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Prevalence And Sex-Related Structural Differences Of The Thebesian Valve In A Select Kenyan Population: Autopsy Study.

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ABSTRACT

Background

The coronary sinus is increasingly being used for cardiovascular interventional procedures. Thebesian valve, an endocardial remnant located at the coronary sinus opening into the right atrium, can hinder catheterization of the coronary sinus. The valve morphology varies between individuals. Despite its clinical relevance, data on its prevalence and morphology, particularly by sex, especially in African population, remain limited. Therefore, this study aimed to investigate the prevalence and sex-related structural differences in the Thebesian valves.

Methods

A total of 100 post-mortem hearts (63 males, 37 females) were examined. The coronary sinus and Thebesian valve were measured, photographed, and classified by morphology. Data were analyzed using appropriate statistical tests, including Mann-Whitney U and Spearman's correlation.

Results

The Thebesian valve was present in 73% of hearts and showed varied morphologies. Absence of the valve was associated with a larger coronary sinus opening. Percentage occlusion of the coronary sinus opening was higher in males, though sex-related structural differences were not statistically significant. Age showed no influence on valve morphology. Positive correlations were observed between heart size and coronary sinus dimensions.

In conclusion, the study highlights anatomical variations that may impact interventional procedures involving the coronary sinus.

Keywords: Thebesian valve, coronary sinus, prevalence, variations.

INTRODUCTION

The heart is a tissue organ that has both arterial supply and venous drainage(1). The coronary sinus (CS) is the central vein that runs in the coronary groove as a continuation of the great cardiac vein after the Valve of Viussens(2). The coronary sinus opening is frequently covered by a fold of endocardial remnant known as the Thebesian valve(3). This valve, which bears the name Adam Christian Thebesius in honour of the early anatomist, has drawn more attention due to its possible involvement in controlling heart function and blood flow dynamics(3). The function of this valve is believed to prevent the retrograde blood flow into the coronary sinus during atrial systole(4). The valve is characterised by a wide diversity of shapes and various studies have grouped them into various classifications(2). This valve has been studied and classified into various shapes and morphologies including fibrous, fibromuscular, muscular composition, and fenestrations which have different compositions and histological structures[4]. 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[5]. The advent of these procedures has led to a renewed interest in the anatomy of the coronary venous system including its various components[6]. 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[7]. This valve covers the coronary sinus at varying percentages making it potentially complicating during coronary sinus catheterization[8].

Age-related changes have been linked to heart valves, most especially to the tricuspid and bicuspid valves[9]. Thebesian valve may differ with age, just like other valves of the heart, which would influence its function[10]. Calcium deposition and fibrosis might be structural changes that affect valve performance[11]. Moreover, variations in the mechanical properties of the tissue might be ascribed to age-related modifications in the extracellular matrix re-modelling and collagen composition of the valve tissue[9]. These developments could have a significant effect on the C.S. catheterization during invasive cardiac operations, therefore causing ineffective coronary sinus catheterization[12]. Studies have shown that variations in the height of the valve might block the coronary sinus opening (CSO), therefore causing ostium to be obstructed[13].

Recent advances in treating heart failure and valvular heart disease, particularly with cardiac resynchronization therapy and percutaneous mitral valve repair, have renewed interest in the anatomy of the coronary venous system, especially the coronary sinus[4]. The CS is crucial for accessing the left atrial and ventricular epicardium during invasive procedures. Although the transvenous left ventricular (LV) lead placement success rate is high (88-95%), it fails in 5-12% of patients, often due to obstructive Thebesian valve[2,4,14]. Despite the increased use of the CS in procedures, its anatomy and variations, particularly in Black African populations, remain underexplored. Therefore, the study aims to investigate the prevalence, age and sex-related structural differences of the Thebesian valve in a select Kenyan population.

Broad Objectives

To determine the prevalence and sex-related structural differences of Thebesian valve in a select Kenyan population.

Specific Objectives

To describe the prevalence of morphologies and variations of coronary sinus opening and Thebesian valve in a select Kenyan population.

To determine the sex-related structural differences of the Thebesian valve.

To correlate coronary sinus length with coronary sinus dimensions.

METHODS

The study was a descriptive cross-sectional study. The hearts used in the study were obtained from the Kenyatta National Hospital Funeral Home, Nairobi City Mortuary and the Chiromo Funeral Parlor. The examination and data analysis were conducted at the Department of Human Anatomy, University of Nairobi. Cochran's formula[15] was used to determine the number of hearts to be harvested, which was estimated to be 100. For ethical approval, the Kenyatta National Hospital-University of Nairobi Ethics and Research Committee (KNH-UoN ERC) provided ethical approval number UP53/02/2024. The management of the individual mortuaries provided permission and the necessary authorities. The families of the deceased were contacted to get their informed consent before using any autopsy material. Kenyan laws, the Human Anatomy Act (Cap 249, 1976) and the Human Tissues Act (Cap 252, 1968), were followed to allow for the use of cadaveric materials. No unnecessary details were disclosed during data dissemination in the dissertation.

Inclusion Criteria

Specimens from all hearts of both sexes without any cardiac pathology were included in this study.

Exclusion Criteria

Subjects with a history of heart surgery or heart grafts, cardiomegaly i.e., hearts that weighed more than 450 grams, heart damage with macroscopic symptoms of decomposition, or any discernible congenital heart defects were excluded from the study. Moreover, autopsy specimens that had been retained for longer than 48 hours after death were excluded from the study.

Sampling method

Before the selection of the specimen used, available post-mortem specimens from the target population in each mortuary were stratified into different age groups. Systematic random sampling was used to select the subjects within different age groups from which samples were collected. The samples obtained were classified into sex.

Dissections and measurements

The chest cavity was opened through 'Y' incisions made on the costal cartilages that were just medial to the costochondral junction and cut through the capsular ligament to disarticulate the sternoclavicular joint and extend to the sternum. The heart was subsequently exposed by removing the sternum and making a longitudinal incision through the pericardium. Then, by cutting the proximal parts of the major vessels at the ligamentum arteriosus level, the heart was removed together with the base of the ascending aorta, pulmonary trunk, superior vena cava (SVC), inferior vena cava (IVC), and all of the pulmonary veins. The hearts were then weighed in grams using an electronic weighing balance SF-400c, and data were recorded on data sheets. The macroscopic features of the heart were examined. The height of the heart was measured from the apex of the heart to the base of great vessels and the width of the heart as the widest section of the heart. The measurements were taken using an electronic Vernier Callipers version CVU 200m(zero error = +0.02). An incision was made on the right atrium from the SVC orifice to the IVC orifice. If necessary, additional incisions were made on the right border of the RV to expose the T.V. better. Situated between the tricuspid valve and the inferior caval orifice, the coronary sinus ostium was located on the posterior wall of the right atrium. The target structures of the study, i.e., coronary sinus ostium and Thebesian valve were kept intact and then inspected in each specimen as shown in *Figure 1*. The length of the coronary sinus was measured as a continuation of the Great Cardiac vein at the Valve of Viuessens up to the opening of CSO at the Thebesian valve using an electronic vernier calliper. Images of the coronary sinus opening and Thebesian valve were taken while the heart was in anatomical position for the classification of the valves into various morphologies as described in *Table 1.* The valves were classified as per the classification by Slawet et al.,(2021)[(2)].

Transverse and craniocaudal(longitudinal) diameters of the CSO were measured as shown in *Figure 3* and the CSO percentage occlusion was calculated according to the commonly used Mehra's formula for the surface area of an ellipse (π

× half the vertical dimension × half the transverse diameter)[16]. The presence of Thebesian was noted and if present, the height of the TV was measured from the posterior or inferior side. Its shape was observed and recorded in the data collection sheet. All the measurements were made using electronic vernier callipers while the heart was anatomically positioned relative to the live body. Measurements were repeated thrice and the average was calculated and recorded as the measurement. The images to classify the valve into various morphologies were taken by the research assistant while the principal investigator was holding the heart and the valve in its anatomical position.

Statistical analysis

All values were standardized to the heart weight of the specimens by deriving indexes as follows: $Standardized\ value = \frac{X\ value}{Heart\ weight} \times 100\%$. After being coded, the morphometric data were loaded into SPSS (version 27.0 for Windows 11, Chicago, Illinois, USA) for statistical analysis. The normality of the data was tested using Kolmogorov- Smirnov test where normal data was expressed in means and standard deviation. Data which were not normally distributed were analyzed using median and interquartile ranges for descriptive statistics. Morphometric results were statistically analyzed for independent variables. Kruskal–Wallis was used to compare the structural differences of Thebesian valves among various age groups. Mann – Whitney U test was used to compare structural differences of the Thebesian valve between males and females. Spearman's Rank-Order correlation test was used for the correlation between gross morphometry parameters of the hearts with the diameter of the coronary sinus. A p-value of <0.05 was considered significant. Photographs and tables were used.

RESULTS

Out of the 100 hearts studied, 63 were males and 37 were females. The median age for the specimen was 37 years ranging from the minimum age of 17 years to maximum age of 88 years. The interquartile range was from 28 to 49. The median weight for the hearts was 289.00 grams in males and 284.16 grams in females.

Morphology of Thebesian valve

The coronary sinus was located on the inferior aspect of the left atrium course on the left atrioventricular groove in all the 100 heart specimens. The majority of Thebesian Valves were observed to originate from either the inferior (67%) or posterior (33%) aspect of the coronary sinus opening. The mean length of the coronary sinus was 38.61mm in males and 36.27 mm in females. The coronary sinus opening was located on the right atrium lateral to the opening of the Inferior Vena Cava.

Heart specimens with absent Thebesian valves for both males and females tended to have larger CS Ostia as shown in *Table 2*. The transverse and craniocaudal dimensions of the CS ostia in hearts with Thebesian valves were 8.16±2.34 mm and 8.24±2.33 mm in males and 7.91 ± 1.48 and 8.07 ± 1.55 mm in females respectively. The transverse and craniocaudal diameters of hearts with TV were significantly smaller when compared with those specimens with no Thebesian valve as shown in *table 2* below. The maximum diameter of the CS ostium tended to vary inversely with the extent of the height of the Thebesian valve.

A wide variety of Thebesian valve morphologies were seen as seen in *Figure 9*, including remnant fold valves (covering <10% of the ostium) and valves that almost completely occluded the CS ostium as shown in *Figure 2*.

The Thebesian valve was absent in 27 of the 100 hearts examined (27%) 17/27(63%) in males and 10/27(37%) in females. A typical example of a coronary sinus opening with an absent Thebesian valve is shown in *Figure 3*. In 12/73 hearts (16.4%)of hearts with a Thebesian valve, the valve was large and covered at least 75% of the CS ostium, whereas the valve covered <10% of the ostium in 25/73 hearts (34.24%).

Various morphologies of the Thebesian valve were noted as shown in *figure 5*. Most T.V. were semilunar in shape (42/73-57.5% of heart specimens, males- 28/42 -, females 14/42). In a minority of specimens, the valve was a fused strand (5/73—6.8% males - 3/5, females – 2/5) or chord strand (9/73-12.3% males – 5/9, females 4/5) as shown in *Table 3* below. We also noted a Y-shaped valve which was a subtype of fused strands Thebesian valve as shown in Figure 4.

Sex-related structural differences on of Thebesian valve

There were similarities and slight differences between males and females across various structural parameters of the heart parameters and Thebesian valve as shown in *table 4* below. The median ages for males and females were 36 and 27 respectively. The interquartile range for both genders showed a similar range from 27 to 54 years. In terms of morphometric measurements, such as height and width of the heart, females exhibit median values of 105.30 mm and 95.73 mm, respectively, compared to males with nearly identical median values of 106.42 mm and 95.84 mm. The length of the coronary sinus ranges from 33.66 mm to 41.43 mm for both males and females, indicating consistency across genders. However, there are notable differences in certain aspects, such as the percentage occlusion of the Thebesian valve, where females have a median of 32.00% compared to males with 65.42. The mean percentage occlusion in males was higher in males than in females ie 50.76% and 44.39% respectively.

Table 5 summarizes the variables with their corresponding p-values from the Mann-Whitney U tests comparing males and females for various structural parameters of the Thebesian valve

The p-values indicate that for every structural characteristic of the Thebesian valve examined between males and females, all of them are above 0.05, implying that there are no statistically significant variations between males and females for the data present.

Correlation between CS parameters and gross heart parameters

The coronary sinus (CS) parameters showed a positive significant correlation with gross heart parameters as shown in table 6. The weight of the hearts showed a strong positive correlation with the CS length ($p < 0.001$), and CSO transverse diameter ($p = 0.028$) Additionally, the CS length was positively correlated with the CSO transverse diameter (rho = 0.414, $p < 0.001$) and CSO craniocaudal diameter (rho = 0.262, $p = 0.009$). The table below summarizes the findings.

DISCUSSION

Our study showed the Thebesian valve (TV) was present in 73% of the hearts examined. Similar findings were obtained in previous studies as shown in *Table 7*. The valve types were either semilunar, chord, fused strands, remnant fold and fenestrated in both males and females and across the various age groups. Two fenestrated valves that covered >75% of the coronary sinus opening(CSO) were found. It has been noted that fenestrated valves could potentially occlude cannulation of the CS(17). 16.4% of hearts that had TV as 'potentially complicating', was in cross range with Gami et al, Anh et al and Ghosh et al as shown in ***Table 9***(17–19). These potentially occlusive TV may require the cardiologist to use the appropriate size of catheter to prevent fatal injuries to the CS or inside the right atrium(7).

The TV exhibits variations in its occurrence, size, shape, and extent of coverage(20). According to the literature, the occurrence of TV varies across different studies from 65% to 95% as shown in table 8(4,7,17–24). Contrary to our study, imaging studies record a lower prevalence of TV which records 36% due to the coronary sinus dynamic nature in a live body, especially during atrial systole(25). Imaging studies record a lower prevalence of TV due to failure of fiberoptic technique to visualize remnant valves and the CS may be dilated(18).

In this study, the classification suggested by Holda et al. was considered(20). Five types of TV have been described, with the most common type being type II (semilunar). While fold, cord/band, fenestrated, and mesh types which have ostial coverage <75% might cause difficulty in cannulation due to the possibility of entanglement of CS catheter, the fibrous type with ostial coverage >75% might obstruct CS cannulation leading to failure of interventional cardiac procedures. According to Hill et al, endoscope visualization might help for successful cannulation of such valves(14).

The attachment TV in the current study from the inferior margin (63%) or posterior margin (27%) of the CSO was a similar finding by Mak et al who found that 33% of the posterior margin and 61% from the inferior margin of the coronary sinus opening(4).

In this study, 5 hearts showed the TV closing 90-100% of the CSO. Valves that cover the CSO completely have been recorded and shown to cause obstruction of CSO(2,26). This implies that visualization of CSO before the catheterization is important as there may be a valve that may occlude the CSO. A recent study from Turkey showed that 8% of examined hearts had TV that 'would result in low probability for CS cannulation due to obstruction by TV. They defined TV characteristics as being 'worst for cannulation' if the TV is fenestrated or band-shaped(23). Most cardiologists, especially those familiar with the CS catheterization technique, would disagree with the definition as imaging can be used and avoid obstruction. Similar to our findings, Silver and Rowley found potentially complicating TV (covering >75% of the CS ostium) in 12% of the hearts examined(27).

Sex-related structural differences of Thebesian valve

There were no significant differences between males and females in the length of the CS, transverse diameter, and craniocaudal diameter of the CSO. Similar findings were found by Verenna et al., (2015) who also did not find sex differences in CS parameters and heights of TV(13). The difference found in the standard deviation of the parameters of the heart might be due to hormonal differences between males and females (28). This indicates that gender does not significantly influence these heart morphometric parameters in the population studied(29).

Percentage occlusion which was significantly higher in males than in females may have been caused by higher means of TV height in males than in females which may have been caused by hormonal and genetic differences (29). Similar findings of percentage occlusion of CSO where males had higher occlusion than females were recorded by Verenna et al (13). This highlights the need for imaging that during CS catheterization for successful procedures.

Correlation between heart morphometry and coronary sinus parameters

The size of the coronary sinus ostium (CSO) is important during the catheterization of the CS (2).The weight of the hearts showed a strong positive correlation with the CS length, and CSO transverse diameter but no significant correlation with the CSO craniocaudal diameter which were similar to Kucybala et al.(30). Additionally, the CS length was positively correlated with the CSO transverse diameter and craniocaudal diameter. This is in line with a study done in the Kenyan population which correlated CS length with gross parameters of the heart and right atrium size (31).This suggests that longer CS tend to have wider transverse and craniocaudal diameters at the CSO. Similar positive correlations between gross heart parameters and CS parameters have been noted in a previous study(2).

Awareness of the length of the CS may facilitate the pre-procedural planning and selection of appropriate size, thickness, length and angulation of catheter and reduce the procedure time and the risk of potential complications during left ventricular lead placement(2).

Limitations

The study was based on heart specimens from autopsies, lacking physiological in vivo haemodynamic conditions, which might have introduced measurement bias. Additionally, the dynamic nature of the TV and CSO couldn't be observed, as these dimensions may vary during the cardiac cycle in living hearts. The study focused solely on anatomical evaluation without microscopic correlations.

Strengths

TV and CS were obtained within 48 hours after death to minimize autolysis and tissue shrinkage unlike most of the studies on coronary sinus and its Thebesian valve which used cadaveric specimens fixed with formalin. All heart measurements were taken in its anatomical position to mimic the position of the heart in a live body.

RECOMMENDATION

The study recommends further microscopic study of the TV where variations to check on collagen density on the various valve types. In addition, the study recommends multicentred study from various regions with a larger sample size to investigate the structural differences of TV in various age groups.

CONCLUSION

The study highlights the morphological variation of the Thebesian valves between males and females and its potential implications in unsuccessful CS cannulation and failure of invasive cardiac procedures. We identified 5 main types of TV. Only 16.4% of the TVs in our sample could potentially occlude the CSO.This study provides unique insight into the anatomy of the CS, which might facilitate successful CS catheterization. The findings can contribute to a better understanding of cardiovascular anatomy and may have implications for clinical practices involving the CS.Thus, detailed anatomical knowledge about the morphology of the TV is pivotal to planning and adapting procedural strategies during various invasive cardiac procedures.

Conflict of Interest

There was no conflict of interest in the study

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TABLES AND FIGURES

Table 1 shows the description of Thebesian valve morphologies.

Type	Name	Description
I	Remnant fold	Residual endocardial flap around the perimeter, that covers <10% of the total CSO area
II	Semilunar	The crescentic endocardial flap covering the CSO in variable degree
III	Fenestrated	Cribriform, net-like valve mostly semi-lunar shaped
IV	Chord strand	A simple endocardial band mostly in the midline of the CSO.
V	Fused strands	Connected in different manners endocardial strands localized mostly in the midline

Table 2 shows the mean of the transverse and craniocaudal diameter of the coronary sinus opening of hearts with Thebesian valves.

Parameter	Sex	With Thebesian valve (mean ±SD)	Without Thebesian valve (Mean ±SD)	p-value
Transverse diameter(mm)	Male	8.16±2.34	8.38±0.95	0.009
	Female	7.91±1.48	8.25±1.78	0.005
Craniocaudal diameter(mm)	Male	8.24±2.33	8.42±1.64	0.036
	Female	8.07±1.55	8.43±1.32	0.045

Table 3 shows frequencies and percentages of various morphologies of the valve

Type of Valve	Name	**Frequency**	Percentage(x/73 ×100%)
I	Fused strands	5	6.8
II	Semilunar	42	57.5
III	Remnant fold	6	8.2
IV	Chord strand	9	12.3
V	Fenestrated	11	15.1

Table 4 shows a summary of variables of gross heart parameters.

Variable	Median		25th Percentile		75th Percentile		p-value.
	Median males	Median females	25th Males	25th Females	75th Males	75th Females	
Weight	0.285	0.265	0.323	0.285	0.265	0.323	0.015
Height	105.30	99.61	112.13	105.30	99.61	112.13	<0.001
Width	95.73	92.01	99.80	95.73	92.02	99.80	<0.001
Length of CS	38.54	33.66	41.43	38.54	33.66	41.43	<0.001

Table 5 summarizes the variables with their corresponding p-values from the Mann-Whitney U tests comparing males and females for various structural parameters of the Thebesian valve.

Table 6 below shows Mann-Whitney U tests comparing males and females for various structural parameters of the Thebesian valve.

Variable	Median differences (Mann-Whitney U)	P - value
Length of Coronary Sinus (mm)	1142.50	0.164
Transverse diameter of CSO (mm)	1107.00	0.418
Craniocaudal diameter of CSO (mm)	1150.00	0.111
Height of Thebesian valve	1054.50	0.800
Percentage Occlusion of TV	1054.00	0.128

The p-values indicate that for every structural characteristic of the Thebesian valve examined between males and females, all of them are above 0.05, implying that there are no statistically significant variations between males and females for the data present.

Table 6 shows correlations between CS parameters and gross heart parameters

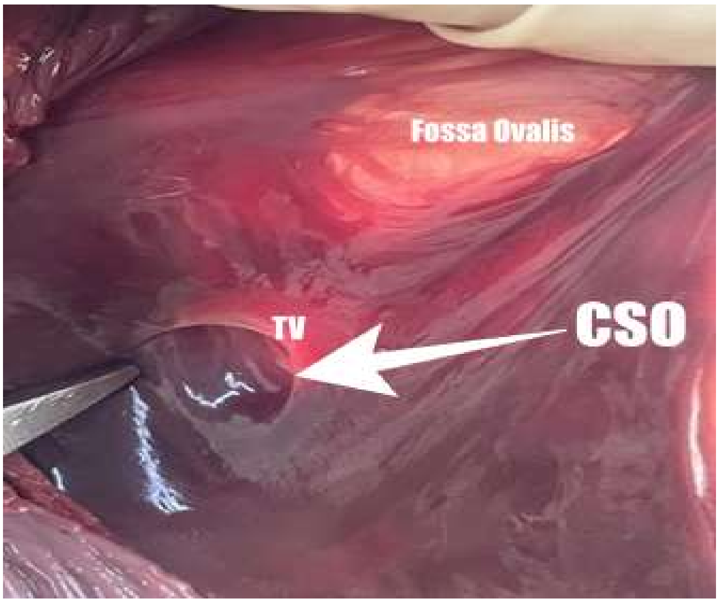
Characteristic variables	CS length		CSO Transverse diameter		CSO Craniocaudal diameter	
	rho	p-value	rho	p-value	rho	p-value
Weight of the hearts	0.465	<0.001	0.219	0.028	0.143	0.155
Height of the hearts	0.260	<0.001	0.360	<0.001	0.195	0.052
Width of the hearts	0.467	<0.001	0.400	<0.001	0.220	0.028
CS length	-	-	0.414	<0.001	0.262	0.009

Table 7 shows the comparison between the present study and those conducted previously

Name of author	Sample population	Type of specimen used	Number of hearts with TV	Number of hearts with occlusive TV
Present study	100	Autopsy	73(73%)	12(16.4%)

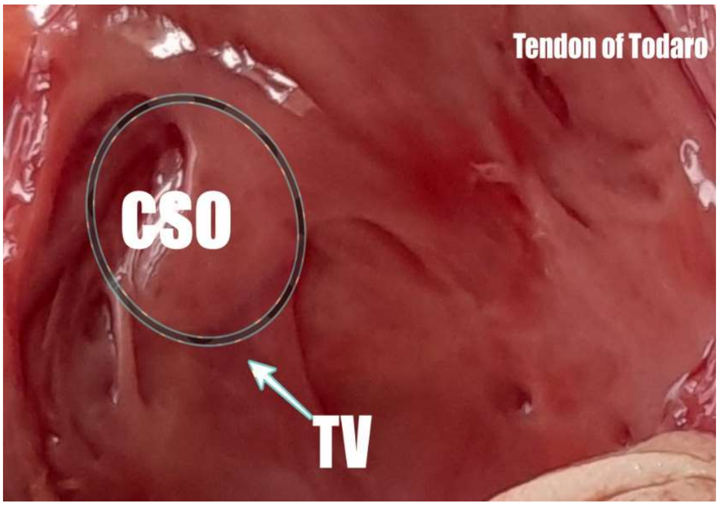
Holda et al	273	Cadaveric	224(82 %)	39(14.3%)
Gami et al	560	Cadaveric	348(82 %)	71(12.5%)
Mlynarski et al	150	Multislice computed tomography	69(46%)	-
Ghosh et al	150	Cadaveric	118(79 %)	27(18%)
Hellerstein and Orbison	150	Cadaveric	128(85)	37(24.7%)
Anh et al	98	In vivo	53(54%)	11(11%)
Mak et al	75	Cadaveric	55(73%)	12(16%)
Keraca et al	52	Cadaveric	35(67%)	4(8%)
Katti and Patil	50	Cadaveric	44(80%)	10(20%)
Randhawa et al.	50	Cadaveric	32(64%)	8(16%)

Figure 1 Coronary Sinus Opening with Thebesian Valve



Legend: The figure above shows an intact Coronary Sinus Opening(CSO) with a Thebesian Valve(TV) located in the right atrium of the heart.

Figure 2 shows the coronary sinus opening completely occluded by the Thebesian valve.

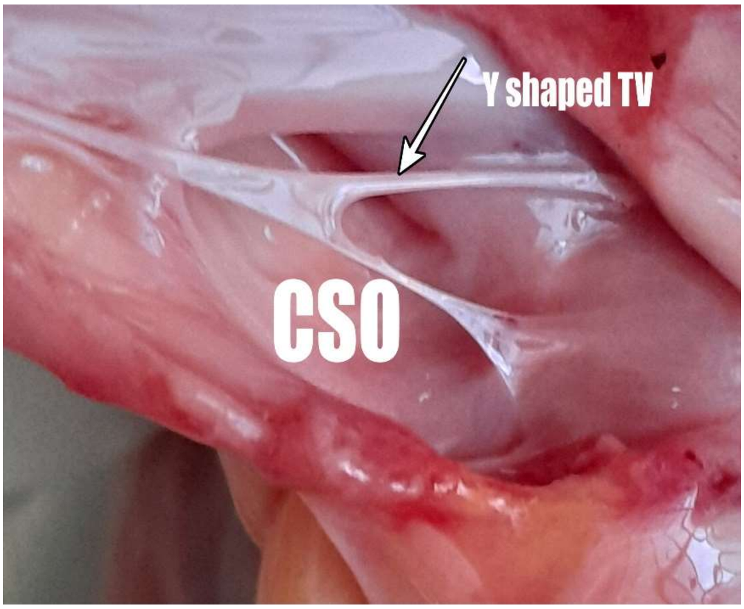


Legend: The figure above shows a coronary sinus opening(CSO) that is fully occluded by the Thebesian valve. Note that the free margin of the valve is covering even the periphery of the coronary sinus opening. TV – Thebesian valve, CSO – coronary sinus opening

Figure 3 shows a coronary sinus opening without a Thebesian valve

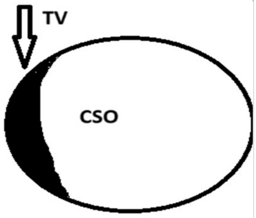
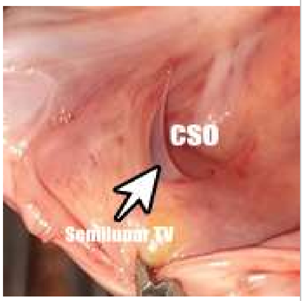
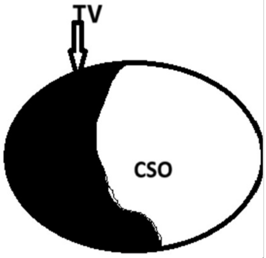
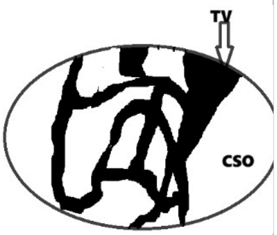
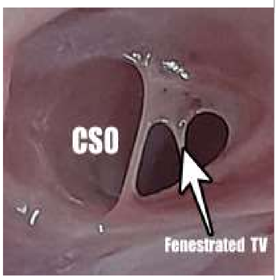
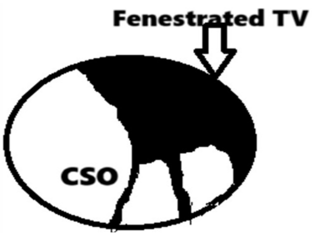
Legend: Figure above shows Coronary sinus Ostia with absent Thebesian valves. CSO – coronary sinus opening.

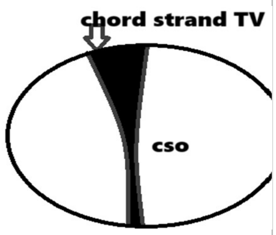
Figure 4 shows a Y-shaped fused type of Thebesian valve.



Legend: The figure above shows a Y-shaped Thebesian valve which is a subtype of fused strands subtype. CSO-coronary sinus opening. TV – Thebesian valve.

Figure 5 Various morphologies of Thebesian valve.

Type	Sample 1	Sample 2	Drawing
I Remnant fold			
II – Semilunar			
III- Fused strands			
IV- Fenestrated			

V – Chord strand			

Legend: The table above shows various morphologies of the Thebesian Valve. CSO - Coronary Sinus Opening, TV - Thebesian Valve Type I -Remnant fold, Type II – Semilunar valve, Type III – fused strands, Type IV- fenestrated valve, Type V – chord strand. Using the images taken, we outlined the various types of valves as shown above.