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ORIGINAL ARTICLE

Visualisation of the oblique vein of the left atrium (vein of Marshall) using cardiac computed tomography: is the game worth the candle?

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Abstract

Background: The vein of Marshall (VoM) is a small vessel that descends obliquely on the back of the left atrium and ends in the coronary sinus near the area where the great cardiac vein continues into the coronary sinus.

Aim: The aim of the study was to examine the frequency of occurrence and anatomical aspects as well as the possibility of visualising the VoM, including an evaluation of the quality of the visualisation, on computed tomography (CT).

Methods: Three hundred patients aged 58.8 ± 11.5 years (111 women) were included into this single-centre study. Cardiac CT was performed in all patients. The search for the VoM was performed by two experienced researchers using two- and three-dimensional techniques. A dedicated Likert-based scale was used to evaluate the quality of the visualisations.

Results: The VoM was found in 61 (20.33%) of 300 patients. Its average diameter was 1.72 ± 0.69 mm with no sex-related differences (men: 1.71 ± 0.69 mm; women: 1.73 ± 0.57 mm; p = 0.91). The average length of the vessel was 9.24 ± 7.58 mm. The VoM was more frequently (p = 0.01) visualised in the systolic phases (68.85% of cases) compared to the diastolic phases (27.86% of cases). Occasionally it was visualised in other phases (3.29%).

Conclusions: Although it was possible to visualise the VoM using cardiac CT in about 20% of the population, this method of visualisation requires that special attention be paid to the quality of the images, especially in the systolic phases. Visualisation may be useful before certain electrophysiology procedures.

Key words: vein of Marshall, oblique vein of the left atrium, computed tomography, venous system

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INTRODUCTION

The oblique vein of the left atrium, sometimes referred to as the vein of Marshall (VoM), is a small vessel that descends obliquely on the back of the left atrium and ends in the coronary sinus near the area where the great cardiac vein continues into the coronary sinus [1–4]. The valve of Vieussens is often used as a marker for its ostium [3, 5]. Cannulation of the VoM before certain electrophysiology procedures such as paroxysmal focal atrial fibrillation (AF) ablation has been considered previously. It can also be useful in cases of unsuccessful AF ablation or post-AF ablation of left atrial flutter using mitral isthmus. Different modes of ablation within the VoM include radiofrequency ablation and ethanol infusion [6–10]. However, in certain cases the VoM cannulation should be avoided, e.g. to prevent an accidental implantation of the left ventricular lead during cardiac resynchronisation therapy. Therefore, knowledge about the existence, position, and dimensions of the VoM is useful.

Cardiac computed tomography (CT) is a useful and accepted method for visualising the coronary venous system due to its complexity, high resolution of the produced images, and the generally high level of accessibility [11–13]. Other diagnostic tools such as echocardiography and cardiac magnetic resonance have limited usefulness for visualising the VoM.

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Table 1. Characteristics of the study population

	Vein of Marshall absent (n = 239)	Vein of Marshall present (n = 61)
Male sex [%]	63.59	60.65
Age [years]	58.60 ± 11.69	59.82 ± 10.88
Left ventricular ejection fraction [%]	60.66 ± 11.69	62.20 ± 10.30
EDV [mL]	148.57 ± 50.08	144.12 ± 39.49
ESV [mL]	59.69 ± 39.38	55.83 ± 26.52
Stroke volume [mL]	86.81 ± 20.22	86.98 ± 20.91
Cardiac output [L/min]	5.29 ± 1.58	5.37 ± 1.53
Myocardial mass [g]	140.72 ± 45.28	135.05 ± 34.64
Myocardial volume [mL]	131.26 ± 44.05	129.97 ± 33.79
Heart rate [bpm]	61.57 ± 10.61	61.71 ± 9.36

Data are shown as mean ± standard deviation. EDV — end-diastolic volume; ESV — end-systolic volume

There is a lack of data about the frequency of occurrence, anatomical variants, and possibilities of visualising the VoM in imaging methods such as cardiac CT. Therefore, the aim of the study was to examine the presence and anatomical aspects of the VoM as well as the possibility of its visualisation, including an evaluation of the quality of the visualisation, in multi-slice cardiac CT.

METHODS

A total of 317 patients aged 58.8 ± 11.5 years (including 111 women) were screened. Ten images did not qualify for the clinical analysis due to their poor technical quality (presence of motion artefacts). Additionally, seven patients were excluded due to AF or other arrhythmias, renal insufficiency, and a known allergy to non-ionic contrast agents.

Finally, 300 patients were included into this single-centre study. Cardiac CT using an Aquilion 64 scanner (Toshiba, Hamamatsucho, Japan) was performed in all participants. All patients had been referred for coronary angiography due to a clinical suspicion of coronary artery disease (typical indication for CT) [14].

The approval of the local Bioethical Committee was obtained. The study protocol conformed to the version of the Declaration of Helsinki that was current at the time that the study was designed.

Computed tomography protocol

Scanning with retrospective electrocardiogram-gating was performed during a breath-hold using 64 slices with a collimated slice thickness of 0.5 mm, according to the standard protocol for coronary arteries. Because of the retrospective gating, a precise retrospective analysis of the CT data in all phases of the cardiac cycle was possible during post-processing. We used the “best mode” option (following manufacturer’s specifications); the helical pitch was 12.8, and the rotation time was 0.4 s. The tube voltage was strictly dependent on the patient’s body mass index (BMI). The presented data are typical for cardiac CT examinations. An average of about 80 to 100 mL of high-quality non-ionic contrast agent was administered to each patient in the study. In patients whose heart rhythm (HR) was too high (> 65 bpm), 5 to 10 mg of metoprolol succinate was administrated intravenously, unless contraindicated. If the HR did not decrease to the expected value (65 bpm), the patient was excluded from the study [15]. Sublingual application of nitro-glycerine was not used in this study.

Post-processing

The search for the VoM was performed using Vitrea 2 (Vital Images, Minnetonka, MN, USA) workstations. Multi-planar reformatted reconstructions and three-dimensional (3D) volume renderings were used. The analyses were performed by two experienced researchers. A dedicated Likert-based scale created previously was used to evaluate the quality of the visualisations [15]. On the five-point scale, one point indicates a very schematic visualisation of the coronary sinus ostium and five points indicate the best quality with a complete clinical input.

Statistical analysis

Statistical analysis of the obtained data was performed using Statistica software (StatSoft Inc., Tulsa, OK, USA). Continuous data are presented as the mean ± standard deviation. Student t test was used to compare the quantitative data with a normal distribution, and the χ^2 test was used for the nonparametric data. The results were considered to be statistically significant at $p < 0.05$.

RESULTS

The characteristics of the study population are presented in Table 1. The VoM was found in 61 (20.33%) of 300 patients. An example of a visualisation using two-dimensional

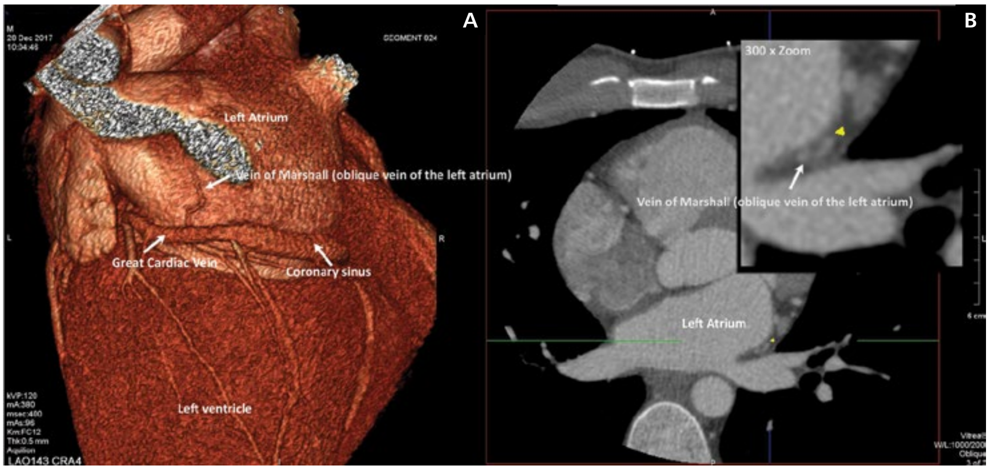

Figure 1. Example of the anatomy of the lateral wall of the heart in a patient with a vein of Marshall. Cardiac computed tomography; **A.** Three-dimensional volume rendering; **B.** Multi-planar reformatting

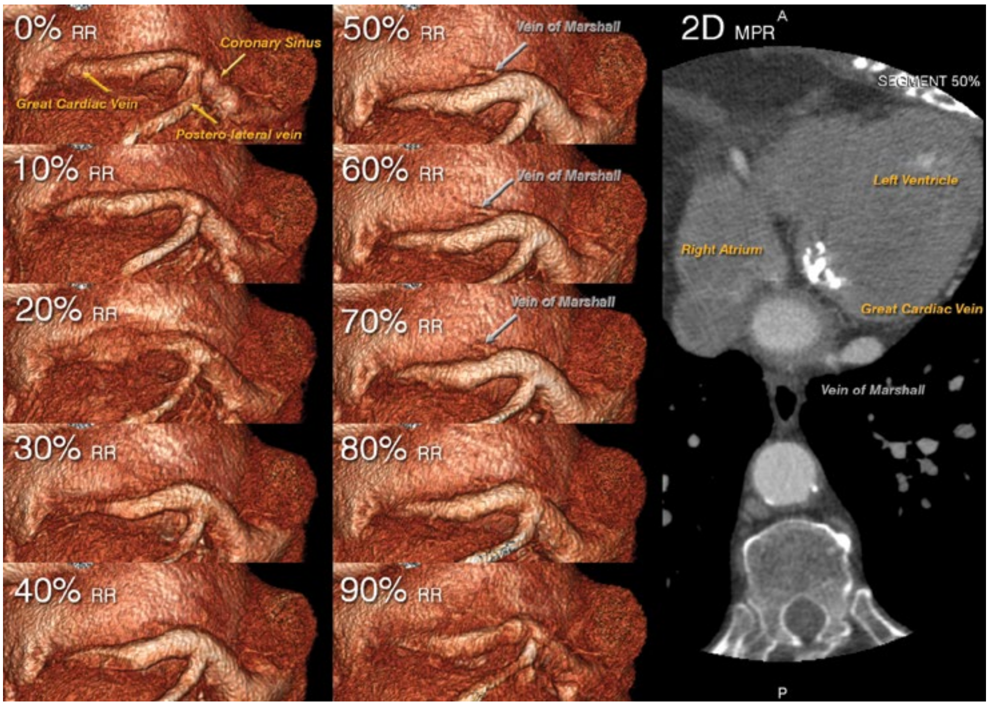

Figure 2. Example of the visualisation of the vein of Marshall according to the phase of the visualisation (% RR interval). Cardiac computed tomography; **Two left panels:** Three-dimensional volume rendering; **Right panel:** Multi-planar reformatting — reference image

multi-planar reformatting and 3D volume rendering is presented in Figure 1.

Measurements

The vein of Marshall is a small vessel; in our study its average diameter was 1.72 ± 0.69 mm and average length was 9.24 ± 7.58 mm. There were no sex-related differences for either parameter (diameter: 1.71 ± 0.69 mm in men vs. 1.73 ± 0.57 mm in women, p = 0.907; length: 9.29 ± 7.81 mm in men vs. 9.16 ± 7.39 mm in women, p = 0.95). An important element in terms of anatomical relationships is the location of the valve of Vieussens (if present), which is normally situated at a close proximity to the place where the VoM connects to the coronary sinus. In our re-

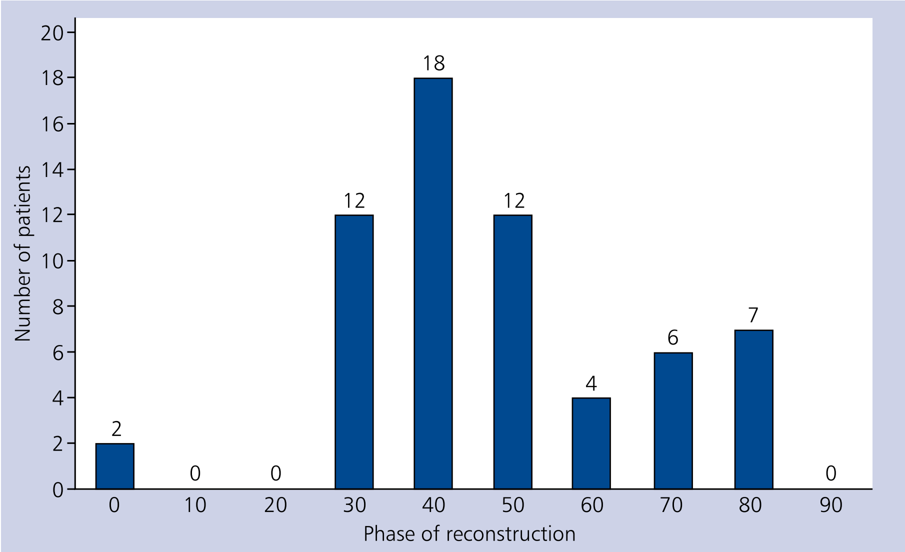

Figure 3. Distribution of the visualisation of the vein of Marshall according to the phase of the visualisation (% RR interval)

search, the average distance between the coronary ostium and the right atrium was 42.67 ± 11.06 mm and it was found to be statistically greater ($p = 0.02$) in men (45.35 ± 11.19 mm) compared to women (38.54 ± 9.68 mm). The VoM was most frequently found in the case of variant 1 according to our previous anatomical classification of coronary veins [12]. In this variant, the anterior, lateral, and posterolateral veins are visible on CT visualisation. In patients with this anatomical variant of the coronary venous system, the VoM was present in 35.89% of cases.

Table 2. Quality of the visualisation of the vein of Marshall according to a dedicated Likert-based scale

Grade	Number of visualisations	Percentage
1	6	9.84
2	30	49.18
3	16	26.23
4	7	11.47
5	2	3.28

Data are shown as number and percentage.

Computed tomography visualisation

The VoM was more frequently ($p = 0.01$) visualised in the systolic phases (30%–40%–50% RR; 68.85% cases) compared to the diastolic phases (70%–80% RR; 27.86% cases). Occasionally, it was visualised in other phases (3.29%). Examples of image reconstruction according the phase of cardiac cycle are graphically presented in Figure 2 and the distribution according to the phase of reconstruction is depicted in Figure 3.

Quality of the visualisation

The average quality of the visualisation assessed in a dedicated Likert-based scale was 2.49 ± 0.94, with no differences between women (2.37 ± 0.87) and men (2.57 ± 0.98; $p = 0.44$). Detailed results regarding the quality of the visualisation are presented in Table 2.

DISCUSSION

The oblique vein of the left atrium is named after John Marshall (1818–1891), who was a famous English surgeon and anatomy pathologist. This vein is an adult equivalent of a persistent left horn of the sinus venosus and is important prenatally; its postnatal role is limited, although in certain cases it is important. For about a decade there have been scientific voices stressing the possibility of using this vein as well as the ligament of Marshall (where the vein of Marshall lies) during different types of ablation, including AF ablation [16].

An example of a scientific contribution documenting this thesis is the paper of Hwang et al. [17]. It examined the characteristics of the potentials within the vein and suggested that the second potential is from the muscle bundle within the ligament of Marshall. The authors concluded that it was possible to record the electrical potentials from the VoM and that the Marshall bundle may be identified as the origin of focal AF in some patients. Because the course of the VoM correlates with areas usually ablated during pulmonary vein antrum isolation, this vein may be a target for ethanol infusion. Valderrábano et al. [7] cannulated the VoM in 10 out of 14 patients using a balloon technique, and ethanol was infused to the vessel. The authors showed that ethanol ablation of VoM is safe in humans, decreases radiofrequency ablation time, and may play a role as an adjunct to pulmonary vein antrum isolation. Walczak et al. [18] presented an interesting case of a patient with recurrent atrial arrhythmias (atrial ectopy, atrial tachycardia, and AF) originating from the VoM. Two sessions of radiofrequency ablation were performed along the course of the VoM. After five years of follow-up, no arrhythmias were observed in the patient despite the fact that no antiarrhythmic drugs were administered.

There are several methods for visualising the VoM. Balloon-occluded coronary sinus angiography using fluoroscopic views is the method that is used most often, almost routinely, during cardiac resynchronisation. In the paper of Tuan et al. [19], 106 patients in whom balloon-occluded coronary sinus angiography was performed were examined. The VoM was found in 74.5% of cases with no significant difference in terms of sex (men vs. women: 72.7% vs. 77.5%). These values are considerably higher compared to the results presented in our paper in which the VoM was found in 61 (20.33%) out of 300 patients. These significant differences could be due to the diverse imaging techniques that were used in both research projects.

We believe that the occurrence of the VoM is higher in the real world than in our research due to the fact that CT cannot visualise very small vessels. This hypothesis was also confirmed by a post mortem study. In their paper, de Oliveira et al. [20] described the anatomical relationships between the VoM and its ostium to the coronary sinus, which were studied in 23 heart specimens. The left atrial oblique vein was identified in 20 (87%) the hearts, while the valve of Vieussens was found in 17 (74%) the specimens (in 16 of which the VoM also was identified). The mean diameter of the left atrial oblique vein was 1.23 ± 0.38 mm, which is comparable to our measurement of 1.72 ± 0.69 mm. This suggests that CT can be treated as a method for the live evaluation of the VoM.

The clinical usefulness of the VoM visualisation is still limited, but is steadily rising due to the association with the possibility of treating certain arrhythmias. While good-quality raw CT images can be re-analysed to find the VoM, higher-resolution scanners can visualise the VoM more precisely.

Dedicated protocol for coronary veins (including delay in contrast administration) can improve the visualisation of VoM in selected cases, especially to help recognise very small vessels. Such a change in the technique of image acquisition can negatively impact the visualisation of coronary arteries. Cannulation of VoM before certain electrophysiology procedures, such as paroxysmal focal AF ablation, can be considered in selected cases. In our paper, patients with arrhythmias were excluded due to the technical limitations of 64-slice scanners. We believe that more advanced scanners (e.g. 256-slice) can resolve the problem of the influence of motion artefacts connected with arrhythmias on image quality. The dose of radiation is safe but substantial (in our research the average dose was 10 to 15 mSv and was strictly dependent on patients' body mass index). Because of the technical limitations of CT, the rate of VoM visualisation was lower in comparison with anatomical studies or coronary sinus occlusion venography. Therefore, this imaging technique should not be used as a single method of visualisation before an intervention within the VoM, but it may be a valuable diagnostic addition for other clinical purposes.

In conclusion, although it was possible to visualise the VoM using cardiac CT in about 20% of the studied population, the visualisation with this tool requires that special attention be paid to the quality of the images, especially in the systolic phases. Visualisation of the VoM could be useful before certain electrophysiology procedures.

Conflict of interest: *none declared*

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WHAT IS NEW?

The presented paper is the first large population analysis of the frequency of occurrence and presentation of some anatomical aspects as well as the possibilities of visualising the vein of Marshall, including an evaluation of the quality of the visualisation, in multi-slice cardiac computed tomography. Our imaging-anatomical research also presents practical instructions on how to visualise the vein of Marshall in computed tomography, including analysis during different phases of the cardiac cycle.