Europace (2009) **11**, 1188–1192
doi:10.1093/europace/eup179

CLINICAL RESEARCH
Electrophysiology and Ablation

Variations in Thebesian valve anatomy and coronary sinus ostium: implications for invasive electrophysiology procedures

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Received 26 March 2009; accepted after revision 10 June 2009; online publish-ahead-of-print 8 July 2009

Aims The coronary sinus (CS) is a commonly cannulated structure in patients undergoing electrophysiology studies, catheter ablation of arrhythmias, implantation of resynchronization therapy devices and, more recently, percutaneous mitral valve repair. The advent of these procedures has led to a renewed interest in the anatomy of the coronary venous system including its various components. To improve our understanding of this structure, we studied the anatomy of the human CS, including the valve that guards its ostium, the Thebesian valve.

Methods and results In 75 randomly selected autopsied human hearts, we measured the transverse and craniocaudal dimensions of the CS ostium and characterized the shape, composition, per cent coverage, and attachment points of the Thebesian valve when present. Of the 75 hearts examined, 54 had organic heart disease including atherosclerotic coronary artery disease, left ventricular hypertrophy, dilated cardiomyopathy, rheumatic heart disease, infective endocarditis, and non-rheumatic valvular heart disease. A wide variety of Thebesian valve morphologies were seen, ranging from the absence of any valve to those where the valve was completely occluding the CS ostium. A Thebesian valve was present in the majority of the hearts examined (55/75 hearts—73%). The average transverse dimension of the CS ostium in hearts with Thebesian valves (7.3 $\pm$ 2.8 mm) was significantly shorter than those without Thebesian valves (9.4 $\pm$ 2.9 mm, $P = 0.005$). Similarly, the average craniocaudal dimension of the CS ostium in hearts with Thebesian valves (7.9 $\pm$ 2.7 mm) was also significantly shorter than those without Thebesian valves (9.3 $\pm$ 2.9 mm, $P = 0.045$).

Conclusion Our study shows that some form of Thebesian valve is present in the majority of hearts (>70%). Of these, a significant minority (16%) had a valve morphology (covering >75% of the ostium, a fibrous, fibromuscular, or muscular composition, and devoid of fenestrations) that makes them a 'potentially complicating' structure interfering with the cannulation of the CS.

Keywords Thebesian valve • Coronary sinus ostium

Introduction

Recent advances in the treatment of patients with heart failure and valvular heart disease, especially as these advances relate to cardiac resynchronization therapy and percutaneous mitral valve repair procedures which modify the coronary sinus (CS) geometry, have led to a renewed interest in the anatomy of the coronary venous system.[1,2]

In clinical electrophysiology, the cardiac venous system has always been of great interest. The CS is a commonly used gateway to the left atrial and left ventricular (LV) epicardium. A wide array of diagnostic and mapping manoeuvres to diagnose and treat arrhythmias are performed via the CS.[3,4] More recently, the CS has become the target structure for LV epicardial lead placement to achieve cardiac resynchronization therapy.[5–8] Although the success rate for transvenous LV lead placement is

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relatively high (88–95% in large clinical trials), the procedure is not successful in 5–12% of the patients.[5] Failure of LV lead placement has sometimes been attributed to inability to insert catheters into the CS.

A majority of cardiac venous blood is returned to the right atrium via the CS and its tributaries. The true anatomical CS is defined as a short venous trunk extending from the valve of Vieussens, at the confluence of the oblique vein of the left atrium (vein of Marshall) and the great cardiac vein, to the CS ostium in the right atrium. The CS ostium is located between the inferior vena cava and the inferior tricuspid annulus.[3] Often times, the opening is guarded by a fold of endocardial tissue, an embryological remnant of the right sinus valve, termed the valve of the CS or Thebesian valve. It has been known to display significant variation and it is noteworthy that even as early as 1951, investigators have speculated on the potential of the valve to interfere with cannulation of the coronary venous system.[9] To assess the possible impact of this structure in procedures that require its cannulation, we examined the anatomy of the Thebesian valve and CS ostium in 75 human cadaver hearts.

Methods

Study population

We examined the Thebesian valve and CS ostium in 75 autopsied human hearts chosen at random from the formalin-fixed specimens at the Jesse E. Edwards Registry of Cardiovascular Disease (St Paul, MN, USA). These hearts had previously been opened in the customary routine manner. The CS ostium was intact in all hearts examined, as was the Thebesian valve (when present). The age, gender, relevant clinical history of the subjects, pathological findings, and diagnoses including atherosclerotic coronary artery disease (atherosclerotic coronary arteries with normal-sized ventricle and no evidence of prior infarction), atherosclerotic coronary heart disease (atherosclerotic coronary arteries along with evidence of myocardial scarring and ventricular remodelling), LV hypertrophy, dilated cardiomyopathy, cardiac enlargement (enlargement of atrium or ventricle as labelled by the Jesse Edwards Registry staff), rheumatic heart disease, infective endocarditis, and non-rheumatic valvular heart disease were recorded.

Quantitative data

The transverse and craniocaudal dimensions of the CS ostium in 75 hearts were directly measured to the nearest millimetre using a calliper. Other observations, including the shape, composition (fibrous, fibromuscular, or muscular), and attachment points of the Thebesian valve, were characterized when present in all 75 hearts. The per cent coverage of the CS ostium was also recorded as well. When the Thebesian valve was seen to cover at least 75% of the CS ostium, non-fenestrated, and fibrous, fibromuscular, or muscular in composition, it was defined as a valve that could potentially complicate attempts to cannulate the CS.

Statistical analysis

Continuous data are presented as mean values and corresponding standard deviations. Categorical data are expressed as numbers and percentages. The paired Student *t*-test was used to evaluate differences in diameters of the ostium of the CS in both transverse and craniocaudal directions. A *P*-value of <0.05 was considered statistically significant.

Results

Baseline characteristics

Demographic data were available from 70/75 hearts. Of these, the mean age was 57.4 ± 19.1 years (range of 19–90 years), 43 of the autopsied hearts (61.4%) were male, and 27 were female (39.6%). Of the 75 hearts examined, 18 were structurally normal and 54 had organic heart disease. Organic heart disease classification included atherosclerotic coronary artery disease (16.7%), atherosclerotic coronary heart disease (25%), LV hypertrophy (51.4%), dilated cardiomyopathy (20.8%), cardiac (including atrial) enlargement (26.4%), rheumatic heart disease (5.6%), infective endocarditis (2.8%), and non-rheumatic valvular heart disease (15.3%). Many hearts had multiple diagnoses. Among the 55 hearts with Thebesian valve present, 45 hearts had history of organic heart disease (82%), including 11 with atherosclerotic coronary artery disease (20%), 14 with atherosclerotic coronary heart disease (25.5%), and 30 with LV hypertrophy (55.5%).

Anatomic observations

A wide variety of Thebesian valve morphologies were seen, including remnant valves (covering $<10\%$ of the ostium) and valves that completely occluded 100% of the ostium. The Thebesian valve was absent in 20 of the 75 hearts examined (27%). A typical example of an absent Thebesian valve is shown in *Figure 1*. When present (55/75 hearts—73%), the Thebesian valve also differed greatly in its composition, including fibrous, fibromuscular, and membranous, as well as the presence or absence of fenestrations.

In 15/55 hearts (27%), the valve was large and covered at least 75% of the CS ostium, whereas the valve covered $<10\%$ of the

Figure 1 Autopsy heart specimen depicting an absent Thebesian valve. The lateral right atrium and lateral right ventricle have been cut open, displaying the septal leaflet of the tricuspid valve, the CS ostium (*white arrow*), and the fossa ovalis. Similar to this specimen, a Thebesian valve was absent in 20 of the 75 heart specimens in our study.

ostium in 10/55 hearts (18%). The extent to which the valve covered the ostium is shown in *Table 1*. Most Thebesian valves were semicircular in shape (36/55—65% of heart specimens). In a minority of specimens, the valve was a strand-like (2/55—4%) or band-like structure (7/55—13%) (*Figure 2A*).

Table 1 Size, shape, composition, and fenestration percentages of Thebesian valves

		n	%
Size	>75%	15	27.2
	50–74%	10	18.2
	25–49%	10	18.2
	10–24%	10	18.2
	<10%	10	18.2
	Total	55	100
Shape	Semicircular	36	65.4
	Strands	2	3.6
	Band	7	12.7
	Remnant	10	18.2
	Total	55	100
Composition	Membranous	25	45.5
	Fibrous	13	23.6
	Fibromuscular	6	10.9
	Muscular	10	18.2
	Total	54	98.2
Fenestrated	Yes	14	25.5
	No	41	74.5
	Total	55	100

This table illustrates the size of the valve in relation to the CS, its shape, composition, and the presence of fenestrations in the hearts examined.

Most Thebesian valves were membranous in composition (25/55—46%), followed by fibrous (13/55—24%), fibromuscular (6/55—11%), and muscular (10/55—18%). Fenestrations were noted in the valve in 14/55 heart specimens (26%) (*Table 1*). Examples of Thebesian valve that were thin, membranous, and fenestrated are shown in *Figure 2A* and *B*.

A unique focus of our study was to identify 'potentially complicating' Thebesian valves, defined as non-fenestrated valves that were fibrous, fibromuscular, or muscular, and covering >75% of CS ostium. As shown in *Table 2*, 12/75 hearts (16%) had Thebesian valves that met this definition. Examples of potentially complicating Thebesian valves are shown in *Figure 3A* and *B*.

We observed considerable variation in the diameter of the CS ostium. Heart specimens with absent Thebesian valves tended to have larger CS ostia. The transverse and craniocaudal dimensions of the CS ostia in hearts with Thebesian valves (7.3 ± 2.8 and 7.9 ± 2.7 mm, respectively) were significantly smaller when compared with those specimens with no Thebesian valve (9.4 ± 2.9 and 9.3 ± 2.9 mm, respectively, $P = 0.005$ and $P = 0.045$). We also observed that the maximum diameter of the CS ostium tended to vary inversely with the extent of the Thebesian valve.

Discussion

Failure to access the CS ostium has been ascribed to a prominent Thebesian and/or Eustachian valve. The Thebesian valve is potentially more troublesome than the Eustachian valve as it can directly cover the CS ostium. To date, only a few anatomic reports provide a detailed description of the cardiac venous anatomy and variations in Thebesian valve structure.[9–13] Obstruction and ostial narrowing by the Thebesian valve may complicate LV lead implantation. Our study shows that some form of Thebesian valve is present in >70% of the hearts examined. In specimens in which the valve

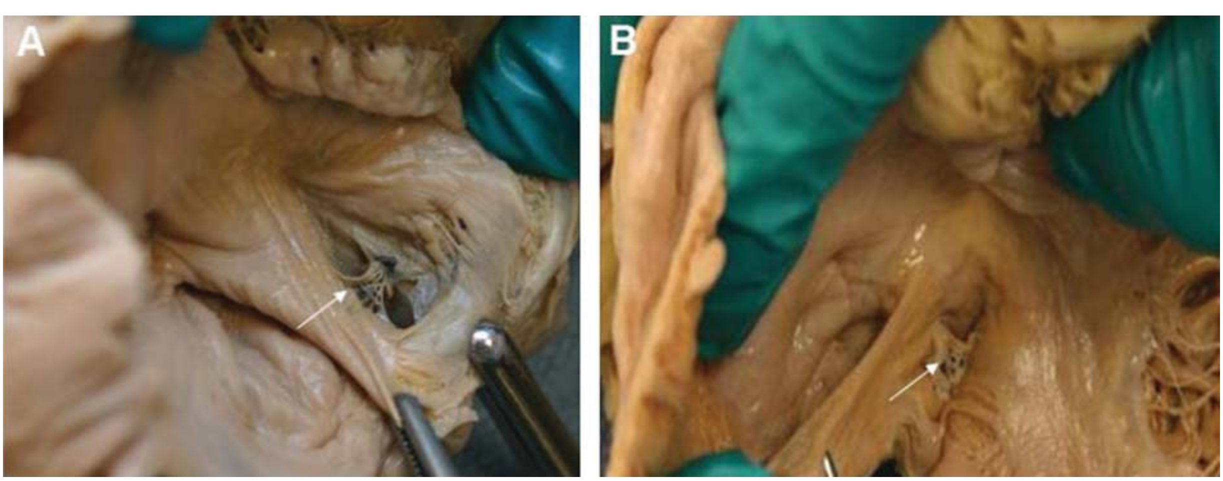

Figure 2 Examples of membranous Thebesian valves with fenestrations. Two autopsy heart specimens are shown in which the right atrium and right ventricle are cut open along the direction of blood flow. (*A*) A 'band-like' Thebesian valve (*white arrow*) that is attached from 9 o'clock to 7 o'clock and from 1 o'clock to 4 o'clock of the ostial margin of the CS. The cranial and caudal aspect of the CS ostium is devoid of any valve attachment. (*B*) A 'crescentic' Thebesian valve (*white arrow*) with attachments along the entire margins of the CS ostium except at the cranial most aspect. The valves shown in (*A* and *B*) are thin and fenestrated, and likely should not impede the passage of a catheter through the ostium.

Table 2 Percentage of heart specimens sorted by the composition of the Thebesian valve and the per cent coverage of the CS ostium

Composition	>75% coverage	50–74% coverage	25–49% coverage	10–24% coverage	<10% coverage
Membranous	10.9	9.1	10.9	7.3	7.3
Fibrous	5.5	1.8	3.6	3.6	9.1
Fibromuscular	5.5	1.8	1.8	3.6	0.0
Muscular	5.5	5.5	1.8	3.6	1.8

The box indicates the percentage of Thebesian valves of fibrous, fibromuscular, or muscular composition that cover >75% of the CS ostium and potentially interfere with cannulation of the CS.

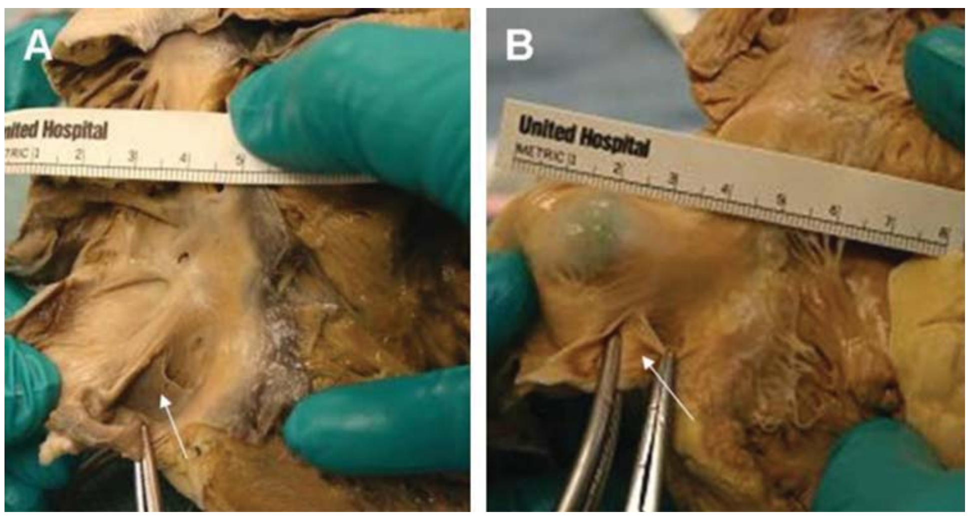

Figure 3 Examples of Thebesian valves that are fibromuscular, non-fenestrated, and occlusive. Two autopsy heart specimens are shown in which the right atrium and right ventricle are cut open along the direction of blood flow. (*A*) A non-fenestrated Thebesian valve (*white arrow*) that is fibromuscular and is seen to occlude ~80% of the ostium except for the cranial most aspect of the ostium. (*B*) A muscular, non-fenestrated Thebesian valve (*white arrow*) that occludes the entire CS ostium. To appreciate the CS ostium, the non-attached cranial most aspect of the valve has to be grasped with the forceps and peeled back. (*A* and *B*) Examples of Thebesian valves that potentially would interfere with CS cannulation (seen in 12/75—16% hearts).

was thin, membranous, and fenestrated, and where it covered <60% of the CS ostium, we believe that it would likely not hinder cannulation of the CS.

On the other hand, when the valve was non-fenestrated, covered >75% of the CS ostium, and was fibrous, fibromuscular, or muscular in composition, it had a potential to prevent cannulation of the CS. Although only a minority of hearts examined (16%) showed a valve that was 'potentially complicating', it is still a surprisingly substantial amount.

Prior autopsy studies showed that Thebesian valves are present in 65–95% of heart specimens and that a large variability in the morphology of these valves was present.[9–13] A recent study from Turkey showed that 8% of examined hearts had Thebesian valves that 'would result in low probability for CS cannulation'.[10] They defined Thebesian valve characteristics being 'worst for cannulation' if the Thebesian valve is fenestrated or band-shaped. Most invasive cardiologists, especially those familiar with CS catheterization technique, would disagree with this definition. A valve that is membranous, band-like, or fenestrated will likely not offer significant impediment to passage of a sturdy catheter. Similar to our findings, Silver and Rowley[11] found a potentially complicating Thebesian valve (covering >75% of the CS ostium) in 12% of the hearts examined.

Characterization of dynamic Thebesian valves

Recently, utilizing fibreoptic technology, Anh *et al.*[14] characterized human Thebesian valves by direct visualization during biventricular pacemaker implantation in 98 patients. A Thebesian valve was noted in 54% of the subjects. Almost all the valves were attached at the posterior (33%) or inferior (61%) margins of the CS ostium. A Thebesian valve covering >70% of the CS ostium was seen in only 6 of the 98 patients. The lower prevalence of Thebesian valve in their study maybe due to limitations of their technology in visualizing smaller valves, especially in the setting of dilated CS ostia. A second study conducted in isolated human hearts utilizing the Visible Heart® technology demonstrated the difficulties in cannulation of the CS when an obstructing Thebesian valve is present.[13]

Clinical implications

Coronary sinus cannulation is unsuccessful in 5–10% of the patients undergoing invasive cardiac procedures. Possible explanations include probing of the interatrial septum with the catheter at the incorrect location, and variations in operator skills and experience. An unrecognized problem is one where the CS is cannulated but the catheter cannot be advanced through the structure. Difficulties in advancing the catheter can be due to (i) a very tortuous proximal CS, otherwise referred to as CS with a 'compound curve',[15,16] or (ii) a CS with a very prominent valve of Vieussens.[17] A prominent Thebesian valve, such as those observed in this study, may be an under-recognized problem interfering with CS cannulation. Furthermore, it has been reported that an unrecognized obstructive Thebesian valve may pose a significant challenge with regards to coronary venous lead placement for cardiac resynchronization therapy.[18,19] Even though reports of inability to cannulate the CS are very infrequent, it is our belief that the true incidence of this problem is greater than has been reported.[14]

With the advent of imaging modalities, the anatomy of the CS and its tributaries may be depicted using multi-slice computed tomography (MSCT).[6,20] Until recently, we have come across only one report detailing the use of electron beam CT in the evaluation of CS ostium and Thebesian valve.[20] Although it may be difficult to image thin and membranous Thebesian valves, thick valves may be visualized. A very recent report showed that the Thebesian valve was imaged in 50% of the 201 patients who underwent MSCT.[21] If a thick valve is seen to be present, the operator should recognize the potential challenge in cannulating the CS. The concept of direct visualization of the valve using fibreoptic technology is intriguing as well.[14] During a particular procedure when the operator is unable to cannulate the CS, this technology can certainly be considered.

Limitations

Our findings and measurements were made in autopsied heart specimens that have been preserved with formalin and where changes in cardiac dimensions may have occurred. It may be difficult to generalize the observations of the study to intact humans in whom the heart and vessels are filled with blood. It is also noteworthy that because our observations and measurements were made in post-mortem heart specimens, the dynamic nature of the Thebesian valve and CS ostium could not be studied. In the intact living heart, CS ostial dimensions may change within the cardiac cycle.

Conflict of interest: A.J.H. is an employee of Medtronic CardioVascular. S.C.K. has received lecture honoraria in the past from St Jude Medical, Boston Scientific, and Medtronic Corporation and has commercialized intellectual property to St Jude Medical.

Funding

The data was obtained with the Medtronic Investigator Initiated Research Program Grant awarded to Dr. Krishnan.

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