Vein of Marshall Pacing and Mapping
Published Literature and Techniques
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Background | Anatomy

The ligament of Marshall (LOM) is an epicardial vestigial fold that contains the oblique vein of Marshall (VOM), the myocardial sleeve (Marshall bundle) and autonomic nerves. The LOM is located in the epicardial aspect of the left lateral ridge, a structure located in between the left atrial appendage (LAA) and the left pulmonary veins (PVs) which are important in atrial fibrillation (AF) ablation. The Marshall bundle (MB) gradually changes into multiple muscle fibers and disappears or inserts into the epicardium of the anterior wall of the left atrium (LA) and the left PVs. The VOM is located in the epicardial aspect of the mitral isthmus and usually connects to the coronary sinus (CS) proximal to the valve of Vieussens with a posterior course along the left lateral ridge.

Figure 1. Illustration of heart indicating the proximity of the ligament of Marshall (LOM), Marshall bundle (MB), Vein of Marshall (VOM) to the left atrium (LA), left atrial appendage (LAA), and pulmonary veins (PV)
**Background** | **Relevance of VOM**

The VOM is implicated in the pathogenesis of AF through multiple mechanisms\(^2\)\(^{10}\).

- Serves as a source of ectopic beats initiating AF
- Serves as a connection pathway with neighboring myocardium and left PVs
- Serves as a tract for parasympathetic and sympathetic innervations that moderates electrophysiological properties of atrial tissue and contributes to AF maintenance

The VOM is located within the mitral isthmus, which is critical for perimtrial atrial tachycardia (AT)\(^1\)\(^{10}\). Incomplete ablation of the mitral isthmus is proarrhythmogenic and can increase the risk of recurrent flutter by up to 4 times\(^1\). The fibers connecting the VOM to the PVs could bypass endocardial ablation lesions leading to PV reconnection\(^2\). Recordings of double potential from the left superior PV may come from the LOM\(^5\). Potential from LOM can be ablated from both the endocardium with radiofrequency (RF) ablation and from epicardium with VOM ethanol injection\(^6\).

Recently, the VENUS-AF trial (Vein of Marshall Ethanol iNFusion in Untreated perSistent Atrial Fibrillation) demonstrated that VOM ethanol infusion in de novo catheter ablation in patients with persistent AF improved the likelihood of freedom from AF or AT at 6 and 12 months\(^10\).

The location, size, tortuosity, and anatomic variability of the LOM and VOM require specialized tools and techniques in order to map and effectively ablate innervations that have been implicated in the pathogenesis of AF and perimtrial atrial flutter\(^1\)\(^9\).
Study Overview

**Condition:** Persistent AF, Symptomatic AT

**Procedure:** Catheter ablation from the endocardium to visualize the electrically isolated area of the VOM

A 64 year old male with recurrent AF 9 months after initial RF ablation of complex fractionated atrial electrogram area failed to terminate the AF or convert it to AT. Mapping and pacing of VOM was attempted using a 2F octopolar catheter (EPstar Fixed Electrophysiology Catheter, Japan Lifeline). The VOM was ablated from the endocardium, specifically targeting the 2F catheter in the VOM using fluoroscopy. Ethanol infusion of the VOM was performed when ectopic activity was recorded from the proximal VOM after ablation.

**Highlights**

- The insertion of the electrode catheter in the VOM could serve as an anatomic indicator for the RF ablation target site, and could determine when electrical isolation of the VOM is achieved.
- Echocardiac contrast injection in the VOM showed earliest contrast appearance in the LA adjacent to the left PVs.
- The most distal VOM region is considered to be the focus of ectopic activity, while the most proximal aspect is connected to the CS musculature.
- Ethanol infusion in the VOM produced a low-voltage area on the posterior wall of the LA, and the anterior aspect of the left PVs.
- Ablation of the middle and distal aspect of the VOM interrupted electrical connections, electrically isolating the distal half of the VOM.
RF Ablation of Left Lateral Ridge to Isolate MB


Study Overview

Condition: Persistent AF

Procedure: Marshall bundle mapping and RF ablation

VOM endocardial mapping using a 1.5F quadripolar catheter (Pathfinder, Cardima) was possible in 45% of the 72 patients in the study. In patients where VOM could not be cannulated, epicardial mapping of the MB was conducted via the subxiphoid pericardial puncture, followed by mapping using a deflectable duodecapolar catheter and an 8F SL transseptal sheath (St. Jude Medical) to stabilize the MB recordings. To isolate the MB, RF energy was applied on the left lateral ridge; however, most patients required additional ablation of the left lateral isthmus, the CS, or epicardial sites. Dissociation of MB or exit block by selective MB pacing was used to confirm successful isolation.

Highlights

• The 1.5F quadripolar catheter may be maneuvered within the VOM to determine MB connection type
• The MB bypasses the tract between the CS, and the left PVs when more than one connection is present, and can serve as a trigger for paroxysmal AF.
  – Single connection: the MB may initiate AF through ectopic activity; however, it may not be a major contributor to AF maintenance.
  – Double connection: The MB – PV connection offers a channel between the PVs and the LA through the CS muscle sleeves. Failure to eliminate this accessory pathway results in electrical stimulation within the PVs followed by LA activation, which might be interpreted as failed PV isolation.
  – Multiple connections: the MB has the highest dominant frequency during sustained AF, where the complex electrical connection pattern between the MB and the LA provides a substrate for reentry. In this case, the MB is not always activated passively through neighboring AF wavefronts, but is capable of independent rapid activation.
RF Ablation at the Insertion Site of the VOM


Study Overview

Condition: Paroxysmal AF

Procedure: RF ablation aimed at the insertion site of the VOM

A 1.5F quadripolar catheter (Pathfinder, Cardima) was inserted into the VOM to record and pace in 28 patients with recurrent AF. Electrograms were attained during sinus rhythm, and spontaneous or induced atrial tachyarrhythmias

Highlights

• Triggers of focal AF episodes reside in the MB and not the PVs.
• RF ablation guided by the diagnostic catheter in the VOM successfully terminated atrial tachyarrhythmias and prevented reinduction, while no additional RF applications were needed in the PVs.
• Using the diagnostic catheter in the VOM as a guide for RF ablation allowed for lesions to be placed in the posterolateral LA between the MB insertion and the ostium of the left inferior PV, resulting in successful treatment of focal AF.
RF Ablation on Opposite Side of the VOM

Kawamura et al. Heart Rhythm, 2018

Study Overview

Condition: AT

Procedure: RF ablation

A 76 year old male with history of AF, in which a leap-frog pattern was identified through endocardial mapping in the LA, and the activation signal bypassed the ablation scars to reach its destination along the intended clockwise perimetral AT. A 2F octopolar catheter (EPstar Fixed Electrophysiology Catheter, Japan Lifeline) was advanced into the VOM for mapping and pacing, and an ablation catheter was placed on the opposite side of the VOM, where RF ablation was performed. Atrial tachycardia was terminated with RF ablation, and bidirectional block was observed with differential pacing on either side of the mitral isthmus.

Highlights

- Ablation of AT is possible through RF ablation on the opposite side of the VOM.
Study Overview

**Condition:** Persistent AF

**Procedure:** Ridge ablation

A 66 year old male underwent circumferential PVI of all four PVs as well as linear ablation of the LA roof and mitral isthmus, and confirmation of complete conduction block of the LA roofline. It was suspected that there was the presence of an epicardial conduction pathway through the MB, bypassing the endocardial mitral isthmus line. A 2F octopolar catheter (EPstar Fixed Electrophysiology Catheter, Japan Lifeline) was inserted into the VOM for mapping and pacing. The activation sequence of the VOM was distal to proximal during LAA pacing, and the presence of electric conduction from the LAA to the VOM via the distal MB to LA connection was suspected. Radiofrequency energy was applied at the ridge, defined as the area between the left PVs and the LAA. The activation sequence of the VOM during LAA pacing was changed from proximal to distal indicating the presence of MB to LA connection and was disconnected by ridge ablation.

**Highlights**

- Ridge ablation allowed for complete mitral isthmus block due to the disconnection of MB to LA connection.
- The MB has an important role in the conduction pathway for perimtrial AT.
- VOM mapping and pacing using a 2F octopolar electrode catheter allows for the identification of epicardial conduction pathways via the MB that are bypassing the endocardial mitral isthmus line.
- Ridge ablation is useful in cases where it is technically difficult to insert an ablation catheter in the VOM that is thin or absent.
- Ridge ablation can be used in difficult cases where the VOM is absent, tortuous, or small.
- Ridge ablation does not involve complex procedural steps, such as additional catheter cannulation into the VOM, and is believed to be the best option for initial attempts to create the MB conduction block.
- It can be difficult to achieve MB conduction block by ridge ablation due to the potential for multiple MB – LA connections, thus, alternative procedures are thought to be preferable.
Mitral Isthmus Block

Study Overview
Condition: Microreentrant tachycardia involving mitral annulus – perimital flutter

Procedure: Bidirectional mitral isthmus block using VOM ethanol infusion
VOM cannulation and mapping and pacing was achieved using a 1.7F quadripolar catheter (Pathfinder, Cardima) in 50 of the 71 total patients in the study. Spontaneous flutter was mapped and entrained from the proximal and distal CS, and the VOM. Perimital flutter was diagnosed when reentrant circuit was mapped around the mitral annulus and entrained from the proximal and distal CS, leading to post-pacing interval of 30 ms of the cycle length. VOM ethanol infusion was used for ablation to achieve mitral isthmus block.

Highlights
• The VOM and its neighboring tissue are within the perimital flutter circuit.
• VOM ethanol infusion allowed for 100% bidirectional mitral isthmus block when VOM cannulation was feasible, with minimal RF ablation time in patients with and without prior ablations.
• VOM ethanol infusion alone can acutely terminate perimital flutter in a fraction of patients (5/19 patients) with previous mitral isthmus ablation.
Key Publications | VOM Ethanol Infusion

Disconnection of Reconnected Left PVs


Study Overview

Condition: AF or atrial flutter

Procedure: VOM ethanol infusion

A total 61 patients were included in the study; 54 of which had successful VOM cannulation, and 32 of those patients underwent VOM ethanol infusion. A 1.7F quadripolar catheter (Pathfinder, Cardima) was inserted into the VOM to record and pace. To assess the role of the VOM in providing a pathway for reconnection, pacing was performed from the VOM and the reconnected PVs. The advancement of the PV potential relative to the atrial far-field signal during VOM pacing indicated VOM-mediated connection. Ablation was performed using VOM ethanol infusion which led to the disconnection of the reconnected left inferior PV, and the disconnection of the left superior PV.

Highlights

- Left PV reconnection after PVI can occur through epicardial connections via the VOM in a minority of cases.
- VOM ethanol infusion eliminated VOM electrical activity and disconnected the left PVs regardless of the connection mechanism, eliminating left pulmonary arrhythmogenesis.
- VOM ethanol infusion eliminated complex potentials that have been linked to the genesis and maintenance of AF.
- Chemical ablation through the VOM can assist in achieving lesion transmurality, regardless of the patterns of the VOM-PV connections.
Findings from the VENUS-AF (Vein of Marshall Ethanol iNfusion for Untreated perSistent AF) Trial


Study Overview

Condition: Persistent AF

Procedure: First time catheter ablation alone vs. VOM ethanol infusion in addition to catheter ablation

A total of 343 patients from 12 referral centers were randomized 1:1.15 into two groups comparing rhythm control effectiveness using catheter ablation alone (158 patients), or VOM ethanol infusion in addition to catheter ablation (185 patients) in de novo ablation of AF. Patients in the VOM ablation group underwent VOM ethanol infusion before RF catheter ablation. Clinical assessment of 12-lead electrograms were obtained at baseline and at 1, 3, 6, 9 and 12 months after initial ablation. Patients underwent continuous 1-month monitoring at 6 and 12 months after ablation using electrocardiographic monitoring.

Highlights

- Technical failure to canulate the VOM occurred in 30 patients.
- VOM ethanol infusion led to low-voltage area in 13/155 patients.
- VOM ethanol infusion led to left inferior PV isolation in 33/155 patients.
- There were no complications attributed to VOM ethanol infusion.
- The overall procedure, fluoroscopy and LA instrumentation time was shorter in the catheter ablation group with longer total RF application time.
- Addition of VOM ethanol infusion to catheter ablation increased the likelihood of freedom from AF and AT at 6 and 12 months.
  - Compared to catheter ablation alone, treatment with VOM ethanol infusion combined with catheter ablation resulted in:
    - 10.4% lower AF burden (p = 0.01)
    - 11.2% greater freedom from AF or AT or repeat procedures without use of AAD (p = 0.04)
    - 11.4% higher freedom from AF after multiple procedures (p = 0.04)
    - 29.3% greater success in achieving perimitral block (p < 0.001)
Techniques | VOM Cannulation

The techniques described in this section are based on published studies\textsuperscript{1,2,6,7,8,9,10} as well as a contemporary review paper on VOM ethanol infusion in the treatment of atrial fibrillation\textsuperscript{11}.

Consult the 2F EPstar Fixed Electrophysiology Catheter Instructions for Use for appropriate use of the device.

I. Under general anesthesia, a quadripolar catheter is positioned at the His bundle and a decapolar catheter is introduced into the CS via the right internal jugular vein, the left subclavian vein or femoral vein under fluoroscopy using a CS sheath, or an 8F fixed or steerable sheath\textsuperscript{8,11}.

II. A 5F or 6F left internal mammary artery (LIMA) guiding catheter with a Y-connector for contrast injection and for angioplasty wire (e.g. 0.014-inch BMW) placement, is inserted in the CS through the 8F fixed or steerable sheath\textsuperscript{8,9,11}.

III. The LIMA catheter tip is positioned posteriorly towards the assumed VOM for contrast injection, and then moved gently up and downwards\textsuperscript{1,8,11}.

- If the VOM cannot be visualized after several contrast injections, the LIMA catheter can be exchanged for a pulmonary artery catheter to perform angiography with proximal balloon occlusion\textsuperscript{8}.

IV. A balloon occlusion venogram using balloon catheter (2x8 mm) is performed to delineate CS anatomy\textsuperscript{1,9}.

- Presence of the VOM is confirmed when a posteriorly directed vein branch is visible in the anterior oblique projection (Figure 2)\textsuperscript{9}.

V. The sheath is advanced to cannulate the VOM\textsuperscript{1}.

VI. Angiographic contrast is injected to confirm access to the VOM\textsuperscript{1}.

VII. A small 1.7F quadripolar catheter (Pathfinder; Cardima) or 2F octopolar catheter (EPstar Fixed Electrophysiology Catheter; Baylis Medical) is inserted in the VOM (Figure 3)\textsuperscript{1,2,6,7,10}.

VIII. Marshall bundle mapping can be done for patients where the VOM cannot be cannulated\textsuperscript{4}.

\textsuperscript{†} Images courtesy of Dr. Akanibo Da-wariboko, Houston Methodist DeBakey Heart & Vascular Center
Techniques | Ethanol Infusion

The techniques described in this section are based on published literature. Consult the 2F EPstar Fixed Electrophysiology Catheter Instructions for Use for appropriate use of the device.

I. After mapping, the small 1.7 F quadripolar catheter (Pathfinder, Cardima), or EPstar 2F Fixed Electrophysiology Catheter (Baylis Medical) is removed.

II. A percutaneous transluminal coronary angioplasty guidewire with a preloaded coronary dilatation balloon catheter (e.g. Voyager OTW) is introduced via the Y connector through the LIMA catheter.

- The size of the coronary dilatation balloon is estimated relative to the 6F 5F LIMA catheter (usually 1.5-2.5 mm in diameter and 6-8 mm in length).

III. The angioplasty guidewire is gently introduced into the VOM with rotational movement, far enough to provide enough support for subsequent advancement of the balloon over the wire.

IV. An angioplasty balloon catheter is advanced over the wire as distally as possible, and inflated to 2-4 atm until a small resistance is felt before wire removal (Figure 4).

V. The VOM is visualized by direct contrast injection into the balloon catheter to check for leakage or collateral blood flow back to the CS.

VI. Depending on the length of the VOM, up to 4 balloon occlusive injections of 98%-100% ethanol (1 cc over 2 mins) are delivered, starting at the most distal location in VOM.

VII. The balloon is slowly retracted 1 cm after each injection, so that the last injection is given from the most proximal portion of the VOM, at the VOM ostium.

VIII. The diagnostic catheter is reinserted into the VOM to record signals and verify ablation (Figure 5 and 6).

Figure 4. (A) Angioplasty balloon in the VOM (white arrow). (B) Staining from occlusive venography indicating ethanol reach (white arrow). (C) Proximal occlusive venogram (white arrow) prior to ethanol delivery.

Figure 5. Venogram showing (A) sequential ethanol delivery from the distal to ostial VOM (white arrows), and (B) reintroduction of EPstar 2F Fixed Electrophysiology Catheter into the VOM post-ethanol infusion.

Figure 6. Intracardiac electrograms (A) before and (B) after VOM ethanol infusion showing VOM signal attenuation (black arrows) measured by the distal electrodes of EPstar 2F Fixed Electrophysiology Catheter.

† Images courtesy of Dr. Akanibo D-awanboka, Houston Methodist DeBakey Heart & Vascular Center
Conclusion

Published clinical evidence show that small diagnostic catheters, such as the 2F EPstar Fixed Electrophysiology Catheter, allow for

- Mapping and pacing of small distal CS branches, including the VOM\textsuperscript{1,2,3,4,5,6,7,12}
- Identification of the precise site of arrhythmia\textsuperscript{1,2,3,4,5,6,7,12}

The feasibility of mapping and pacing of VOM using a small diagnostic catheter can lead to less RF ablation and potentially reduce the need for repeat procedures\textsuperscript{1,4}.

The 2F EPstar Fixed Electrophysiology Catheter offered by Baylis Medical is the only commercially-available multipolar 2F microcatheter in North America that allows for electrogram recording and pacing during diagnostic electrophysiology studies.
References


