG.

Limitations
This series included patients since 2001, and no irrigated tip catheters were available in the early cases of this series. One could argue that if this technology were available, it could have precluded the need for an epicardial approach in some patients, particularly those in close proximity with the coronary venous system.

Conclusions
Epicardial ablation through percutaneous subxiphoid access was successful in a minority of patients in whom this approach was attempted. A new attempt of endocardial mapping and transvenous approach is highly advisable after a failed percutaneous epicardial approach. A subset of patients may require open-chest surgery. Pericardial instrumentation was safe in this series of patients. Anatomy evaluation conducted prior to the procedure, use of a steerable sheath, and irrigated-tip catheters may improve patient selection and ablation results.

Conflict of Interest Disclosures: None
References:


**Table 1:** Clinical characteristics of 21 patients with WPW refractory to multiple attempts at ablation

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Abbreviation: RFCA= Radiofrequency catheter ablation, APP= Accessory pathway potential, CA= cardiac arrest, EAM= electroanatomical mapping, EPICARDIAL= Epicardial, ERP= Effective refractory period, VA= Ventriculo-atrial.
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<td>3</td>
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<td>CS distal</td>
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<td>Yes</td>
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<td>CS distal</td>
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<td>Yes</td>
<td>Yes</td>
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<td>Endocardial</td>
<td>No</td>
<td>Yes</td>
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<td>7</td>
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<td>EPICARDIAL/Fem CS diverticulum</td>
<td>MCV &lt; EPICARDIAL</td>
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<td>MCV</td>
<td>No</td>
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<td>ENDOCARDIAL &lt; EPICARDIAL</td>
<td>Endocardial</td>
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<td>Yes</td>
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Abbreviations: CS= Coronary sinus, EPICARDIAL= Epicardium, Fem= Femoral, Jug= Jugular, LAL= Left anterolateral, LAS= Left anteroseptal, LFW= Left free-wall, LPS= Left posteroseptal, MCV= Middle cardiac vein, RAS= Right anteroseptal, RL=Right lateral, RP= Right posterior, RPS= Right posteroseptal, RTA= retrograde transotic access, RV= Right ventricle, TS= transeptal
Figure Legends:

Figure 1: Flowchart of the management and outcomes of catheter ablation in 21 WPW patients who underwent Endocardial/Epicardial mapping and/or ablation. Abbreviations: EPI < ENDO: epicardial activation mapping earlier than endocardial, ENDO < EPI: endocardial activation mapping earlier than epicardial, EPI=ENDO: isochronic endocardial and epicardial activation mapping.

Figure 2: (A) Case 10 – Left panel shows a CT lateral view of the heart. The yellow line represents the course of the ablation catheter in the pericardial space, from its entrance (anterior approach) until the earliest ventricular activation site at the postero-septal region. Middle panel shows fluoroscopic image in LAO view during right coronary artery angiography. Note the close relationship between the ablation catheter (RF EPI) and the posterior descending branch (PDA). Right panel shows fluoroscopic image in RAO view during levo-phase visualization of the middle cardiac vein (white arrowheads). The ablation catheter tip (RF) is in close contact with the middle cardiac vein (MCV). The hatched yellow line depicts the level of the annulus. The ablation catheter tip is sitting 1.5 cm below the annulus. (B) Accessory pathway was ablated within 4 seconds of radiofrequency current delivery through the open irrigated-tip ablation catheter (black star). MCV: middle cardiac vein, CS os: coronary sinus ostium, EPI: Epicardium.

Figure 3: Case 11 – (A) Fluoroscopic image A (LAO 45°) shows an ablation catheter in the left septal annulus (MA) through a steerable sheath (Agilis®) introduced from transeptal puncture, a second ablation catheter inside the middle cardiac vein (MCV), and a decapolar inside the
coronary sinus (CS). (B) Fluoroscopic image B shows an ablation catheter inside the middle cardiac vein, a decapolar catheter inside the coronary sinus and another ablation catheter introduced though a pericardial steerable Agilis® sheath. The ablation catheter inside the pericardium is located in close relation with the middle cardiac vein. Electrograms recorded from the epicardium show an accessory pathway potential (APP) and a negative unipolar signal steeper than the one recorded from within the middle cardiac vein. (C) Fluoroscopic image C depicts the close relationship between the posterior descending artery (PD) and the middle cardiac vein (star). (D) Ablation of the AP within 5 seconds of radiofrequency application with an irrigated-tip catheter (40 watts, 30 ml/min of saline infusion). A negative T wave in inferior leads (cardiac memory) emerged immediately (next day serum troponin rose up to 1.3 – normal < 1). PERI: pericardium.

**Figure 4**: Case 3 – Upper left panel shows activation mapping with earliest activation inside a posterior coronary sinus branch. Radiofrequency current could not be delivered due to local high impedance (400 ohms). Upper right panel shows fluoroscopy image of the contrasted vein (arrow). Lower left panel shows activation mapping from the epicardium (earlier than the one at the posterior vein with an AP potential-arrow). Ablation was successfully accomplished from this site. Lower right panel depicts the fluoroscopic image of the ablation catheter inside the posterior vein (thin arrow) and the other in the epicardium (thick arrow). EPI: Epicardium, HRA: high lateral right atrium.

**Figure 5**: Case 16 – Left panel shows 12-lead ECG during pre-excited atrial fibrillation. Middle panel depicts during levo-phase of left ventriculography of the coronary sinus diverticulum. Note
the absence of coronary sinus communication with the right atrium. Right panel shows during activation mapping at the epicardium: despite a continuous fractionated activity (arrow) from atrial to ventricular electrograms, epicardial ablation failed.

**Figure 6:** Case 16 – Left panel (A thru D) shows details from excision of the coronary sinus diverticulum and reconstruction of the coronary sinus course and mouth. Right panel shows ECG leads before and after surgical ablation.
21 pts WPW refractory to 1.9±1 RF sessions

EPI/ENDO SESSION

ACTIVATION MAPPING RESULTS

EPI < ENDO
N=6
- EPI ABLATION
  N=6
  SUCCESS
  N=6

EPI = ENDO
N=3
- EPI-GUIDED ENDO ABLATION
  N=3
  SUCCESS
  N=2
  FAILURE
  N=1

ENDO < EPI
N=9
- MCV
  N=3
  SUCCESS
  N=5
  FAILURE
  N=4

- CS
  N=2

- ENDO
  N=4
  FAILURE
  N=4

NO EARLY SIGNALS
N=3

OPEN-CHEST SURGERY
N=4
LAO – Levo Phase

Coronary sinus

Diverticulum

Case # 16
Accessory Atrioventricular Pathways Refractory to Catheter Ablation: The Role of Percutaneous Epicardial Approach

Maurício Ibrahim Scanavacca, Eduardo Back Sternick, Cristiano Pisani, Sissy Lara, Carina Hardy, André d'Ávila, Frederico Soares Correa, Francisco Darrieux, Denise Hachul, Miguel Barbero Marcial and Eduardo A. Sosa

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Supplemental Material

FIGURE 1 Supplemental Material: Case 2 – ECG before and after successful epicardial ablation in a patient with left posterior AP.