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Combined Ethanol and Radiofrequency Ablation for the Elimination of Focal Atrial Tachycardia Originating from the Marshall Bundle

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Patient Consent:
I confirm that written informed consent has been obtained from the patient included in this case report for the publication of their information and any accompanying images. A copy of the written consent is readily available for review by the Editor-in-Chief of this journal upon request.

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HIGHLIGHTS

1. The presented case involves a 29-year-old male with recurrent atrial tachycardia (AT) originating from the Marshall bundle (MB), a rare and challenging localization for focal AT. Often diagnostic evaluation is challenging thus comprehensive mapping and special tools are necessary to reveal the location and tachycardia mechanism.

2. Detailed electrophysiological studies (EPS) and mapping were crucial in identifying the tachycardia focus. Comprehensive mapping revealed automatic atrial tachycardia presumably originating from the epicardial focus on the LA posterior wall. The earliest activation was recorded at the Vein of Marshall (VoM) ostium within the CS.

3. The treatment involved a combination of ethanol ablation and targeted radiofrequency ablation (RFA). This dual approach effectively completely eliminated AT in two sequential steps first targeting the entire course of VoM with ethanol infusions, then followed by limited RFA within CS guided anatomically by VoM ostium location and electrically by activation mapping.

4. In instances where mapping of focal atrial tachycardias yields suboptimal results, acknowledging their possible epicardial origin is crucial for successful intervention. Ethanol infusion into the ballon-occluded VoM demonstrates efficacy in challenging cases, especially those associated with MB-related AT.

5. Comprehensive VoM ethanol ablation offers sustained results and helps prevent recurrences. While additional RFA can improve the results of VoM ethanol infusion, careful consideration is required when planning RFA, as it may result in the closure of the VoM, thereby complicating future identification and access to this delicate structure.

6. This case is unique as it presents a highly probable VoM origin of automatic AT with no concomitant AF. The VoM represents a potential source of refractory AT due to its unique anatomical and electrophysiological properties. This case emphasizes the importance of recognizing the VoM as a critical target in refractory AT. The combined ablation strategy provides a valuable approach for treating similar cases, highlighting the need for comprehensive mapping and tailored stepwise ablation.

ABSTRACT

Introduction and Importance

Atrial tachycardias (AT) originating from the Marshall bundle (MB) are rare and present significant challenges in diagnosis and management. We present the case of a 29-year-old male with recurrent AT successfully treated with a combined ethanol and radiofrequency ablation approach. This case highlights the effectiveness of this dual ablation strategy in resolving AT originating from the MB, contributing valuable insights into managing complex AT cases.

Case Presentation

A 29-year-old male with recurrent, symptomatic palpitations was initially suspected of orthodromic atrioventricular reentrant tachycardia, but an initial electrophysiological study (EPS) failed to induce arrhythmia. Subsequent spontaneous episodes led to a detailed EPS, revealing automatic AT originating presumably from an epicardial focus on the posterior wall of the left atrium (LA). Detailed mapping identified the earliest activation at the vein of Marshall (VoM) ostium within the coronary sinus (CS). Suspecting the involvement of MB structures, VoM ethanol ablation was performed. Complete arrhythmia elimination was achieved with radiofrequency ablation (RFA) at the VoM ostium within the CS, with no recurrence.

Discussion

Most cases in the literature are associated with atrial fibrillation (AF) or AT within AF, typically involving reentry mechanisms. The given case is unique as it presents a highly probable VoM origin of automatic AT with no concomitant AF. The VoM's anatomical and electrophysiological properties make it a potential source of refractory AT. In this case, ethanol ablation supplemented by targeted, limited RFA emerged as an effective strategy, highlighting the importance of comprehensive mapping and tailored ablation approaches in managing complex atrial arrhythmias.

Conclusion

The potential implications for clinical practice include recognizing the VoM as a critical target in refractory AT cases and adopting a combined ablation strategy to improve patient outcomes in similarly challenging scenarios.

KEYWORDS

Coronary sinus, Marshall bundle, Vein of Marshall, Focal atrial tachycardia, Radiofrequency catheter ablation, Ethanol ablation

ABBREVIATIONS

AT - atrial tachycardia

AF- atrial fibrillation

CA - catheter ablation

CS - coronary sinus

ECG – electrocardiogram

EPS - electrophysiological study

LA - left atrium

MB - Marshall bundle

RA - right atrium

RFA – radiofrequency ablation

VoM – vein of Marshall

INTRODUCTION

Focal ATs, beyond a clear connection with AF, constitute approximately 15% of all supraventricular tachycardias and most commonly occur in young individuals without obvious cardiac pathology [1]. Overall, 75% of them are generated from the RA, and 25% of the foci can be found in the LA. More than 70% of these arrhythmias are progressive and can lead to the development of arrhythmogenic cardiomyopathy. Often, ATs are poorly managed with antiarrhythmic drugs. In contrast, elimination by RFA is usually highly effective and has dramatically improved long-term results [2]. Advances in electroanatomical mapping allow accurate localization of ectopic foci with targeted treatment delivery [3, 4]. Unfortunately, RFA may be ineffective in 5-24% of patients, particularly after heart surgery, previous ablations, or the presence of atypical focus localization, including MB [5].

MB is a rare localization of focal AT, with only a few clinical cases described in the literature [6, 7]. MB is a rudimentary fold of the pericardium that contains muscle fibers with multiple insertions into the posterolateral wall of the LA and the CS, forming a substrate for reentry circuits, small blood vessels, and sympathetic and parasympathetic nervous fibers embedded in fat. MB includes VoM, which drains into the CS. VoM is an embryological remnant of the left superior vena cava, which may remain open during fetal development. The VoM drains into the CS and traverses the posterior surface of the LA, ascending obliquely to the LA appendage and laterally to the left pulmonary veins, usually lying in the ridge between two structures, where it can be targeted by RFA [8, 9].

It has been shown that MB can behave as a catecholamine- and cholinergic-sensitive automatic focus, providing a source of rapid firing in the left atrium and can be a source of atrial tachyarrhythmias as well as a trigger for AF and the epicardial part of the re-entry circuit in atypical atrial flutters [7, 10,11]. Despite the possibility of successful ablation by endocardial RFA after careful mapping, the potential for direct elimination with ethanol injections seems more reliable and straightforward [12]. The identifiable VoM is present and can be cannulated and then used for ethanol ablation in 70-90% of the patients [13,14]. Central venous access to

engage the CS and VoM might include the right internal jugular vein, as initially described by Valderrabano M., and the femoral vein, utilized by the majority of other operators [15,16].

CASE PRESENTATION

Patient B., 29 years old, was admitted to the hospital with complaints of frequent, regular palpitations occurring several times a week without any apparent reason. These episodes lasted from a few minutes to 3-5 hours and were accompanied by chest heaviness, shortness of breath, dizziness, and lightheadedness. The episodes began and ended suddenly with no clear effect from the usage of IC, II, and IV antiarrhythmic drugs classes. According to the patient's history, the palpitations had been troubling him for several months.

ECG during arrhythmic episodes recorded regular 1:1 PR tachycardia with a slightly fluctuating RR interval of 320-380 ms, QRS duration of 70 ms, long RP interval of 180 ms, and P waves slightly negative in leads II and III, and isoelectric-biphasic in other leads. The ECG during sinus rhythm was insignificant. The patient underwent further examination. Laboratory tests revealed no pathological changes, and thyroid dysfunction was excluded. Transthoracic echocardiography showed a structurally normal heart. Initially, a concealed decremental accessory pathway with orthodromic atrioventricular reentrant tachycardia was suspected.

After obtaining written consent, the patient underwent standard invasive EPS. Decremental conduction was seen during programmed atrial and ventricular pacing with no preexcitation, conduction gaps, echoes, or other phenomena. During right ventricular stimulation, atrial activation occurred concentrically through the normal conduction system. No arrhythmias were induced during various modes of ventricular and atrial stimulation, including the administration of isoprenaline, atropine, and aminophylline. The initial procedure was finished with no clear result. However, the next day, the patient experienced several spontaneous episodes of sustained tachycardia. The patient was taken back to the lab with recurrent episodes of arrhythmia for further evaluation.

PROCEDURE DETAILS

Puncture of the left subclavian vein and double puncture of the right femoral vein were performed. A 10-pole diagnostic catheter (Celsius CS, Biosense Webster), a 4-pole diagnostic catheter (Celsius, Biosense Webster), and a mapping/ablation catheter (Celsius ThermoCool, Biosense Webster) were placed in the coronary sinus, the His bundle region, and into RA/RV. The procedure was performed using the EnSite Velocity Cardiac Mapping System and the EP-WorkMate Recording System (Abbott). The initial earliest activation was seen in the mid-CS. Ventricular entrainment during tachycardia revealed a V-A-A-V pattern and an ECG of 1:1 PR tachycardia with a variable cycle length of 350-500 ms, indicating a focal atrial mechanism (Figure 1).

The ablation catheter was introduced into the LA via transseptal puncture, and activation mapping of the LA was performed during tachycardia. The earliest endocardial activation was localized to the inferoposterior region of the LA, corresponding to the mid-CS projection. Despite extensive mapping in this area, the earliest point of activation was only 6 ms ahead of the CS reference and was not preceding the onset of the P wave on the external ECG. The early excitation zone was wide, extending superiorly and laterally along the posterior wall (Figure 2).

The next step involved activation mapping of the right atrium (RA) and CS. In the RA, no activation time advancement relative to the reference signal was detected. During CS mapping, the earliest zone was identified in its mid-portion; the activation was 20 ms earlier compared to the CS reference and 11 ms earlier relative to the onset of the P wave on the surface ECG. Considering the mapping data, the possibility of the epicardial origin of the tachycardia focus, possibly connected to the CS orifice, was considered. As the projection of the earliest mapping points was identified on the roof of the middle part of the CS, and keeping in mind the results of LA endocardial mapping, possible VoM involvement in the arrhythmia mechanism was suspected. In this situation, the decision to postpone RFA delivery in the earliest zone was made to avoid inadvertently obliterating the VoM ostium and precluding further ethanol ablation within its orifice. The CS was engaged with an Abbott LV lead delivery sheath from the left subclavian vein, and the anatomy of the CS and its tributaries were revealed by contrast delivery through the sheath, allowing for the identification of VoM. (Figure 3)

It was observed that the early activation zone in the CS exactly corresponds to the ostium of the VoM within the CS. As special mapping tools to selectively map the VoM were not available during the procedure, it was impossible to define the exact location of the arrhythmic foci. Thus, the synthesis of all available diagnostic information guided the decision to adopt VoM ethanol ablation.

Cannulation of the VoM was performed with a short 6 mm OTW balloon preloaded with a soft coronary guidewire and facilitated by an Abbott subselector directed to the CS roof. After that, the wire was withdrawn, and the balloon was inflated up to 3-4 atm. Ethanol deliveries were performed with a total of 6 ml of ethanol, slowly administered in 3 steps (2 ml each) during VoM balloon occlusion for 90 seconds at three levels of the VoM: distally, in the mid-segment, and proximally, with the final injection targeting the most proximal stable balloon location in the VoM ostium (Figure 4).

During each session of ethanol infusion, tachycardia terminated, followed by its resumption within several minutes with a slower rate and slightly different P-wave morphology. When all achievable segments of the VoM orifice were ethanol injected, including the most accessible proximal part, an ablation catheter was inserted into the mid-segments of the CS where the earliest activation signal was recorded. Anatomically by angiography, this was exactly at the ostium of VoM, where several RFAs (30W, 30-45 seconds, irrigation 20 ml/min) were delivered for a total duration of 3 minutes. During the first application, tachycardia ceased immediately upon restoration of stable sinus rhythm, and the arrhythmia did not recur thereafter despite repeated pacing maneuvers and pharmacological challenges(Figure 5).

POSTOPERATIVE PERIOD

The postoperative course was uneventful, and the patient was discharged the day after the procedure. Over the subsequent 2 years of follow-up, which included repeated ECG and Holter monitoring, no atrial arrhythmias were recorded, and remarkably, the patient had no symptoms and did not need any antiarrhythmic medications. This favorable outcome highlights the efficacy and durability of the combined ethanol and radiofrequency ablation strategy in managing atrial tachycardias originating from the MB.

DISCUSSION

A unique aspect of the presented clinical case is the rare localization of the tachycardia focus. In recent years, the VoM has emerged as a new achievable and effective target for ethanol ablation in persistent AF and mitral isthmus-dependent AT [14, 17]. However, cases documenting atrial tachycardia originating from VoM in young individuals without a fibrotic substrate in the LA and no connection with AF are scarce. The absence of conclusive results from activation mapping of both atria in our case prompted consideration of an epicardial focus, particularly within the VoM, as the earliest activation point was recorded in the close correspondence to the VoM ostium. As focal ATs often tend to relapse within neighboring areas, our decision to eliminate the whole route of VoM with combined ethanol and RF ablation seems reasonable. A left subclavian venous puncture might offer the advantage of using regular instrumentation and techniques for CS cannulation, similar to those used in routine resynchronization implants [18]. We admit that the best understanding of the arrhythmia mechanism would have been achieved with special mapping tools for the small vessels (multipolar microcatheter and/or isolated wires), but it would supposedly not change our stepped strategy of entire venous structure ablation, including thorough ethanol ablation followed by locally applied RFA. In our case, combined ablation involving VoM ethanol injection and RFA on the CS roof proved to be effective in resolving this particular AT. As seen in the case of Chin JY et al. [7], closing MB arrhythmia exits distally (in our case with ethanol injections) and finally proximally with RF ablation allowed for arrhythmia elimination with excellent immediate and mid-term results.

CONCLUSION

Effective management of atrial tachycardias originating from VoM involves a strategic approach combining ethanol ablation and RFA. In cases of unsatisfactory results during the mapping of focal ATs, consideration of their potential epicardial localization is essential for achieving effective results. Ethanol infusion into the VoM proves to be effective in complex cases, particularly those involving MB-related ATs. Complete VoM ethanol ablation offers sustained results and helps prevent recurrences. Although RFA can enhance the results of VoM ethanol infusion, caution is necessary when planning RFA as it can lead to VoM closure, hindering future identification and access to this tiny structure. Therefore, it should be planned as the

second step of the ablation procedure. This case highlights the importance of a comprehensive ablation strategy tailored to VoM anatomy and the unique challenges posed by its involvement in atrial arrhythmogenesis.

METHODS

This case report has been reported in accordance with the SCARE 2023 criteria as outlined in the SCARE 2023 guidelines.[19]

PATIENT CONSENT

The patient provided informed consent before the commencement of this case report, allowing their clinical information and any related photos to be published. The patient gave written approval for the use of their information in this case report after being informed of its nature and purpose.

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CONFLICT OF INTEREST

The authors declare no conflict of interest relevant to this article. No financial or non-financial interests have influenced the development of this work.

ETHICAL APPROVAL

This is a case report and does not need ethical approval

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FIGURE 1*: 12-Lead ECG during sustained tachycardia episode*

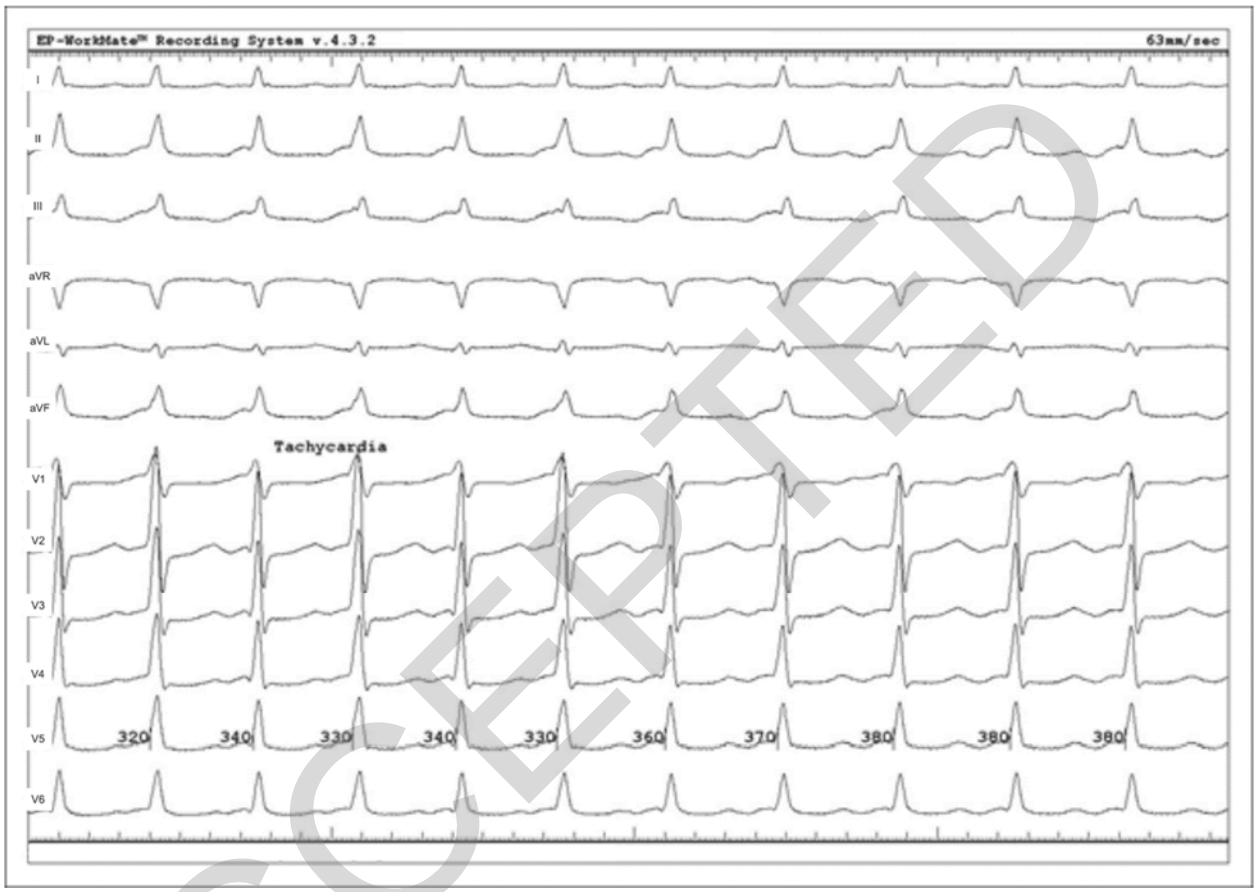

FIGURE 2*: Endocardial electroanatomical LA mapping. The color distribution pattern indicates a focal tachycardia mechanism. The earliest activation zone (white color) is broad, and located in the posterior-inferior aspect of LA (marked with dashed lines). The latest activation zone (purple) is localized in the left upper pulmonary vein.*

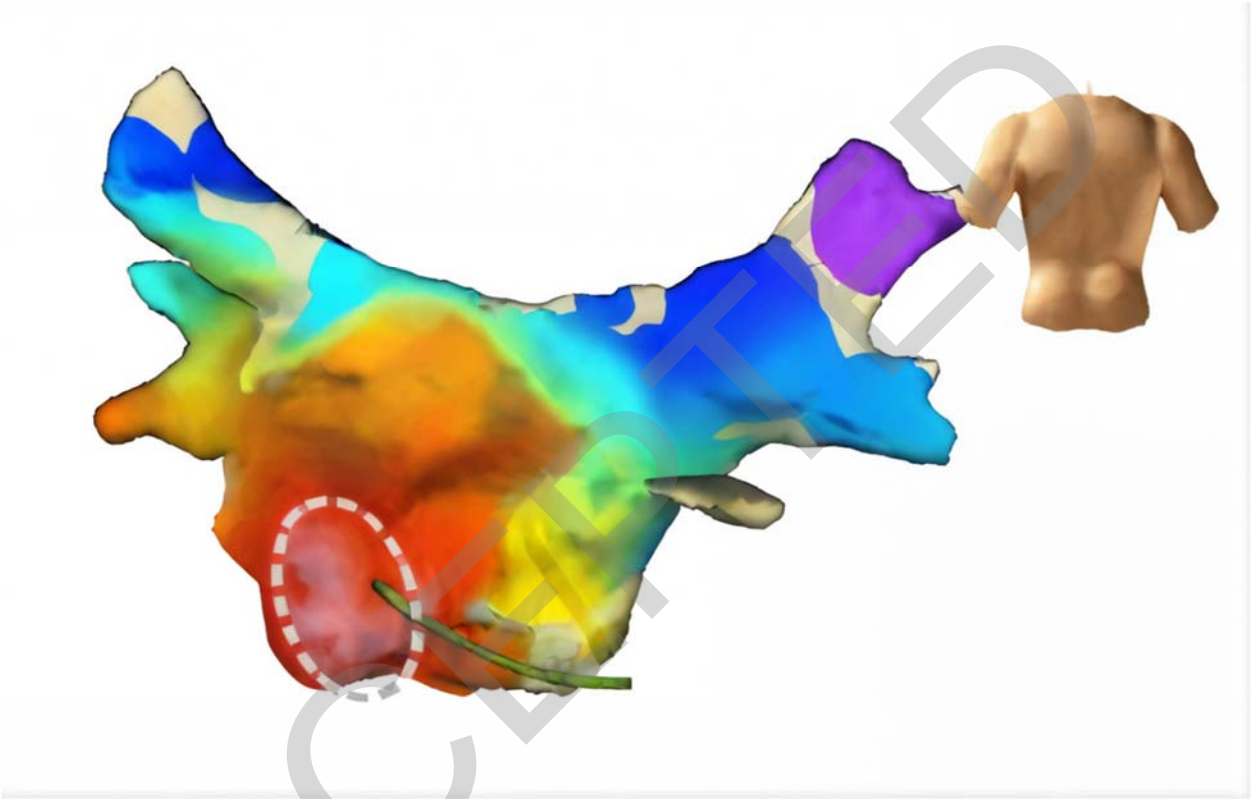

FIGURE 3: *Contrast CS venography with the identification of the Marshall vein (black solid arrows). The ablation catheter (black dashed arrow) is positioned at the site of earliest activation on the CS roof, anatomically corresponding to the ostium of the VoM.*

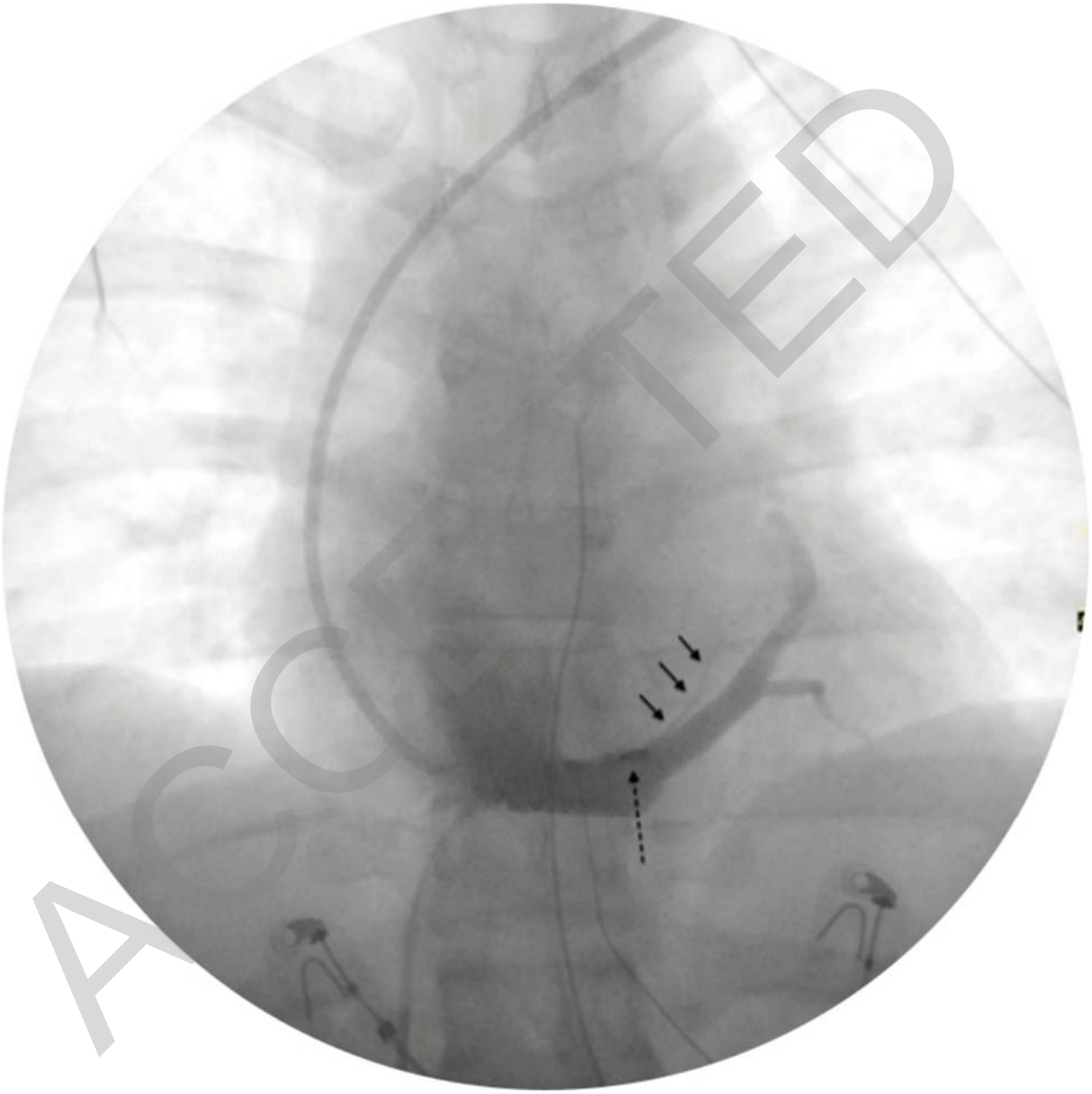

FIGURE 4: *Balloon placement in the middle portion of VoM. Dashed arrows indicate a balloon over the wire (1) inside the VoM, facilitated by subselector use (2) and CS engagement with the delivery system (3).*

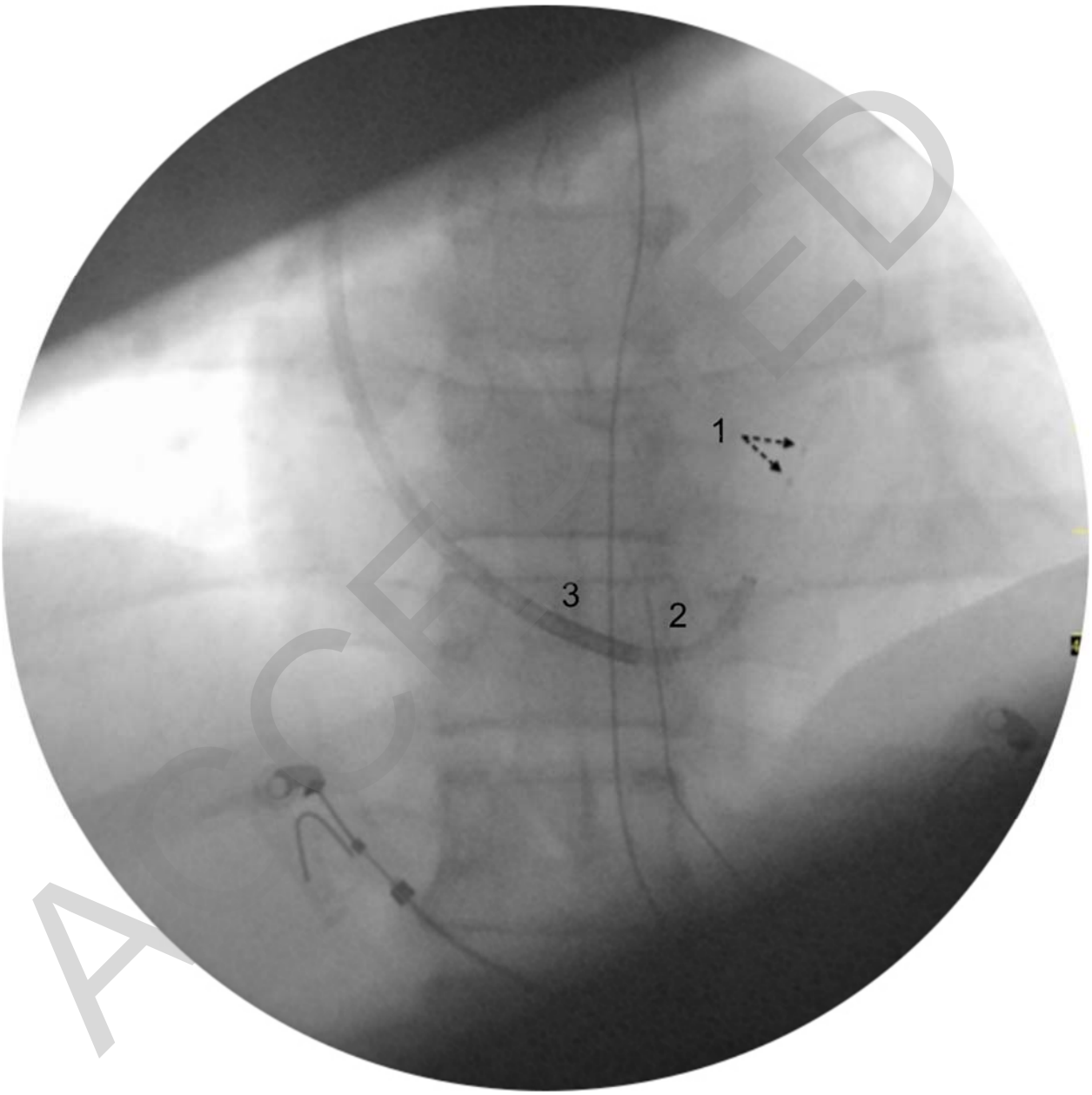

FIGURE 5: *Immediate arrhythmia ceasing and SR restoration after RFA initiation at the VoM ostium. Shown are surface ECG leads I, II, III, V1 (traces 1-4 sequentially), and 5 bipolar CS signals from distal to proximal (CS 1-2, CS 3-4, CS 5-6, CS 7-8, CS 9-10), followed by distal, proximal and unipolar signals from ablation catheter positioned in the CS (Abl d, Abl p, Abl uni). The vertical solid line indicates the start of RF delivery.*