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Endocavitary Structures in the Outflow Tract: Anatomy and Electrophysiology of the Conus Papillary Muscles

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Abstract

Catheter ablation is an increasingly used and successful treatment choice for right ventricular outflow tract (RVOT) arrhythmias. While the role of endocavitary structures and the regional morphology of the ventricular inflow tract and the right atrium as a cause for difficulty with successful ablation are well described, similar issues within the RVOT are not well understood. It is also not commonly appreciated that one of the papillary muscles is located within the proximal right ventricular outflow tract. We report 3 patients in which ventricular arrhythmia was targeted and ablated in the conus papillary muscle. The anatomic features, potential role of the fascicular conduction system, and unique challenges with mapping arrhythmia arising from this structure are discussed.

Keywords

Lancisi bundle; Purkinje fiber; premature ventricular complex; right ventricular outflow tract; ventricular tachycardia; conus papillary muscle; endocavitary structures; ventricular fibrillation

Introduction

Right ventricular outflow tract (RVOT) arrhythmia is the most common ventricular arrhythmia arising in structurally normal hearts.^{1, 2} Catheter ablation is an increasingly used and successful treatment choice for patients with RVOT arrhythmia and drug-refractory symptoms. Procedural failure, however, occurs in up to 25% to 30% of attempted ablations.^{3, 4}

Several predictors for ablation failure have been identified, including difficulty with initiating arrhythmia, origin of arrhythmia at or above the semi-lunar valves, and discrete myocardial sleeves within the great arteries.⁵⁻⁹

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While the role of endocavitary structures (papillary muscles, moderator band, and pectinate-like trabeculations) causing difficulty with ablation in the right ventricular inflow portions have been well described,^{10, 11} their role has not been well appreciated for right ventricular outflow tract ablation.

Specific difficulty with mapping and ablating papillary muscles of the inflow tract caused by variable exit, catheter stability, and related conduction tissue is known.¹⁰ While the potential arrhythmogenic target related to papillary muscles in the right ventricle has been reported,¹² technical and mapping problems presented by the conus papillary muscle (CPM), given its origin in the outflow tract and adjacent parahisian conduction tissue, are unknown.

In this manuscript, we report 3 patients where ventricular arrhythmia was eliminated by visualizing, mapping, and targeting the conus papillary muscle. We describe the regional anatomy, the utility of intracardiac echocardiography (ICE),¹³ and the unique electrograms and exit sites mapped on this structure.

Case 1

A 47-year-old female with symptomatic premature ventricular complexes (PVCs) was referred for ablation. Her symptoms were refractory to medical therapy, and two prior attempts at PVC ablation were unsuccessful. Holter monitor showed brief runs of nonsustained, polymorphic ventricular tachycardia (VT), triggered by frequent PVCs of two principal morphologies. At EP study, frequent PVCs of the two morphologies noted previously on Holter were repeatedly observed (Figure 1). Both PVCs had an identical coupling interval and showed a left bundle branch block inferior axis pattern. AVL was isoelectric in one PVC morphology, while positive in the second PVC.

During point-to-point mapping, the earliest electrograms for both PVCs were close to each other and were located in the posteromedial proximal RVOT (Figure 2). The local electrogram was 35 ms ahead of both QRS morphologies. With further mapping, a pre-potential suggestive of a fascicular signal was noted between these two breakout sites, and pacing at low output reproduced both principal PVC morphologies (Figure 2). Fluoroscopy (Figure 3) and ICE imaging (Figure 4) showed that the mapping catheter was positioned on the mid-portion of the conus papillary muscle. Radiofrequency energy delivery in this region simultaneously eliminated both PVCs with runs of polymorphic VT seen during ablation. There was no evidence of recurrence at 6 months follow-up.

Case 2

A 63-year-old with prior history of non-ST elevation myocardial infarction from coronary vasospasm was referred for ablation of medically refractory and highly symptomatic PVCs. A 48-hour Holter monitor showed 33,000 PVCs and brief 6- to 8-beat runs of VT. At EP study, two PVCs were noted (Supplemental figure 1). Mapping of the first PVC found earliest activation just above the septal parietal trabeculation. The earliest site of activation for the second PVC was at the posteromedial wall of the proximal RVOT where a sharp Purkinje potential was seen ahead of the local ventricular electrogram. ICE imaging confirmed that the ablation catheter was located on the conus papillary muscle. Ablation at

this site successfully eliminated the PVCs with no recurrence or symptoms at approximately one-year follow-up.

Case 3

A 25-year-old female with refractory symptomatic ventricular arrhythmia that included PVCs and short runs of polymorphic VT was referred for ablation. Several PVCs were noted, including one that was successfully targeted and ablated in the vicinity of the pulmonic valve. One of the PVCs had earliest activation on the posterior proximal RVOT and was at the base of the conus papillary muscle visualized with ICE (Supplemental Figure 2). Ablation at this site eliminated this PVC, with runs of polymorphic VT during ablation

Discussion

We report 3 patients that required mapping and ablation on the conus papillary muscle to eliminate ventricular arrhythmia.

Regional anatomy and clinical relevance

Papillary muscles occur at multiple and variable sites in the right and left ventricular inflow chambers.^{14, 15} In the right ventricle, one of the septal papillary muscles arises from the outflow tract.¹⁶⁻¹⁹ This muscle has been referred to as a Lancisi muscle or bundle with clinicians referring to it as the conus papillary muscle in conjunction with the tendinous chord at the medial papillary muscle complex.^{16, 18, 19} Autopsy studies have demonstrated the presence of the CPM in 82% of human hearts,²⁰ and when present is found at the base of the subpulmonary infundibulum adjacent to the distal bundle of His as it penetrates the membranous septum and proximal right bundle branch (Figure 5). In many cases, the belly of the CPM lies at the posterior extremity of the septal marginal trabeculation, while in others it arises near its root. More anterolaterally, discrete trabeculation without attached chordae may be found.

The endocavitary structures (CPMs, prominent trabeculations) may cause difficulty with mapping and ablation. While the supra-valvar myocardial sleeves are a recognized cause of difficulty, and techniques for imaging and mapping have been developed, similar site-specific mapping and assessment of contact when ablation may be of value in such cases.

Electrocardiographic and electrogram characteristics

In our patients, variable morphologies of at least two distinct varieties were noted clinically. As has been described with papillary muscle VT in the left ventricle,¹⁰ this phenomenon may represent varying exit at the base of the papillary muscle. An important clue when mapping these arrhythmias in our patients was the finding of approximately equally early electrogram sites at the base of the RVOT crux at disparate locations. This suggested a site between these locations which was eventually found and determined with concurrent ICE imaging to be the CPM.

The local electrograms in these patients show the presence of a fascicle-like signal that preceded ventricular activation. The proximity of the His and right bundle to the CPM

suggests that some terminal branches from the right bundle lies in close relationship to the CPM similar to what has been described with the left ventricular papillary muscles and the moderator band.¹⁰ This possible Purkinje fiber origin may also explain polymorphic ventricular arrhythmia that was observed in some instances with these patients.^{21, 22} Recently, a malignant form of ventricular arrhythmia in patients with bileaflet mitral valve prolapse has been described.²³ Interestingly in these patients, in addition to site of origin for the arrhythmia-inciting PVCs in the LV papillary muscle, a second morphology arising from the right ventricular outflow tract was noted. Whether or not this activity represents fascicular origin in the PCM needs further evaluation. As with papillary muscle mapping and ablation elsewhere, ICE imaging may be critical to identify this structure and monitor ablation. Tricuspid valve function can be simultaneously followed during energy delivery with the ICE probe placed within the inflow portion of the right ventricle and imaging done of the RVOT and tricuspid valve looking above from this distal location.^{13, 24}

Summary

The CPM may represent the site of origin for ventricular arrhythmia and be the cause for difficulty with ablation of patients with RVOT VT. Simultaneous early activation sites at more than one location in the proximal RVOT, varying QRS morphologies with similar coupling intervals, and Purkinje-like signals preceding ventricular activation are clues that should lead the invasive electrophysiologist to consider this possibility and use ICE to determine exact catheter locations on the CPM.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Abbreviations

CPM	conus papillary muscle
CIE	intracardiac echocardiography
PVC	premature ventricular complex
RVOT	right ventricular outflow tract
VT	ventricular tachycardia

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Figure 1. PVCs of Patient 1 recorded in the EP laboratory
(Left panel: PVC 1; Right panel: PVC 2)

Figure 2. Activation and pacemapping of PVCs in Case 1

Left panel: Intracardiac electrogram near ablation site shows a pre-potential (marked by red arrow) between the breakout sites of both PVCs, and was 95 ms ahead of the surface QRS.

The ventricular electrogram was 20 ms after the onset of the surface QRS.

Right panel: Pacemapping at the site of ablation with low output capture reproduced both PVC morphologies.

Figure 3. Ablation catheter at the ablation site in Case 1
(Left: LAO view; Right: RAO view)

Figure 4. Conus Papillary Muscle was the site of PVC ablation

Left panel is an illustration showing correlative structures seen on the ICE image (right panel). The body of the conus papillary muscle is marked with an asterisk in both images. The body of the conus papillary muscle is seen with an attached tendinous chord (marked by arrow) that is part of the tricuspid valve (TV).

Figure 5. Conus papillary muscle location and related anatomical structures

Panel A. Gross anatomical dissection showing anatomical structure of the conus papillary muscle and its inter-relationships with the surrounding structures.

Panel B. Illustration of gross specimen from Panel A showing structures related to the conus papillary muscle (noted with an *). Notice the belly of the muscle situated in between the anterolateral and posterolateral aspects of the septomarginal trabeculation, along with its tendinous chordal connection to the tricuspid valve.