A thorough cadaveric investigation of coronary ostia and its relationship with sinotubular junction

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SUMMARY

Coronary arteries take origin from the sinus of Valsalva present at the aortic root bounded by a circumferential ridge called sinotubular junction (STJ). Developmentally, the location and morphology of these ostia may vary, and can cause variations in origin of coronary arteries and further complications in any interventional cardiac procedure. This has made it necessary to find the variation in number and location of ostia, their size, shape and relation with surrounding structures. The present study included 40 formalin-fixed cadaveric hearts. The average diameter of the right coronary ostium (RCO) was 3.1 mm and the left coronary ostium (LCO) was 4.2 mm. With regard to the shape of the ostium, the RCO was described as circular in 92.5% (37/40), horizontally elliptical in 7.5% (3/40) of cases. The LCO was circular in 90% (36/40), horizontally elliptical in 5% (2/40) of cases. The RCO was located below STJ in 65% cases (26/40), at STJ in 22.5% (9/40) and above STJ in 22.5% (9/40) cases. LCO were below STJ in 50% (20/40), at STJ in 27.5% (11/40) and above STJ in 22.5% (9/40) cases. Multiple ostia in single aortic sinus were recorded in 24.4 % of cases. The study of the location, shape and morphometry of coronary ostia is essential for any cardiac interventional procedures done for diagnostic and therapeutic evaluation.

Key words: Left coronary artery – Ostia – Right coronary artery – Sinus – Sinotubular – Tubular

ABBREVIATIONS:

LCO - left coronary ostium

RCO - right coronary ostium

CO - coronary ostia

STJ - sinotubular junction

INTRODUCTION

Coronary arteries are functional end arteries irrigating the heart, arising from the coronary ostia, which are two in number, located in the sinus of Valsalva, also known as aortic sinuses. These aortic sinuses are three in number located distal to the aortic valve at the root of the ascending aorta. The right coronary artery arises from the anterior aortic sinus, left from the left posterior aortic sinus, and the remaining third sinus is known as non-coronary sinus, because no coronary artery arise from that. The junction between aortic

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sinuses and aorta is called sinotubular junction (STJ). Usually, the coronary ostia (CO) are located within the sinuses below STJ. However, the ostium may sometimes present at and above this circumferential ridge. Today, with the changes in living and working style, cardiac prognosis is proven to be worse, especially in young adults, and death occurs because of myocardial ischemia. So routine medical checkups must include coronary angiography. So as for purposes of diversity every cardiologist should have sound anatomical knowledge of normal, as well as variant topography of CO. The position and shape of CO and its relationship with STJ is valuable for any interventional as well as surgical cardiovascular procedure, such as coronary catheterization. After going through previous studies, the authors found that the studies were either angiographic studies or the studies conducted in populations of different countries, so data on Indian population are scarce. So, it is crucial for clinicians to know the pattern of these variations in selected demographic data. Further, the present study can add a range to the previous data for reference in designing of catheters in accordance with the requirements of the Indian population. So, this has motivated us to study the variant location, shape, size of coronary ostia and its relationship with STJ in Indian population.

MATERIALS AND METHODS

This study is a descriptive cross-sectional study. A total of 40 heart specimens preserved in 10% formalin were procured for the study in the dissection hall of the Anatomy Department from the cadavers used for routine undergraduate teaching. The heart specimens were both from male and female cadavers with a mean age of 60 years. Micro dissection was done on the heart to expose both coronary arteries and to remove the fat layer from epicardium so as to get a clear view of arteries. Then, the ascending aorta was transversely cut 2.5 cm above the level of origin of the coronary arteries. After getting a clear view of all the aortic leaflets and ostia, a longitudinal incision was given on the posterior wall of the noncoronary sinus. Then, the aortic root was opened like a book, and the following measurements were taken with the help of a 0.01 mm sensitive digital vernier caliper (Fig. 1):

1. Shape of CO.
2. Diameter of CO.
3. Location of CO in relation with STJ.
4. Height of cusps and ostium from bottom of sinus.
5. Location of ostium in relation with upper margin of aortic cusps.
6. Presence of any accessory ostia.
7. Location of ostium in relation with valve commissures.

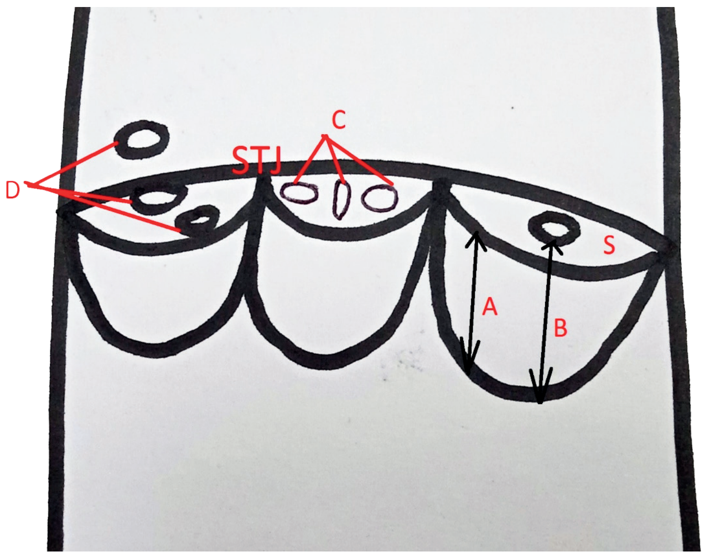

Fig. 1.- A and B: Distance of upper margin of aortic cusp and ostium from bottom of sinus. S: aortic sinus. C: different shapes of CO. D: location of ostium in relation with STJ.

Any cadaveric hearts with gross cardiomegaly and death because of any cardiac reason were excluded from the study. The measurements were double-checked by other authors so as to avoid any subjective bias. The results were tabulated in Microsoft Excel, and then statistical analysis was done by a data analysis tool.

RESULTS

Shape: As seen from Table 1, the shape of CO varied from circular, horizontally elliptical to vertically elliptical in appearance. Predominantly, the shapes of the ostia were circular. And none of the right and left ostia were found vertically elliptical in shape (Figs. 1 and 2).

Table 1. Shape of left and right coronary ostium.

Author (year)	Sample size (n)	Population	Right ostia (%)			Left ostia (%)		
			Circular	Horizontally elliptical	Vertically elliptical	Circular	Horizontally elliptical	Vertically elliptical
Present study	40	India	92.5	7.5	-	90	5	-

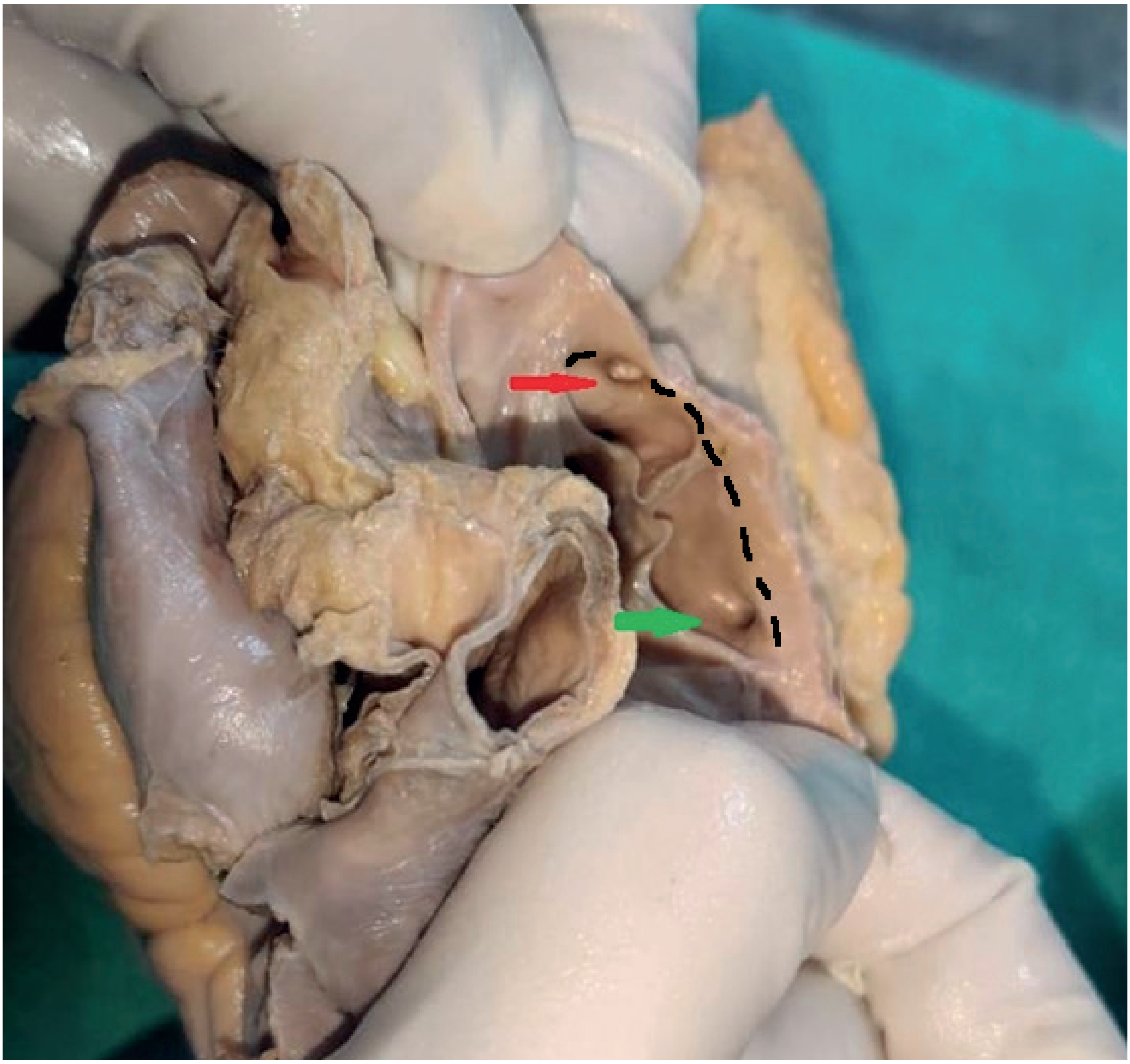

Fig. 2.- Red arrow: LCO, circular, centrally located, at STJ. Green arrow: RCO circular, below STJ, near commissure towards right.

Diameter: The mean diameter of LCO is 4.2 mm and that of RCO was 3.1 mm and when t-test was applied on the mean values; the difference was statistically significant (Table 2).

Relation to STJ: As shown in Table 3 and Figs. 2, 3, 4, CO showed variation in vertical placement. The most preferred location of both CO was sinus in nature.

Height of upper margin of the cusp and ostium from bottom of sinus: the average height of the upper margin of the cusp of the anterior aortic sinus from the bottom was 10.69±0.98 mm and that of the left posterior sinus was 10.82±0.99 mm. The average distance of the ostium from the bottom of the sinus in case of RCO was 13.44±1.3 mm, and that of LCO was 13.84±1. 2 mm (Table 4).

Location of the ostium in relation with upper margin of aortic cusps: in the present study, we found both the ostia were present above the upper margin of the respective cusps.

Table 2. T-test: paired two sample for mean.

	RCO	LCO
Mean	3.140769	4.2
Variance	0.25337	0.433695
Observations	40	40
Pearson Correlation	0.475318	
Hypothesized mean difference	0	
Degree of freedom	38	
t Stat	10.8464	
P(T<=t) one-tail	1.7E-13	
t Critical one-tail	1.685954	
P(T<=t) two-tail	3.4E-13	
t Critical two-tail	2.024394	

Table 3. Positions of CO with respect to STJ.

	Below STJ (n/%)	At STJ	Above STJ
Right coronary ostia	26(65)	9(22.5)	5(12.5)
Left coronary ostia	20(50)	11(27.5)	9(22.5)

Fig. 3.- Red arrow: Horizontally elliptical left ostium, centrally placed below STJ.

Fig. 4.- Red arrow LCO, circular, centrally placed above STJ.

Table 4. Measurement of height of aortic cusp and ostium from the bottom of sinus.

	Height of the cusp from bottom of the sinus		Height of the ostium from bottom of the sinus	
	Average	Range (mm)	Average	Range (mm)
Right	10.6992	8-12	13.44575	9-15
Left	10.8282	9-14	13.847	8-16

Location of the ostia with reference to commissures: out of 40 RCO, 80% (32/40) were located in the center of the respective sinus, only 17.5% (7/40) were towards the commissure on the right. In case of LCO, all the ostia were located in the center of the respective sinus with a frequency of 97.5% (39/40); only 2.5% (1/40) were located towards the commissure on the left (Figs. 5, 6).

Accessory ostia: accessory ostia were found in 24.4% cases only in the anterior sinus, and no such ostia were found in the left sinus (Figs. 5, 6).

DISCUSSION

The present study was conducted in a series of 40 hearts. In all the specimens, it was found that there were three aortic sinuses within their respective aortic cusps. The cusps of the aortic valve were connected with each other at the commissures, and on the inner side of the aorta a clear ridge was seen above the commissures, which indicate STJ. The CO location could vary from sinus to tubular and sinotubular junction, as shown in (Fig. 1). The location of CO is crucial for interventional cardiologists during catheter manipulation in procedures like angioplasty, angiography, or transcatheter aortic root valve replacement (Kulkarni and Paranjpe, 2015). In the present study, the left ostia were below STJ in 50% (20/40), at STJ in 27.5% (11/40) and above STJ in 22.5% (9/40) cases. The findings of this study correlate with values of Indian studies done by Nalluri et al. (2016) and Agrawal et al. (2018), who observed LCO relation with STJ in 52%, 39%, 9% and 64%, 32%, 4% respectively. However, the values did not correlate with the Indian study done by Kaur et al. (2012), who found it 78%, 15%, 7% with STJ. This discrepancy could be explained

Fig. 5.- Arrow A and B indicating accessory ostia and arrow C indicates RCO near commissure towards right.

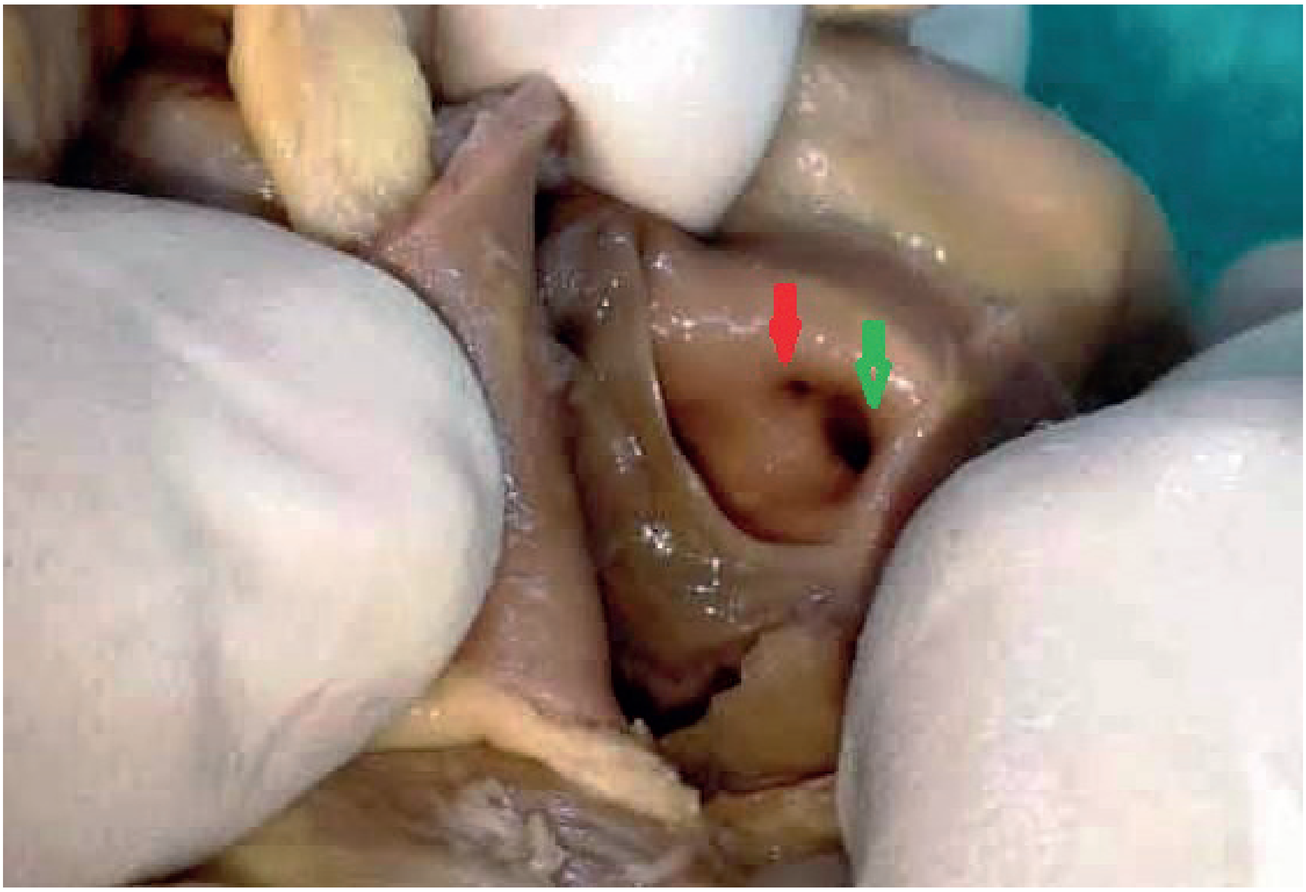

Fig. 6.- Red arrow indicating accessory ostium and green arrow towards RCO circular, near commissure towards right.

by the fact that in some cases, even when the ostia were above the level of commissures, the sinotubular ridge arched over the ostial opening rather than being straight. The difference in the findings described above might be due to overlooking the arched pattern of the sinotubular ridge. Moreover, when the results of the present study were compared with previous studies done by Pejkovic et al. (2008), Kosar et al. (2009), Govsa et al. (2010) and Nasr Tahlawi (2018), as shown in Table 5, it did not correlate, because of the impact of different geographical and racial background. RCO were present below STJ in 65% (26/40), at STJ in 22.5% (9/40) and above STJ in 2.5% (5/40) cases. The findings of this study correlate with values of Indian studies done by Nalluri et al. (2016), who observed RCO relation with STJ in 65%, 24%, 11%, and Agrawal et al. (2018) recorded in 78%, 10%, 12%. However, the values did not correlate with the Indian study done by Kaur et al. (2012), who found it in 83%, 14%, 3% with STJ, and Luckrajh et al. (2019) and Pejkovic et al. (2008) records were 88%, 12%, 0% and 19%, 71%, 10% respectively, as shown in Table 5. Regarding high origin of the coronary arteries, Kim et al. (2006) and Montaudon et al. (2007) stated that, if coronary artery origin was more than 1 cm above STJ, it was considered to be a high take-off, and within 1 cm above STJ it is normal. The failure rate of coronary catheterization was higher in patients having a coronary ostium above STJ. These ectopic coronary arteries frequently have slit like orifices and a tangential proximal course along the aortic wall, on which they lie, loosely attached to the aortic tissue. The right coronary artery is the most frequently ectopic artery, but the left coronary artery (or separately, the left anterior descending and circumflex artery) may also originate ectopically (Nishi et al., 2010). High take-off coronary arteries may link with sudden cardiac death, myocardial ischemia and increased risk of atherosclerosis. As far as myocardium perfusion was concerned, wherever CO might be located it did not affect coronary flow, according to Joshi et al. (2010); but, in case of aortic valve dysfunction. when aortic valve might flatten upon ostium in maximum systolic pressure, CO located above STJ would be functionally advantageous.

In the present study, the accessory ostia were noticed only in the right sinus in 24.4% cases, and no such ostia were noticed in the left sinus. These accessory ostia were circular in shape, smaller in size as compared to main ostium (Figs. 5, 6). As such, no independent artery was arising from these minute ostia. Wherever in anterior sinuses accessory ostia were present, the main ostium was found to be shifted near the commissure. The presence of multiple ostia within the coronary sinuses with or without original variations of the coronary arteries might be due to the growth of the coronary arteries into the aorta from the peritruncal ring of coronary vasculature, not grow out of the aorta (Fiss, 2007). Moreover, Udaya Sankari et al. (2011) added that this process involves apoptotic changes by the molecular mechanism through vasculoendothelial and fibroblast growth factors, where these factors stimulate the vasculogenesis and angiogenesis. However, the presence of multiple openings within AAS was explained as a result of the absorption

Table 5. Position of CO and its relationship with STJ.

Author (year)	Sample size	Population	RCO relation to STJ (%)			LCO relation to STJ (%)		
			Above	At	Below	Above	At	Below
Pejkovic et al. (2008)	150	Austria	10	71	19	60	18	22
Kosar et al. (2009)	700	Turkey	0.14	0.71	-	-	-	-
Kaur et al. (2012)	77	India	3	14	83	7	15	78
Govsa et al. (2010)	100	Turkey	3	13	78	13	29	58
Nalluri et al. (2016)	80	India	11	24	65	9	39	52
Agrawal et al. (2018)	50	India	12	10	78	4	32	64
Nasr and Tahlawi (2018)	60	Saudi Arabia	3.3	16.7	80	6.3	20	73.3
Present study	40	India	12.5	22.5	65	22.5	27.5	50

of the bulbous cordis into both ventricles during the heart folding by Stankovic and Jesic (2004). As far as diameter of CO was concerned, in the present study the mean diameter of RCO was 3.14±0.25 and that of LCO was 4.2±0.43. These compare favorably with other studies done by Kulkarni and Paranjpe (2015), Bhimalli et al. (2011), Cavalcanti et al. (2003) and Kaur et al. (2012) as shown in Table 6. Table 2 shows that the difference in the mean was statistically significant between LCO AND RCO diameter with p-value less than 0.05 at 95% confidence interval. Using the t-test, t statistic observed is greater than t critical, hence the mean diameters of LCO and RCO differ significantly. The diameter of the CO needs to be considered in the designing of equipment such as catheters for coronary angiography, coronary perfusion cannulas for the administration of cardioplegic solution and stents for aorto-ostial lesions, according to Kaur et al. (2012). This may ensure optimal results and avoid retrograde aortocoronary dissection (Dombe et al., 2013). The present study samples were irrespective of gender, but previous studies by Nasr and Tahlawi (2018) and Mobin et al. (2021) had shown no statistically significant difference in the parameters studied among male and female. In the present study, a circular shape ostium was found in 92.5% of RCO and 90% of LCO, whereas 7.5% of RCO and 5% of LCO were horizontally ellipsoid in shape. And none of the CO were vertically ellipsoid in shape. When the results of the present study were compared with data available in the literature, it did not correlate favorably (Table 7). This might be because of different racial and geographic backgrounds. The knowledge of the shape of the ostium is important while inserting and manipulating catheters in procedure like angiography, angioplasty (Kulkarni and Paranjpe, 2015).

According to the literature, there were cases reported of sudden death in young individuals and on autopsy CO found to be slit-like. Slit-like ostia are often associated with acute angulations of the

Table 6. Comparison of mean diameter of CO with other studies.

Studies	RCO	LCO
Kulkarni and Paranjpe (2015)	2.5 ± 1.0	2.8 ± 1.0
Bhimalli et al. (2011)	2.38 ± 1.33	3.17 ± 0.34
Cavalcanti et al. (2003)	3.46 ±0.94	4.75 ±0.93
Kaur et al. (2012)	3.9 ± 1.0	4.6 ± 1.0
Ortale et al. (2005)	5.0 ± 0.9	
Kohler et al. (1981)	3.833	4.833
Ballesteros and Ramirez (2008)	3.58 ± 0.59	
Present study	3.14±0.25	4.2±0.43

Table 7. Shows different shapes of CO and comparison with previous studies.

Author (year)	Sample size (n)	Population	Right ostia (%)			Left ostia (%)		
			Circular	Horizontally elliptical	Vertically elliptical	Circular	Horizontally elliptical	Vertically elliptical
Luckrajh et al. (2019)		South Africa	52	24	24	30	60	5
Kulkarni & Paranjpe (2015)	90	India	16	76	7	23	73	10
Govsa et al. (2010)	100	Turkey	60	-	-	55	-	-
Present study	40	India	92.5	7.5	-	90	5	-

initial part of the coronary artery, and predispose individuals to ischemia of the myocardium by Garg and Tiwari (2000). As far as horizontal placement of ostium was concerned, it might be located in the center of the sinus or slightly to the left or the right near the commissure. In the present study, 80% of RCO were in the center, and 17.5% near the commissure towards the right. In case of LCO, in 97.5% cases they were located in the center, and in 2.5% of cases it was towards the commissure on the left. There was paucity of literature for the data regarding variation in horizontal placement of the ostium. Knowledge of variation in the horizontal location of the ostia is important while doing Jatene's procedure of catheterisation. During catheterisation, the aortic valvular leaflet may be damaged if the ostium is located close to the leaflet. The average distance of the right ostium and the cusp from the bottom of the sinus in the present study was 10.6 mm and 13.44 mm, and that of the left cusp and ostium was 13.84 mm and 10.8 mm, which was almost equal on both the sides (Table 4). The aforesaid parameter was noted by few authors, such as Joshi et al. (2010), Jatene et al. (1999), and in all the studies RCO was placed higher than LCO. But in contrast, LCO was placed a little higher than RCO by Nalluri et al. (2016). It needs further study to find which one is higher in location. An abnormal localization of the coronary ostium is important in performing aortotomy incision for aortic valve exposure, preparing a coronary button in root replacement, and approaches for aortic root enlargement. Preoperative diagnosis of such coronary abnormalities is also important for surgical correction of congenital heart diseases, such as tetralogy of Fallot and transposition of great arteries. The limitation of the present study on variations in coronary ostia is due to the small sample size irrespective of age and gender difference.

CONCLUSION

The present study elucidates that the diameter of LCO was bigger than RCO; a circular shape and sinus location was predominant in both the ostia. The height of both the ostia was found equal from the bottom of respective sinus. The accessory ostia showed a maximum of two in number, were minute in size and only in right anterior aortic sinus. And important finding was that, wherever accessory ostia were present, the main ostia were shifted near the commissure. This anatomical study will help cardiologists and interventional surgeons to enhance their knowledge in variations of coronary ostia. This awareness will help to reduce the morbidity and mortality associated with coronary artery interventions.

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