ATRIAL FIBRILLATION

RESEARCH ARTICLE

Pulmonary Vein Isolation: Making the Most of Local Vein Capture with Exit Block

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ABSTRACT. Demonstration of pulmonary vein exit block is a critical endpoint of pulmonary vein (PV) isolation. Local pulmonary vein capture with exit block to the left atrium supports achieving such an endpoint. We sought to describe the frequency of such phenomena and the generalizability of a single local vein capture with exit block to whole vein exit block. We reviewed the charts and intracardiac electrograms of 23 consecutive patients who underwent circumferential antral PV isolation at Montefiore Medical Center over a 4-month period. PV signals were recorded using a circular mapping catheter (CMC). Following ablation, electrogram recordings were analyzed for evidence of PV entrance and exit block. We determined the first time local vein capture was demonstrated with exit block and compared it to the first demonstration of whole PV exit block. Intracardiac electrograms for 23 patients were examined for a total of 88 PVs. The mean patient age was 60.3 years, 65% were paroxysmal atrial fibrillation (AF). Local vein capture with exit block was seen in 66% of PVs. Local vein capture, noted on a single CMC electrode pair with exit block predicted whole vein exit block (PPV = 100%). Local vein capture with exit block also reliably distinguished non-PV potentials from PV potentials. Local pulmonary vein capture with exit block is demonstrable in the majority of pulmonary veins. Local vein capture recorded from a single pair of CMC electrodes reliably signifies complete PV electrical isolation.

KEYWORDS. atrial fibrillation, catheter ablation, pulmonary vein isolation

Introduction

Our understanding of atrial fibrillation (AF) and our techniques for catheter-based ablation of AF have rapidly advanced over the past 10 years. The majority of triggers producing paroxysmal AF originate in and around the pulmonary veins (PVs).\textsuperscript{1} Durable PV electrical isolation remains the basis for successful ablation of AF. Using either segmental ostial or wide antral circumferential ablation techniques, acute procedural success is easily determined by demonstrating bidirectional conduction block between the PVs and the left atrium.\textsuperscript{2-4} AF recurrence rates due to PV reconnection occur in a significant proportion of patients, and several investigators have reported techniques that may help to ensure durable PV isolation.\textsuperscript{5-7} Regardless of the technique used to ensure durable lesions, demonstration of PV entrance and exit block remains a critical endpoint for AF ablation procedures.

Demonstration of bidirectional conduction block between the left atrium and the PV is demonstrated by placement of a circular mapping catheter (CMC) into the PV. During normal sinus rhythm or atrial pacing, entrance block into the PV is typically demonstrated by the absence of PV potential recordings on one or more CMC electrodes. Entrance block is demonstrated by the presence of PV potential recordings on all or more electrodes of the CMC. Exit block is demonstrated by pacing from the PV and recording PV potential block on the CMC. PV entrance block, PV exit block, and PV electrical isolation are well established endpoints for AF ablation procedures. In the absence of PV entrance block, PV isolation may be incomplete. In the presence of PV entrance block, PV reconnection is likely. Therefore, demonstration of PV entrance block is a critical endpoint for AF ablation procedures. Demonstration of PV exit block is also a critical endpoint for AF ablation procedures. Demonstration of PV exit block is typically achieved by pacing adjacent to the PV. PV exit block is typically demonstrated by recording PV potential block on the CMC. Demonstration of PV exit block is typically achieved by pacing adjacent to the PV. Demonstration of PV exit block is typically achieved by pacing adjacent to the PV.
define PVEB as a failure to capture the left atrium by pacing circumferentially from each of the bipolar electrode pairs of the CMC positioned at the entrance of or in the PV. Pacing around the circumference of the vein with resultant lack of left atrial capture from each paced location increases the likelihood that the PV is indeed electrically isolated from the left atrium. However, PVs are of varying sizes and morphologies. Although efforts are taken to fully expand the CMC prior to pacing, contact between the electrodes and the PV is often poor. This is not surprising as most PVs are oval in shape. Although local PV capture (LPVC) is not mentioned as a requisite in most literature, LPVC during pacing with resultant exit block into the left atrium has been described as favorable and supportive of exit block. Conventionally, operators pace all CMC bipoles to demonstrate exit block around the circumference of the vein. Several investigators have written about the importance of LPVC with PVEB to the left atrium.\textsuperscript{8,9} However, to our knowledge no study has demonstrated whether recording LPVC from a single CMC electrode pair is sufficient to confirm PVEB. Theoretically, spatially discrete muscle fibers connecting the PV and left atrium may allow for LPVC with exit block in one area of the PV while other areas may still be connected to the left atrium.\textsuperscript{10} We are not aware of any clinical studies characterizing the frequency in which LPVC is demonstrated following PV electrical isolation, nor the generalizability of LPVC with PVEB. Common causes of false-positive PVEB include poor CMC electrode contact due to large PVs or positioning of the CMC deep within the PV beyond the extensions of myocardial muscle sleeves. In order to avoid false-positive PVEB, operators in our laboratory spend a great deal of time positioning the CMC such that its electrodes oppose the walls of the PV and pace from all 10 CMC electrode pairs. This process is time consuming. Pacing a single electrode pair where LPVC is evident saves time and may be employed to demonstrate PVEB.

\textbf{Figure 1:} Local Vein Capture at 100 mm/s, 400 mm/s, and 800 mm/s sweep speeds. Local vein capture during pacing from the PV can be subtle and appear as discrete sharp deflections very close to the stimulus artifact.
We hypothesized that LPVC recorded on at least one set of CMC electrode pairs is necessary and sufficient for demonstrating PVEB. Demonstration of exit block with LPVC at a single site would reduce unnecessary pacing and provide a more rapid end point when determining PVEB in several scenarios including adenosine injection, differentiation of far field atrial capture and when the CMC cannot be introduced into the PV.

Methods

We retrospectively reviewed the charts and intracardiac electrograms of consecutive patients who underwent catheter-based AF ablation at the Montefiore Medical Center from January 1, 2011, to June 15, 2011. The following parameters were collected for each patient: age, gender, left atrial diameter, left ventricular ejection fraction (LVEF), chronicity of AF. All patients underwent circumferential antral PV ablation utilizing a 3.5-mm irrigated tip catheter. A deflectable 20-pole circumferential catheter with distal ring configuration ( Biosense Webster, Diamond Bar, CA) was placed in the ostium of each PV, guided by fluoroscopy and intracardiac echocardiography. Mapping and ablation was performed using a three-dimensional mapping system (CARTO, Biosense Webster, Diamond Bar, CA or EnSiteNavX St. Jude, St. Paul, MN). Catheter ablation was performed utilizing the above catheters and a deflectable decapolar catheter positioned in the coronary sinus. A single transeptal puncture was performed with intracardiac echocardiography guidance utilizing a medium curl Agilis NxT steerable sheath (St. Jude) and a SafeSept wire (Pressure Products, San Pedro, CA). A 3-mm guidewire was advanced to the left atrium to retain access and the Agilis NxT sheath was withdrawn to the right atrium. A second long sheath (Preface, Biosense-Webster) was advanced to the left atrium through the same puncture point. Following transeptal puncture, a bolus of 50 IU/kg of heparin was administered.

Figure 2: Local vein capture with exit block to identify far-field LAA. In Panel A, pacing from PV 13,14 results in local vein capture (seen in PV 9,10 and PV 19,20; arrows) with exit block. The signals seen on PV 9,10 through PV 17,18 (arrowhead) and the rest of the left atrium are dissociated from the pacing. Panel B demonstrates pacing from the probe (located in the LAA) pulls in the LAA signals. This confirms that the electrograms seen on PV 9,10 through PV 17,18 are far-field LAA signals.
and a goal ACT of 350–400 s was maintained throughout the procedure. Mapping of the left atrial and PV geometry was performed with a circumferential catheter and the ablation catheter. Wide antral circumferential ablation was performed around the left and right PVs. Radiofrequency ablation was performed with a power of up to 25 W on the posterior wall and 35 W anteriorly. PV isolation was performed with the endpoint of abolition or dissociation of all activity in all PVs.

Electrogram recordings made on a Prucka CardioLab electrophysiologic recording system (GE Medical Systems, Houston, TX) were analyzed at 100 mm/s and 400–800 mm/s sweep speeds for demonstration of PV entrance and exit block. The presence of entrance block was determined when PV signals could not distinctly be identified on all bipolar electrograms. Exit block was defined as the inability to capture the left atrium from each of the bipoles of the CMC at maximum pacing output (20 mA, 2 ms pulse width). The presence of local vein capture with exit block for each PV was collected. We determined the first time of demonstrated local vein capture with exit block and compared it with the time of first demonstration of whole PV exit block performed by pacing around all bipoles of the CMC in each PV.

Results

Intracardiac electrograms for 23 patients were examined for a total of 88 PVs. The mean patient age was 60.3 years and 17 out of 23 (52%) were male. The majority (65%) of the patients had paroxysmal AF. Mean left atrial diameter was 3.9 cm and the mean LVEF was 57.6%. Local vein capture with exit block was seen in 58 of 88 PVs (66%). Local vein capture signals were often subtle and frequently buried within the tail of the stimulus artifact or seen in a few bipoles of the CMC (Figure 1). Local vein capture with exit block always predicted complete PVEB as demonstrated by pacing all CMC electrodes. LPVC with PVEB predicted whole vein exit block with 100% PPV. In veins where LPVC with PVEB was achieved, the median and mean number of bipoles where LPVC was noted were four and five respectively. Spontaneous dissociated PV potentials were seen in 24 of 88 PVs (27%).

Far-field superior vena cava or left atrial appendage (LAA) signals were occasionally noted on CMC recordings. Three of the 23 patients demonstrated far field SVC signals when mapping the RSPV. Four of the 23 patients demonstrated far-field LAA signals when mapping the LSPV (Figure 2). In one case, local vein capture with exit block and dissociation of SVC potential from the PV pacing required reduction in the pacing amplitude to eliminate far-field capture (Figures 3–5).

Discussion

We have demonstrated that LPVC recorded on at least one set of CMC electrode pairs is sufficient to
Figure 4: Far-field capture of SVC. Pacing at 20 mA from T7 at the RSPV results in 1:1 capture of the left atrium.

Figure 5: Local vein capture with exit block of RSPV. Lowering of the pacing output from 20mA to 7mA at T7 in the RSPV resulted in loss of far-field SVC capture and demonstration of local vein capture (visible in T3 and T4; arrow) with exit block.
demonstrate PV exit block. When LPVC is identified the possibility of false-positive exit block can be eliminated. More importantly, LPVC noted on just one pair of electrodes predicted complete PVEB, eliminating the need to pace all CMC electrode pairs. These findings allow an operator to determine PVEB in situations where the entire CMC is unable to be placed into the PV. In such cases assessment of exit block may be performed using either a small section of the CMC or even the proximal poles of the ablation catheter (Figure 6).

In our study the majority of veins (66%) demonstrated LPVC with PVEB; however, identification of LPVC was easiest at higher sweep speeds. Often, local vein potentials are seen within the pacing artifact and are likely missed at sweep speeds of 100 mm/s. Although it may be easier to visualize dissociation between PV pacing and the left atrium at slower sweep speeds, recognition of local vein capture with exit block is easier at higher sweep speeds of >200 mm/s (Figure 1).

The use of adenosine to uncover dormant PV conduction highlights the importance of LPVC. Identification of CMC electrodes that allow for LPVC during adenosine infusion can be critical for uncovering dormant exit conduction to the left atrium. Several investigators have reported unidirectional conduction block between the left atrium and PVs. Following adenosine injection, there may be a limited time period for determining bidirectional PV conduction block. Confirming LPVC with PVEB during adenosine injection eliminates the possibility of dormant exit conduction.

Far-field signals from the SVC or LAA may be seen on the CMC in the RSPV and the LSPV respectively. Entrance and exit block is frequently questioned when such signals are present. Pacing maneuvers such as differential pacing or perivenous pacing may be performed to distinguish far-field signals from evidence that more ablation is required. Far-field SVC or LAA signals were also able to be distinguished from local vein potentials by the demonstration of local vein capture with exit block and the resulting dissociation of the SVC or LAA signal (Figure 2). Once local vein capture with exit block is achieved, the dissociated signal can

Figure 6: Use of the ablation catheter in demonstrating local vein capture with exit block. In panel A, pacing from the distal poles resulted in local vein capture (arrow) which is seen on the proximal pole. Exit block to the left atrium is apparent in the CS catheter and lasso catheter which are both located in the LA. In panel B, a dissociated potential is seen on the probe distal and proximal.
automatically be assumed to be a non-PV signal. Since far-field capture is possible, one may need to reduce the pacing output to achieve local capture only. Once the far-field capture is eliminated, exit block can be recognized. An alternative to avoid far-field capture is to achieve local vein capture with exit block in a part of the PV that is further away from the SVC or the LAA. The merits of using local vein capture with exit block to identify far-field signals is the lack of need for a catheter in the SVC or the LAA and the fact that it can be recognized immediately while assessing for PV exit block without any other special pacing maneuvers.

**Conclusion**

Local PV capture with exit block is not a new electrophysiological concept, but it may be under-recognized as evidence of local PV capture is frequently buried close to the pacing artifact. In fact, local PV capture with exit block was noted during pacing in the majority of isolated veins. When demonstrated, it reliably signifies that the whole vein is clinically isolated and distinguishes far-field non-PV signals from PV signals.

**References**