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EDITORIAL COMMENT

Da Vinci Anatomy Card #1: The Eustachian Valve and its Implications in Invasive Cardiology and Cardiac Surgery*

Alejandro Jiménez Restrepo, MD,[a] Juan E. Mesa, MD,[a] Damián Sánchez-Quintana, MD, PhD,[b] José Ángel Cabrera, MD, PhD[c]

The anatomy of the eustachian valve (EV) is of relevance to the interventional cardiologist, cardiac electrophysiologist, and cardiothoracic surgeon, as this anatomical structure (along with its variants) may hinder procedures in the right atrium (RA) and right ventricle from an inferior approach. The understanding of this important anatomical structure may help overcome complicated procedures due to EV anatomical variants and prevent potential complications.

NORMAL ANATOMY OF THE EUSTACHIAN VALVE

The orifice of the inferior vena cava (IVC) is located in the posteroinferior region of the RA. The EV arises from the anterior portion of the IVC orifice and extends toward the anteroinferior region of the RA, usually taking a crescent shape created by a fold of endocardial tissue (1). Embryologically, the EV is formed from tissue derived from the superior portion of the right sinus valve and the sinus septum (2). Although the EV is absent in 30% of anatomical specimens (1,3), the eustachian ridge (ER), which is an extension of the insertion point of the EV into the RA, is invariably present; in fact, the free border of the EV continues as the tendon of Todaro that runs in the musculature of the ER and extends into the central fibrous body, whereas the ER is located below the fossa ovalis and above the coronary sinus ostium (**Figures 1 and 2**) (4).

ANATOMICAL VARIANTS OF THE EV AND ITS CLINICAL IMPLICATIONS

Variations in EV anatomy may impede access to the right-sided chambers. Filament-like extensions arising from the EV, known as the Chiari network, which are a remnant of the embryological right valve of the sinus venosus, are commonly seen on transesophageal and intracardiac echocardiographs and, depending on its extent and structure, may hinder catheter advancement from the IVC into the RA (Video 1) and occasionally lead to catheter or guidewire entanglement (5-8). Sub-EV pouches (known as sub-eustachian recesses) are present in up to 45% of individuals (9) and have been associated with longer radiofrequency applications required to achieve bidirectional blockage across the cavotricuspid isthmus in typical atrial flutter ablations (10). An enlarged eustachian ridge and an EV have also been described as barriers to cavotricuspid isthmus blockage (11,12) (**Figure 3**) and transcatheter closure of interatrial septal defects (13). Gross anatomy studies have identified the presence of a prominent EV in up to 26% of specimens (14). A

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From the [a]Division of Cardiovascular Medicine, Marshfield Clinic Health System, Marshfield, Wisconsin, USA; [b]Department of Human Anatomy, Faculty of Medicine, Badajoz, Spain; and the [c]Division of Cardiology, Hospital Universitario Quirón Salud, European University of Madrid, Madrid, Spain.

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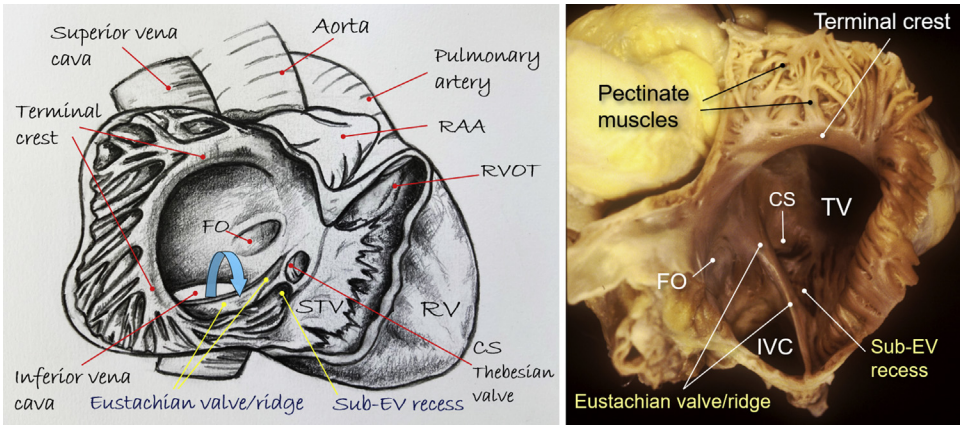
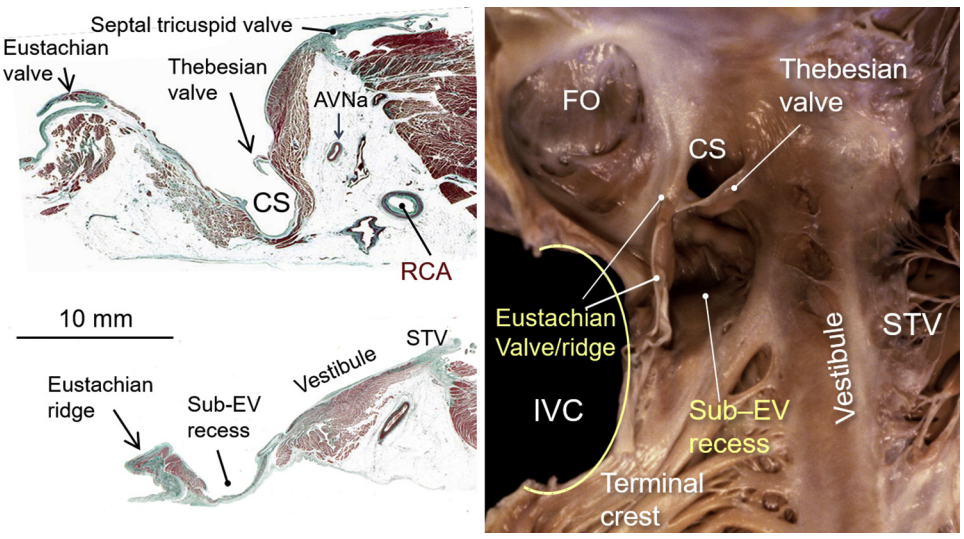
FIGURE 1 Anatomical Drawing and Corresponding Gross Anatomy Specimen of the RA Structures and its Anatomical Relationships



The EV arises from the anterior segment of the IVC and extends anteriorly as the ER below the FO and above the CS ostium. The free border of the ER becomes the TT extending into the CFB. The blue arrow represents the direction of a catheter or wire going into the anterior RA towards the RV when entering from an inferior approach, and showcases how a prominent EV/ER could hinder such approach. CFB = central fibrous body; CS = coronary sinus; ER = eustachian ridge; EV = eustachian valve; FO = fossa ovalis; IVC = inferior vena cava; RA = right atrium; RAA = right atrial appendage; RVOT = right ventricular outflow tract; TT = tendon of Todaro.

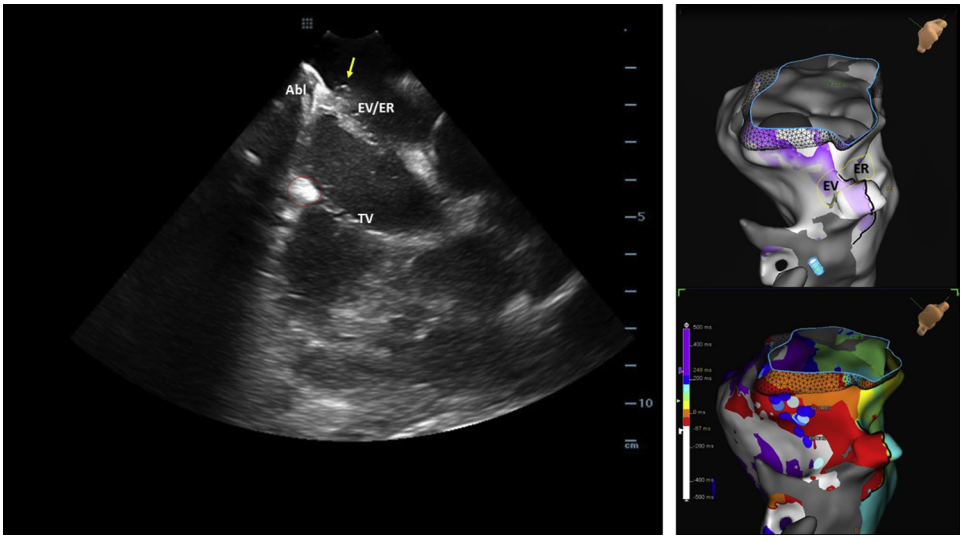
thick ER >4 mm is seen in 24% of the normal population studied using computed tomography scanning (15), and this EV variant has been cited as a cause for IVC obstruction (16,17) and right-to-left shunting (18) following surgical repair of atrial septal defects. This occurs when the prominent EV is mistakenly identified intraoperatively as the lower rim of an atrial septal defect and is sutured to the interatrial septum, affecting IVC flow or diverting it into the left atrium. Finally, case reports of EV

FIGURE 2 Histological Slide and Corresponding Gross Anatomical Specimen of the EV, ER, Septal CTI, Inferior Pyramidal Space



Note the presence of prominent eustachian and Thebesian valves, as well as a large sub-EV recess. AVNa = atrioventricular nodal artery; CTI = cavotricuspid isthmus; RCA = right coronary artery; other abbreviations as in Figure 1.

FIGURE 3 Still Frame of ICE Image Displaying a Prominent Chiari Network, EV and ER Hindering Catheter Movement (ABL) During Typical Atrial Flutter Ablation



Note the echo-bright area **(red dotted circle)** corresponding to the ablated area near the tricuspid valve. The 3D activation maps (**top right,** propagation; **bottom right,** isochronal right) show counter-clockwise activation across the CTI, including the EV/ER. This 3D anatomical view is generated by impedance and requires contact between the catheter and the tissue. This creates a "hollow" space (**yellow dotted area** in the mid CTI) where the prominent EV/ER lies, as the catheter is unable to generate geometry below these intracavitary structures. Using ICE and 3D mapping for guidance, a linear ablation lesion set was made in the lateral aspect of the CTI **(blue tags, right bottom map)** bypassing the prominent EV and ER in order to achieve bidirectional block. 3D = 3-dimensional; ABL = ablation catheter; CTI = cavotricuspid isthmus; ICE = intracardiac echocardiography.

thrombosis (19) and infective endocarditis (20) have been reported, and catheter or wire manipulation could lead to pulmonary embolism or paradoxical systemic emboli in the presence of a concomitant patent fossa ovalis.

CONCLUSIONS

EV variants are common, and although frequently seen as a mere curiosity or incidental findings on echocardiogram (as they are usually asymptomatic), they can present significant challenges in a variety of interventions. The precise anatomical understanding of the EV and its variants becomes relevant when planning procedures where this structure may interfere with a successful outcome, such as the case beautifully presented by Patel et al. (17) in this issue of *JACC Case Reports*.

AUTHOR DISCLOSURES

The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

ADDRESS FOR CORRESPONDENCE: Dr. Alejandro Jiménez Restrepo, Marshfield Clinic, 1000 North Oak Avenue, Marshfield, Wisconsin 54449, USA. E-mail: jimenezrestrepo.alejandro@marshfieldclinic.org.

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APPENDIX For supplemental videos, please see the online version of this paper.