

Morphometric Analysis of Aortic and Pulmonary Orifices and their Valvular Components: A Cadaveric Study with Clinical Implications

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Abstract

Background: For the success of cardiovascular surgeries such as the Ross procedure, transcatheter valve interventions, and the designing of prosthetic valves detailed morphometric knowledge of the aortic and pulmonary orifices, including their semilunar valves, is crucial. This study aims to provide a comprehensive morphometric analysis of the aortic and pulmonary roots and their valvular components in human cadaveric hearts. **Material and Methods:** A descriptive observational study was conducted on 30 adult human formalin-fixed cadaveric hearts. Measurements of the aortic and pulmonary orifices were taken using a measuring scale and thread. Parameters recorded included internal circumference, external circumference, and dimensions of the semilunar cusps (depth and lunule dimensions). **Results:** The mean internal and external circumferences of the aortic orifice were $[6.68\text{cm} \pm 1.658\text{cm SD}]$ mm and $[8.56\text{cm} \pm 1.48\text{cm}]$ mm, respectively. For the pulmonary orifice, the internal and external circumferences were $[6.14\text{cm} \pm 0.95\text{cm SD}]$ mm and $[8.21\text{cm} \pm 1.12\text{cm}]$ mm. The average depth of the aortic cusps was $[1.15\text{cm} \pm 0.17]$ compared to $[1.13\text{cm} \pm 0.129]$ for the pulmonary cusps. The average depth of the aortic lunule was $[1.05\text{cm} \pm 0.15\text{cm}]$ compared to $[1.08\text{cm} \pm 0.146\text{cm}]$ for the pulmonary lunule. The differences in dimensions between the aortic and pulmonary parameters were analyzed using the paired Student's t-test. A p-value of <0.05 was considered statistically significant. **Conclusion:** The pulmonary orifice and its cusps exhibit specific dimensional relationships with the aortic orifice. Precise anatomical baseline data provided in this study is vital for cardiothoracic surgeons to prevent sizing mismatches during valve replacement and reconstructive surgeries.

Keywords: Aortic orifice & Valve, Pulmonary orifice & Valve, Coronary ostia, Ross Procedure, Morphometry, Anatomy, Cadaver, Indians, Semilunar Cusps.

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INTRODUCTION

In the human heart, the roots of the aorta and pulmonary trunk, along with their respective semilunar valves, act as crucial hemodynamic gateways. During diastole the complex geometric configuration of these roots—comprising the annulus, the semilunar cusps (leaflets), the sinuses of Valsalva, and the sino-tubular junction—ensures unidirectional, low-resistance blood flow and competence.^[1] Understanding the precise Morphometry of these structures is no longer merely of academic anatomical interest. To prevent complications such as paravalvular leak, conduction blocks, or coronary occlusion in the minimally invasive procedures like Transcatheter Aortic Valve Implantation (TAVI) and Transcatheter Pulmonary Valve Replacement (TPVR), exact anatomical dimensions are required.^[2] Furthermore, the Ross procedure heavily relies on the anatomical similarity and dimensional compatibility between the pulmonary and aortic roots, as it utilizes the patient's own pulmonary valve to replace a diseased aortic valve.^[3] The dimensions of the valvular components, specifically the depth of the cusps and the size of the lunules, determine the competence of the valve. Variations or asymmetry in these dimensions can predispose individuals to valvular regurgitation or stenosis.^[4] While several studies have evaluated these roots

radiologically, cadaveric studies provide direct, precise physical measurements that serve as the gold standard for anatomical baseline data. Therefore, this study aims to comprehensively evaluate the Morphometry of the aortic and pulmonary orifices, comparing their internal and external circumferences, and detailing the dimensions of their cusps (depth and lunule) in an adult cadaveric population.

MATERIALS AND METHODS

Study Design and Specimen Collection: The cross-sectional study was conducted after obtaining Institutional Ethical Committee Clearance No: KIMS/IEC/A393/M/2026 from IEC of Kempegowda Institute of Medical Sciences, Bangalore 560070.

The study sample size was 30 adult human hearts obtained from

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the routine dissection of MBBS teaching in the Department of Anatomy.

The hearts were dissected out during routine MBBS teaching and preserved in 10% formalin. Hearts with gross pathological changes, such as visible valvular vegetations, severe calcification, evidence of previous cardiac surgery, were excluded from the study.

Dissection and Measurement Protocol: The aorta and pulmonary trunk were carefully dissected and transected approximately 1-2 cm above the sino-tubular junction to expose the semilunar valves. The roots were gently flushed with water to remove any clots or debris. All measurements were taken twice by a single investigator using a measuring scale and a non-stretchable measuring thread and the average was recorded to minimize observer bias.

Parameters Measured

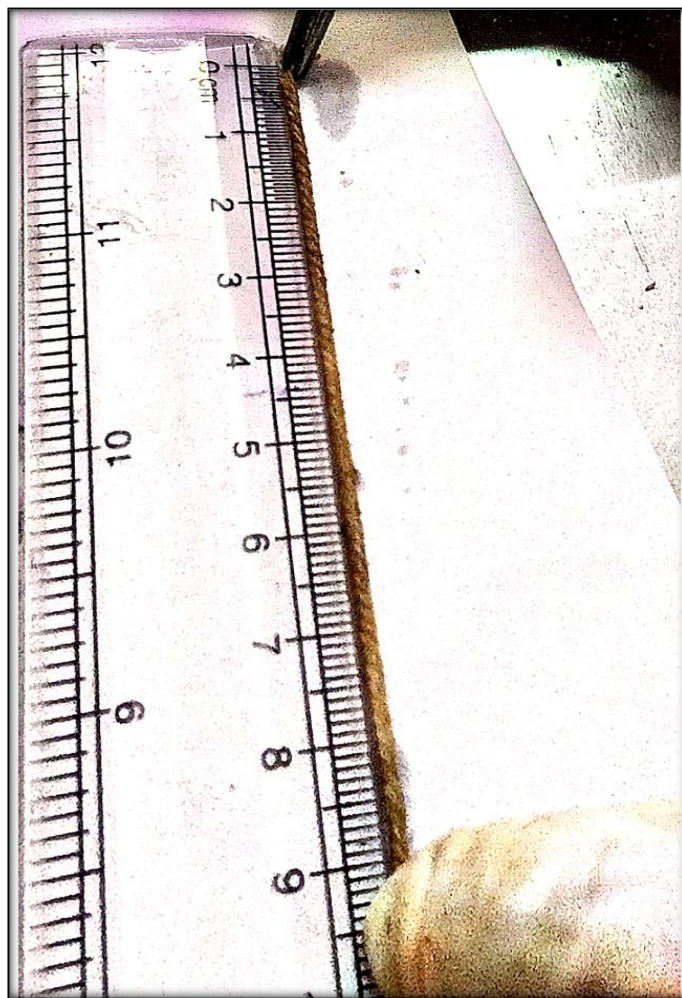
1. Internal Circumference: Measured at the level of the anatomical ventriculo-arterial junction (basal ring) using a standardized measuring thread laid along the internal contour.

2. External Circumference: Measured externally at the level corresponding to the internal basal ring.

3. Cusp Depth: The vertical distance from the nadir (lowest point of the attachment) of the cusp to the midpoint of its free margin (nodule of Arantius).

4. Lunule Size: The length from nodule to the wall along the free margin of cusp (lunule) were measured for each cusp. (Both Aortic and Pulmonary valves.)

5. Size (Antero-posterior & Transverse diameters) of the coronary ostia were measured using divider and measuring scale.



Measurement using thread and scale.



Measurement of External diameter of Aortic orifice.



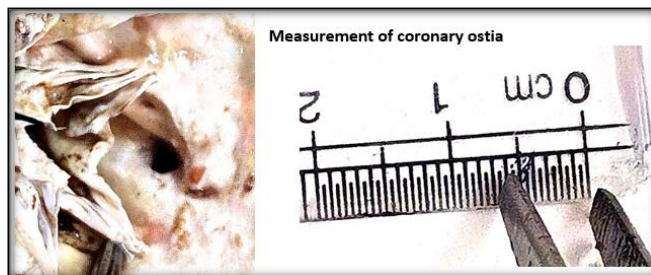
Measurement of external diameter of Pulmonary orifice.



Diagram showing measuring coronary ostia size.



Measurement of internal diameter



Statistical Analysis: Data were tabulated in Microsoft Excel and analyzed using [Insert Software, e.g., SPSS version 26.0]. Continuous variables are expressed as Mean $\pm$ Standard Deviation (SD) and range. The differences in dimensions between the aortic and pulmonary parameters were analyzed using the paired Student's t-test. A p-value of <0.05 was considered statistically significant.

RESULTS

From the data obtained by studying $n=31$ specimens, one specimen had only 2 valves in the aortic orifice.

Table 1: Statistical analysis of Aortic orifice

	AORTIC ORIFICE			
	Internal circumference in cm	External circumference in cm	Size of the valves	
			X=depth [in cm]	Y= Lunule [in cm]
Average	6.68	8.56	1.15	1.05
Standard deviation	1.658	1.48	0.17	0.15
Median	6.5	8.5	1.2	1.05
Area	3.57cm ²	5.7cm ²		

Table 2: Statistical analysis of Pulmonary orifice

	PULMONARY ORIFICE			
	Internal circumference in cm	External circumference in cm	Size of valves	
			A = depth[in cm]	B = lunule[in cm]
Average	6.14	8.21	1.13	1.08
Standard deviation	0.95	1.12	0.129	0.146
Median	6.2	8.1	1.1	1.1
Area	3cm ²	5.2cm ²		

Table 3: Measurements and statistical analysis of Coronary ostia

	Coronary OSTIA		
	No. of ostia[n=30]	Right [AP & Transverse diameters] in cm	Left[AP and Transverse diameters] in cm
	N=3 had only one coronary ostium].	Right ostium absent n=1	Left ostia absent in n=2
Average		0.486	0.558
Standard deviation		0.115	0.122
Median		0.5	0.6
Area		0.125cm ²	0.24cm ²

Circumferential Measurements: The mean internal circumference of the aortic orifice was $[6.68\text{cm}] \pm [1.658\text{cm SD}]$ mm (Range: [Min]-[Max] mm), whereas its external circumference was $[8.56\text{cm}] \pm [1.48\text{cm}]$. In comparison, the pulmonary orifice exhibited a slightly [smaller] internal circumference of $[6.14\text{cm}] \pm [0.95\text{cm SD}]$ and an external circumference of $[8.21\text{cm}] \pm [1.12]$ cm. The difference between the internal circumferences of the two orifices was statistically significant. The differences in dimensions between the aortic and pulmonary parameters were analyzed using the paired Student's t-test. A p-value of <0.05 was considered

statistically significant.

Cusp Dimensions: Depth and Lunule

Analysis of the semilunar cusps revealed dimensional variations. Aortic Cusps: Mean depth of Aortic cusps is $[1.15\text{cm}] \pm [0.17]$ cm. Mean size of lunule is $[1.05\text{cm}] \pm [0.15]$ cm

Pulmonary Cusps: Mean depth of pulmonary cusps is $[1.13\text{cm}] \pm [0.129]$ cm. Mean size of lunule is $[1.08\text{cm}] \pm [0.146]$ cm

Measurements of coronary ostia: Out of 30 specimens 3 specimens have only one coronary ostium. Among these right coronary ostium is absent in one specimen and left coronary ostium is absent in 2 specimens. Mean diameter of right coronary

ostium is $[0.486 \text{ cm}] \pm [0.115 \text{ cm SD}]$ and Mean diameter of left coronary ostium is $[0.0122 \text{ cm}] \pm [0.122 \text{ cm SD}]$.

DISCUSSION

The present study provides a detailed morphometric baseline of the aortic and pulmonary orifices and their cusps in, Indian population. The precise geometry of these structures is fundamental to normal cardiac hemodynamics.^[1]

M.N. Islam, et al study done on bovine hearts in 2005 showed mean height of aortic cusps as 14.38mm, mean length of lunule being 30mm.^[6] Similar study was done on 20 bovine hearts by Akhtar S. et al, in 2011 also showed mean height as $25.2 \pm 2.59 \text{ mm}$, length of cusps being $31.2 \pm 4.2 \text{ mm}$.^[7]

In 1984, Steve Westaby, et al study on 160 adult human hearts, including hearts, showed circumference of normal aortic orifice as $7.28 \pm 0.92 \text{ mm}$, diameter as $23.20 \pm 3.3 \text{ mm}$; also pulmonary orifice circumference as $7.63 \pm 0.93 \text{ mm}$ and diameter of $24 \pm 3.0 \text{ mm}$.^[5] Our study shows the mean internal circumference of the aortic orifice was $[6.68 \text{ cm}] \pm [1.658 \text{ cm SD}]$ mm whereas its external circumference was $[8.56 \text{ cm}] \pm [1.48 \text{ cm}]$. In comparison, the pulmonary orifice exhibited a

slightly [smaller] internal circumference of $[6.14 \text{ cm}] \pm [0.95 \text{ cm SD}]$ and an external circumference of $[8.21 \text{ cm}] \pm [1.12 \text{ cm}]$. Our study was done on those adult human hearts without any gross anatomical defects.

In 2013, the study by Mukhia R., et al., done on 25 adult human Indian cadavers showed mean aortic circumference measured as 7.9 ± 0.9076 [10] our study results are higher than this study. We got slightly higher mean value of external circumference of both aortic and pulmonary orifice.

2012 study by Dalbir Kaur, et al., on 77 cadaveric adult human heart of south Indian population, measuring coronary ostia, right being $3.9 \pm 1.0 \text{ mm}$ & left $4.6 \pm 1.0 \text{ mm}$.^[9] Our study shows similar results of diameters of both the ostia on 31 hearts in south Indian population.

Another study in 2024 by Adithya Narayan, et al., on cadaveric 41 adult human hearts from Prayagraj, Aortic root circumference as $8.4 \text{ cm} \pm 2.25$; cusp length $12.25 \text{ mm} \pm 2.62$, cusp length $25.5 \text{ mm} \pm 6$.^[13]

Our results - Mean depth of Aortic cusps is $[1.15 \text{ cm}] \pm [0.17 \text{ cm}]$. Mean size of lunule is $[1.05 \text{ cm}] \pm [0.15 \text{ cm}]$.

Pulmonary Cusps: Mean depth of pulmonary cusps is $[1.13 \text{ cm}] \pm [0.129 \text{ cm}]$. Mean size of lunule is $[1.08 \text{ cm}] \pm [0.146 \text{ cm}]$. Our study results are lesser than the above study done in 2024.

Table 4: Discussion of results

Year	Author	Aortic circumference	Cusp depth and width	Pulmonary orifice circumference	Cusp depth and width	Coronary ostia right	Coronary ostia Left
1984	Steve Westaby	$7.28 \pm 0.92 \text{ mm}$,		$7.63 \pm 0.93 \text{ mm}$			
2005	M. N. Islam, et al.,	Bovine-	14.38mm		30mm.		
2011	S. Akhtar et. al.,		$25.2 \pm 2.59 \text{ mm}$		$31.2 \pm 4.2 \text{ mm}$		
2013	Rajeev Malhotra, et al.,	Human 7.9 ± 0.9076	23mm				
2012	Dalbir Kaur, et.al.,	Human -	-	-	-	$3.9 \pm 1.0 \text{ mm}$	$4.6 \pm 1.0 \text{ mm}$
2024	Adithya Narayan, et al.,	Human 8.4 ± 1.4	25.02 mm [I] 11.41 ± 3.19 [H]	-	-	-	-
Our study (2026)	Present study	Human Int. circ. 6.68 ± 1.68 Ext. circ. 8.56 ± 1.48	H- $1.15 \text{ cm}] \pm 0.17$ Length- 1.05 ± 0.15	Int. circ. 6.14 ± 0.95 Ext. circ. 8.21 ± 1.12	H- 1.13 ± 0.129 L- 1.08 ± 0.146	0.49 ± 0.11	0.56 ± 0.12

Limitations

The limitations of this study include its cadaveric nature; formalin fixation is known to cause mild tissue shrinkage, typically estimated at 2-5%. Therefore, the in vivo dynamic dimensions might vary slightly from our static measurements. Additionally, the age and exact cause of death for all specimens were not available, precluding age-stratified analysis. Even the number of specimens $n=31$ is a limitation. It could be extended to $n=\text{more number of specimens}$.

CONCLUSION

Detailed morphometric profile of the aortic and pulmonary orifices and their valvular components are established in this study. Significant, quantifiable differences in the

circumferences and cusp dimensions between the two roots are observed. Understanding these precise dimensions, particularly the depth of the cusps and the size of the lunules, is imperative for cardiothoracic surgeons and biomedical engineers. These anatomical baselines will aid in improving the design of prosthetic valves, enhancing the safety of transcatheter procedures, and refining techniques for reconstructive surgeries like the Ross procedure, ultimately reducing postoperative complications.

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Conflicts of interest

There are no conflicts of interest.

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