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An anatomical investigation of the coronary ostia and its relationship to the sinotubular junction within a select South African population

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SUMMARY

The coronary ostia (CO) lie within the left and right aortic sinuses, respectively; and are bound by the sinotubular junction (STJ) superiorly. The high frequency of cardiac procedures that require catheterization has necessitated the reappraisal of the anatomy of the origin of the coronary arteries. Therefore, this study aimed to describe the CO by recording its diameter, shape, and relation to the sinotubular junction in a select South African population.

The present study included the gross dissection of 50 formalin fixed, adult cadaveric hearts. The average diameter of the right coronary ostium (RCO) was 3.29mm and the left coronary ostium (LCO) was 3.87mm. With regard to the shape of the ostia, the RCO was described as circular in 52% (26/50), horizontally ellipsoid in 24% (12/50) and vertically ellipsoid in 24% (12/50) of cases. The LCO was circular in 30% (15/50), horizontally ellipsoid in 60% (30/50) and vertically ellipsoid in 10% (5/50) of cases. The RCO was located below the STJ in 88% (44/50) and at the level of the STJ in 12% (6/50) of cases. The LCO was recorded below the STJ in 64% (32/50), at the level of the STJ in 32% (16/50) and above the STJ in 4% (2/50) of cases. Multiple ostia arising from a single aortic sinus was recorded in 14% (7/50) of cases. In 2% (1/50) of cases, the RCO was located in the non-coronary sinus. In addition, the RCO arose from the left aortic sinus in 2% of cases. The results of the present study correlate with those of previous studies. Anomalous CO, although asymptomatic has been linked to myocardial infarction and sudden cardiac death. It is, therefore, imperative for the clinician to be aware of variant CO anatomy, which may alert them to the predisposition of cardiac risks.

Key words: Coronary ostia – Coronary anatomy – Morphology – Morphometry – Sinotubular junction – Myocardial infarction – Sudden cardiac death

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INTRODUCTION

Since the advent of coronary angiography in 1958, the anatomy of the coronary arteries (CA) has been under much investigation. A sound anatomical knowledge of these structures is invaluable for the accurate interpretation and diagnosis of pathologies related to the heart. In recent years, variations of CA anatomy are becoming more frequent in diagnostic work ups as a cause of cardiac pathologies. One of the subsets of the CA variations under scrutiny is the anomalous origin of these arteries.

Standard anatomical textbooks state that the left and right CA arise from the aorta, where their ostia arise from the left and right aortic sinuses, respectively (Standring, 2015). The aortic sinuses are bounded by the sinotubular junction superiorly and the cusps of the aortic valve inferiorly (Standring, 2015). A third aortic sinus is present and it is termed the 'non-coronary sinus' as it does not generally contain an ostium (Standring, 2015). There

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are varying reports in the literature of the morphological (shape and location) and morphometric (diameter) parameters of the coronary ostia (CO) in different population groups (Cavalcanti et al., 2003; Govsa et al., 2010; Bharambe and Arole, 2012; Dombe et al., 2013; Kulkarni and Paranjpe, 2015; Meshram et al., 2017; Zhou et al. 2017; Agrawal, 2018; Nguyen and Talarico, 2018).

The anomalous location of the CO is the most commonly reported variation. Firstly, many studies have located the CO in the opposite aortic sinuses: *ie*. the right CO was located in the left aortic sinus and the left CO was located in the right aortic sinus (Bharambe and Arole, 2012; Kaur et al., 2012; Sirikonda and Sreelatha, 2012). Loukas (2013) stated that this anomaly occurs in 0.03-0.1% of the general population. Secondly, the ectopic locations of the CO from within the pulmonary trunk, aorta and brachiocephalic artery have been recorded (Loukas, 2016). Such variations have a critical clinical import, as they lead to pathologies such as Bland-White-Garland syndrome, which lead to death in many cases (Szmigielska et al., 2013). Thirdly, the number of ostia present within the aortic sinuses is also variable (Bharambe and Arole, 2012; Mallashetty and Bhosale, 2012; Dombe et al., 2013; Meshram at al., 2017). Bharambe and Arole (2012) recorded up to 5 separate ostia present in 1 aortic sinus. It is crucial for the interventional cardiologist to be aware of the number of ostia present for accurate, successful catheterization. Lastly, the high take-off of the CA is a rare variation in which the ostium is found 1cm or more above the sinotubular junction (STJ) (Loukas et al., 2016). The STJ is an anatomical landmark delineating the junction of the aortic sinus and the tubular aorta (Standring, 2015). High take-off CA is found in literature primarily as case reports (Motamedi et al., 2009; Rosenthal et al., 2012; Salehi et al., 2013; Heo et al., 2014; Atik and Leal, 2017). These cases have been linked to sudden cardiac death, myocardial ischemia leading to myocardial infarction, as well as an increased risk of atherosclerosis, emphasizing the importance of this anatomical variation.

Although variant anatomy of the CA are less

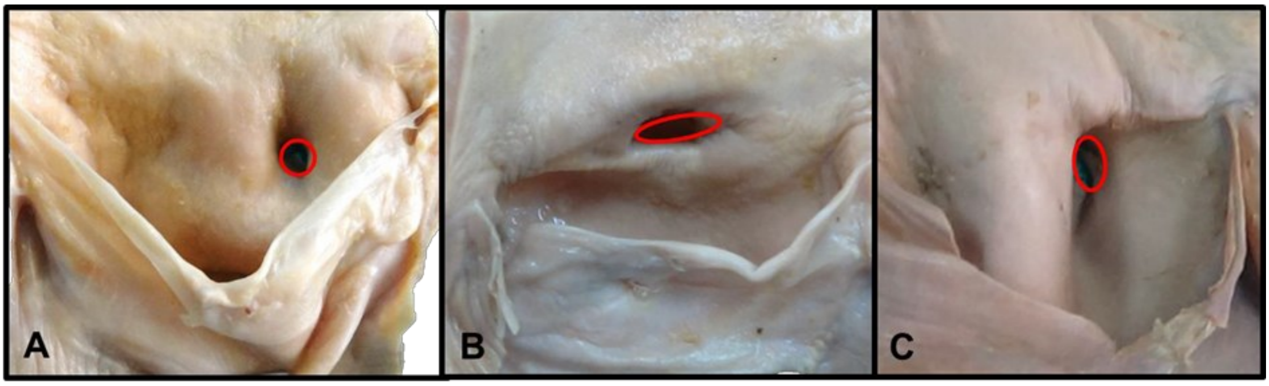

Fig 1. Shapes of coronary ostia. **A**: Circular; **B**: Horizontally ellipsoid; **C**: Vertically ellipsoid.

Table 1. Diameters of the right (RCO) and left coronary ostia (LCO).

Author (Year)	Sample Size (n)	Population	Diameter (mm)	
			RCO	LCO
Pejkovic et al. (2008)	150	Austria	3.60	4.10
Govsa et al. (2010)	100	Turkey	3.32	4.22
Parimala and Sreelatha (2012)	100	India	2.77	4.11
Dombe et al. (2013)	64	India	2.50	3.30
Kumari and Priya (2015)	100	India	2.82	3.88
Kulkarni and Paranjpe (2015)	90	India	2.50	2.80
Nalluri et al. (2016)	80	India	3.17	4.10
Silitongo et al. (2016)	125	Zambia	3.66	4.62
Jyothi and Dakshayani (2017)	49	India	3.43	4.27
Zhou et al. (2017)	167	China	2.95	4.12
Agrawal (2018)	50	India	3.09	4.26
Nguyen and Talarico (2018)	125	Vietnam	-	4.62
Present study (2018)	**50**	**South Africa**	**3.29**	**3.87**

common than acquired coronary artery disease, their propensity to cause premature cardiac morbidity and mortality make them highly significant (Satija et al., 2012). Therefore, this study aimed to document the morphology and morphometry of the coronary ostia, as well as to determine their relation to the sinotubular junction in a select South African population.

MATERIALS AND METHODS

A total of 50 cadaveric heart specimens embalmed in 10% formalin were employed in this study. These specimens were obtained from the Department of Clinical Anatomy, University of Kwa-Zulu Natal, South Africa. The aorta was transected approximately 3cm above the STJ and longitudinally incised along the posterior wall of the aorta, to allow for the visualization of the CO.

This was a descriptive study where the shape and diameter of the CO were recorded, as well as their relation to the STJ. Measurements were taken with the use of a digital calliper, and measurements of ellipsoid shaped ostia were taken along the major axis.

Adult heart specimens with no macroscopic damage to the aorta were included in this study. Specimens with macroscopic damage or ostial calcification were excluded from this investigation.

RESULTS

a. **Diameter**: The average diameter of the right coronary ostium (RCO) was 3.29 mm and the left coronary ostium (LCO) was 3.87 mm (Table 1).
b. **Shape**: The shapes of the CO were classified as either circular, horizontally ellipsoid and vertically ellipsoid. The RCO was described as circular in 52% (26/50), horizontally ellipsoid in 24% (12/50) and vertically ellipsoid in 24% (12/50) of cases (Fig. 1, Table 2).
   The LCO was circular in 30% (15/50), horizontally ellipsoid in 60% (30/50) and vertically ellipsoid in 10% (5/50) of cases (Fig. 1, Table 2).
c. **Relation to STJ**: The RCO was located below the STJ in 88% (44/50) and at the level of the STJ in 12% (6/50) of cases (Fig. 2, Table 3). The LCO was recorded below the STJ in 64% (32/50), at the level of the STJ in 32% (16/50) and above the STJ in 4% (2/50) of cases (Fig. 2, Table 3).
d. **Variations**:
   i) Multiple ostia (2 or more) arising from a single aortic sinus was recorded in 14% (7/50) of cases [12% (6/50) in the right aortic sinus; 2% (1/50) in the left aortic sinus].
   ii) In 2% (1/50) of cases, the RCO was located in the non-coronary sinus; in this case, the right aortic sinus had no ostia present.
   iii) In 2% (1/50) of cases the right coronary artery arose from the left aortic sinus.

DISCUSSION

The present study found the diameters of the right and left coronary ostia to be 3.29mm and mm, respectively (Table 1). This current South African study compares favourably with previously reported studies (of different population backgrounds) which all concluded that the LCO was larger than the RCO (Pejkovic et al., 2008; Dombe et al., 2015; Silitongo et al., 2016; Joythi and Dakshayani, 2017; Thakre et al., 2017) (Table 1). 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 (Kaur et al., 2012; Dombe et al., 2013; Kulkarni and Paranjpe, 2015). This may ensure optimal results and avoid retrograde aorto-coronary dissection (Dombe et al., 2013). Furthermore, since differences in ostial diameters have been attributed to ethnic differences and geographic location, it is important for the clinician to be aware of the average diameters of the CO within specific population groups (Kaur et al., 2012; Kulkarni and Paranjpe, 2015).

The shapes of the CO were classified as circular, horizontally ellipsoid or vertically ellipsoid (Fig. 1). In the present study, the RCO was circular shaped in 52% of cases (Fig. 1A, Table 2). This correlates with the findings of a Turkish study by Govsa et al. (2010), who observed circular RCO in 60% of cases; however, the Indian study by Kulkarni and Paranjpe (2015) only observed this in 16% of cases (Table 2). The LCO was found to be circular shaped in 30% of cases in the present study. However, Govsa et al. (2010) and Kulkarni and Paranjpe (2015) recorded circular LCO in 55% and 23% of cases, respectively (Table 2).

The present study observed horizontally ellipsoid shaped RCO in 24% of cases (Fig. 1B, Table 2). This finding is significantly lower than that of Kulkarni and Paranjpe (2015) who recorded this in 76.6% of cases. The LCO was found to be horizontally ellipsoid in 60% of cases which correlated with the finding of Kulkarni and Paranjpe (2015) who observed this in 73.3% (Table 2).

The RCO was vertically ellipsoid in 24% of cases; however, Kulkarni and Paranjpe (2015) only observed this shape in 7% of RCO (Fig. 1C, Table 2). On the other hand, the LCO was vertically ellipsoid in 5% of cases in the present study; whereas Kulkarni and Paranjpe (2015) recorded this in 10% of cases (Table 2). There is a noticeable paucity of literature describing the shapes of the CO. This data has significance in the design of catheters used in angiography and angioplasty (Kulkarni and Paranjpe, 2015). Furthermore, Lilly et al. (2011) listed the shape of the CO as one of the high-risk features of 'anomalous coronary artery from the opposite sinus' which should be identified in radiological imaging.

The location of the CO in relation to the STJ is important to note during manipulation of the cathe-

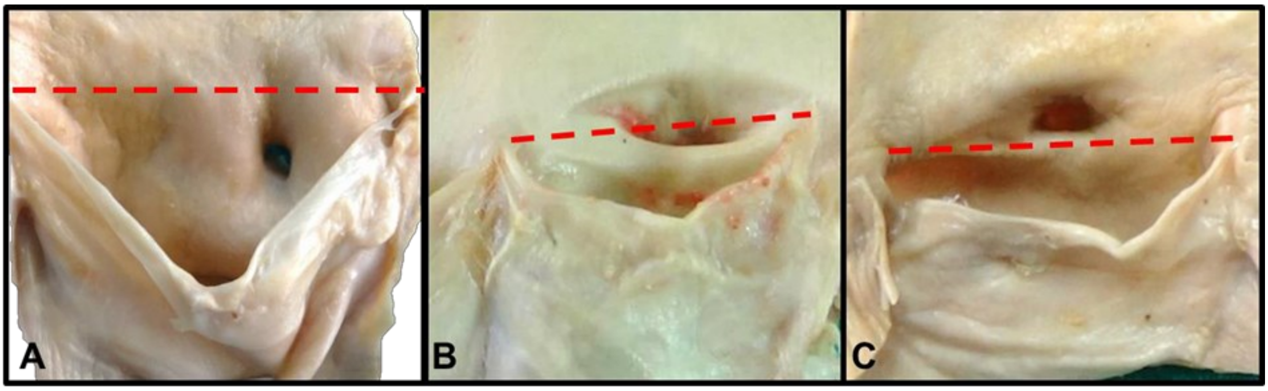

Fig 2. Position of the coronary ostia in relation to the sinotubular junction (STJ). A: below STJ; B: on STJ; C: above STJ. Key: Dashed red line – STJ.

Table 2. Shapes of the right (RCO) and left coronary ostia (LCO).

Author (Year)	Sample size (n)	Population	RCO			LCO		
			Circular	Horizontally ellipsoid	Vertically ellipsoid	Circular	Horizontally ellipsoid	Vertically ellipsoid
Govsa et al. (2010)	100	Turkey	60.00	-	-	55.00	-	-
Kulkarni & Paranjpe (2015)	90	India	16.00	76.60	7.00	23.00	73.30	10.00
Present study (2018)	**50**	**South Africa**	**52.00**	**24.00**	**24.00**	**30.00**	**60.00**	**5.00**

Table 3. Position of the coronary ostia (CO) in relation to the sinotubular junction (STJ).

Author (year)	Sample size (n)	Population	RCO relation to STJ (%)			LCO relation to STJ (%)		
			Above	On	Below	Above	On	Below
Alexander and Griffith (1956)	18950	USA	0.03	-	-	0.02	-	-
Kardos et al. (1997)	7694	Hungary	0.06	-	-	-	-	-
Nerantzis and Marianou (2001)	510	Greece		0.20	-	-	0.20	-
Calvacanti et al. (2003)	51	Brazil	28.00	12.00	30.00	40.00	18.00	42.00
Hou et al. (2007)	540	China	-	-	-	0.19	-	-
De Jonge et al. (2008)	230	Netherlands	0.43	-	-	-	-	-
Lytrivi et al. (2008)	168	USA	31.55	-	-	2.38	-	-
Pejkovic et al. (2008)	150	Austria	10.00	71.00	19.00	60.00	18.00	22.00
Koşar et al. (2009)	700	Turkey	0.14	0.71	-	-	-	-
Govsa et al. (2010)	100	Turkey	3.00	13.00	78.00	13.00	29.00	58.00
Joshi et al. (2010)	105	India	3.80	6.66	89.52	4.76	15.23	80.00
Yildiz et al. (2010)	12457	Turkey	4.46	-	-	-	-	-
Zhang et al. (2010)	1879	China	1.60	-	-	0.05	-	-
Kaur et al. (2012)	77	India	3.00	14.00	83.00	7	15.00	78.00
Sivri et al. (2010)	12844	Turkey	0.14	0.03	-	-	-	-
Hill and Sheppard (2013)	2304	UK	0.09	-	-	-	-	-
Türkvatan et al. (2013)	2375	Turkey	0.12	-	-	0.08	-	-
Yurksel et al. (2013)	16573	Turkey	0.006	-	-	-	-	-
Krittayaphong et al. (2014)	3703	Thailand	0.45	-	-	-	-	-
Namgung and Kim (2014)	8864	Korea	0.10	-	-	-	-	-
Poynter et al. (2014)	198	USA	1.01	-	-	-	-	-
Nalluri et al. (2016)	80	India	11.00	24.00	65.00	9.00	39.00	52.00
Agrawal (2018)	50	India	12.00	10.00	78.00	16.00	16.00	68.00
Present study (2018)	**50**	**South Africa**	**0.00**	**12.00**	**88.00**	**4.00**	**32.00**	**64.00**

ter during angiography, angioplasty and transcatheter aortic valve replacement (Kulkarni and Paranjpe, 2015). Therefore, preoperative knowledge of the position of the CO in relation to the STJ is crucial in the management of pathologies of the aortic root and coronary arteries (Dombe et al., 2013). In the present study, the RCO was located below the STJ in 88% of cases (Fig. 2A, Table 3, which is a representation of the CO in different population groups). This finding correlates with that of the Turkish study by Govsa et al. (2010), and the Indian studies of Kaur et al. (2012) and Nalluri et al. (2016) who observed this in 78%, 83% and 65% of cases, respectively (Table 3). However, in a Brazilian study by Cavalcanti et al. (2003) and an Austrian study by Pejkovic et al. (2008), the RCO was only found below the STJ in 30% and 19% of cases, respectively. The RCO was found at the level of the STJ in 12% of cases, which correlated with the findings of Cavalcanti et al. (2003) (12%), Govsa et al. (2010) (13%) and Kaur et al. (2012) (14%) (Fig. 2B, Table 3). However, Pejkovic et al. (2008) recorded the RCO at the level of the STJ in 71% of cases, which is significantly higher than the findings of the present study.

The LCO was recorded below the STJ in 64% of cases. This finding correlates with that of Govsa et al. (2010), Kaur et al. (2012) and Nalluri et al. (2016) who observed this in 58%, 78% and 52% of cases, respectively (Table 3). The LCO was at the level of the STJ in 32% of cases which correlates with most studies, except with Kaur et al. (2012) who only observed this in 15% of cases (Fig. 2B, Table 3). The present study recorded the LCO above the STJ in 4% of cases (Fig. 2C). This result is lower than all previous studies analysed and correlates the closest with the findings of Nalluri et al. (2016) who observed this in 9% of cases (Table 3).

Prajapati et al. (2013) stated that CO located above the STJ remain open during systole and diastole, which ensure continuous blood flow and decreases coronary insufficiency. However, Joshi et al. (2010) stated that the aortic cusp does not flatten against walls of the aortic sinus (except in aortic valve dysfunction), even at maximum systolic pressure. This implies that the position of the ostia above the STJ is not necessarily advantageous. This is further substantiated by the serious clinical implications of high take-off CA *viz.* myocardial infarction and sudden cardiac death. Therefore, Joshi et al. (2010) suggested that the position of the CO within the aortic sinus (ie. below the STJ), is functionally advantageous.

Many variations of the CO have been recorded in literature *viz.* CA origin from the opposite aortic sinus, solitary CO, ectopic origin from the pulmonary trunk and multiple CO. This study recorded multiple CO arising from a single aortic sinus in 14% of cases. The presence of multiple CO is rare but may have major clinical consequences (Dombe et al., 2013). Myocardial perfusion may be affected by the presence of multiple CO, and failure to recognise this variation may prolong the angiographic procedure and lead to errors in the interpretation of angiograms (Kulkarni and Paranjpe, 2015). Dombe et al. (2013) further stated that multiple CO is a hazard to cardiac surgery, as these small arteries, which barely get opacified during angiography, are not detected preoperatively and may get nicked during surgery. The multiple ostia found in this study represented the right coronary artery, conus artery, the sinoatrial nodal artery and the vaso vasorum to the pulmonary trunk. This finding closely correlates with the studies of Dombe et al. (2013) and Meshram et al. (2017), who also recorded the presence of these arteries arising directly from an aortic sinus.

Lastly, the anomalous origin of a CA from a different aortic sinus was found in 4% of cases in the present study. In 2% of cases the RCO was located in the non-coronary sinus, and in 2% the RCO arose from the left aortic sinus.

CONCLUSION

The high frequency of cardiac procedures that require catheterization has necessitated the reappraisal of the anatomy of the origin of the coronary arteries. The CO are clinically important structures, as they serve as the entry point for the arterial supply of the myocardium. Subsequently, an anomaly of the CO may result in potentially fatal outcomes, such as myocardial infarction and sudden cardiac death. A plethora of reports originating worldwide give testimony to this; in which cases these anatomical variations were usually discovered during autopsy, when it is too late for the patient to be helped. Therefore, the existence and importance of anatomical variations of the CO is emphasized, as this may alert clinicians to predisposing anatomical risks. Furthermore, the morphology and morphometry of the CO described may aid in the design of appropriate equipment to be used in interventional cardiac procedures and lead to optimal outcomes. A limitation in this study is the lack of ethnic demographic data and the small sample size. It is recommended that similar ostial parameters should be investigated via imaging modalities such as angiography and echocardiography.

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