A DISSECTION STUDY OF THE THIRD CORONARY ARTERY

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Abstract:

The conus artery usually is the first branch of the Right coronary artery, supplying mostly the region of the Pulmonary infundibulum. This artery sometimes takes a separate origin from the anterior aortic sinus. forming an additional coronary artery besides the right and left coronary arteries. Such an artery is known as the Third Coronary artery (TCA). This artery often anastomoses with a similar branch from the anterior interventricular artery to from the annulus of Vieussens, that forms an important anastomotic channel of the heart. The occurrence of the Third coronary artery however has shown wide variations in different studies across the world, ranging from 0 % to 51%. This study therefore aims to study the Third coronary artery mainly its origin, course and distribution. The study was carried out with 70 formalin fixed hearts in the Department of Anatomy, Gauhati Medical College, Guwahati, Assam, India. The study found third coronary artery in 11.43 % of the specimen. The occurrence of 1º, 2º and 3º pattern of origin was found in 2.86%, 8.57% and 0 % respectively. The ostium of the Third coronary artery was seen to be located in the anterior aortic sinus. Branching pattern was also observed. The results were analyzed manually using Z-test. Knowledge of the variations in occurrence of Third Coronary artery has important clinical implications.

Keywords: Coronary Arteries, Coronary Vessels, Heart, Blood Supply, Coronary Angiographies
DOI:10.48047/ecb/2023.12.8.530

Introduction:

Prior to the Renaissance era, knowledge of coronary anatomy was very limited. A single coronary ostium was described by Fallopius in Venice in 1562 [(1)]. Two main coronary vessels were accurately described by G.P. Morgagni only in 1761 [(1)]. The conus artery or third coronary artery (TCA) was described much later by Banchi in 1904 [(2)].

The conus artery has been described as the first branch of the Right Coronary artery (RCA)[(3)]. The conus artery is the first branch of the RCA in 64% cases while in 36% cases it arises separately from the anterior aortic sinus [(4)]. It is then called the 'Third coronary artery'. Thus the difference between the TCA and conus artery is mostly at its origin although the two names are sometimes used synonymously. The name 'Third Coronary artery' was given by Schlesinger in 1949 [(5)]. This artery is also known by varied names like 'conal coronary artery', 'right infundibular branch', 'supernumerary coronary artery', 'right Vieussens artery', 'gentle Vieussen's artery', 'adipose artery', 'accessory coronary artery', 'Arteria coni arteriosi', 'right conus artery' and 'Preinfundibular artery'[(4), (6), (7), (8)].

The Third coronary artery has been found to be the most common variation of coronary circulation[(4),(9),(10)]. The conus artery has been described as a supernumerary vessel that arises behind the right aortic valve cusp most often from a separate ostium near that of the RCA but occasionally from a common ostium with the latter artery[(11)]. The orifice of the conal artery is usually in front of the coronary orifice or at the same level [(9)].

After originating from the aortic root, the conus artery curves away from the RCA across the anterosuperior free right ventricular wall at the level of the pulmonary valve and terminate in small arterial twigs near the anterior interventricular sulcus where it is regularly met and joined

by analogous small branches from the proximal left anterior descending coronary artery [11]. This anastomotic pathway forms an arterial circle or ring called 'Vieusssens' arterial ring' or 'Circle of Vieussens' [6, 11]. Although its exact functional significance is unknown, it is believed to act as an important anastomotic bridge between the right and left coronary arteries [6, 12].

Young victims of sudden death showed a higher incidence of coronary anomalies than adults undergoing routine autopsy (4-15% versus 1% respectively) [1]. Hence it becomes necessary to be aware of coronary variation and anomalies. The TCA does not produce any physiological disturbance[13], but identification of its origin and its location radiologically is an important presurgical procedure particularly in the treatment of conditions like Tetralogy of Fallot [10]. As these branches are usually smaller than the tip of the diagnostic catheter, selective catheterization of such vessels were rarely done [1]. Therefore standard approaches for coronary angiographies may fail to visualize the TCA. Hence sound knowledge of the TCA is necessary for accurate interpretation of coronary angiograms and proper management of coronary insufficiencies [14].

Materials and Methods:

A total of 70 hearts (50 male and 20 females) without any obvious pathology or congenital abnormality were collected from the departments of Anatomy and Forensic Medicine and studied during 2006 - 2009 after obtaining the necessary ethical clearance. The hearts were preserved in 10% Formalin [Formalin = 40% solution of Formaldehyde in water. 10% Formalin= 10 parts Formalin +90 parts water]. Dissections of the hearts were done in the Department of Anatomy, Gauhati Medical College, Guwahati, Assam, India. Visceral pericardium and subepicardial fat were removed. The right coronary artery and the conus artery (if present) were carefully dissected out and followed till their termination. Origin of the conus artery (if present) was noted. Distance from the origin of the RCA was recorded using Vernier calipers, wherever possible. The ascending aorta was transversely sectioned about 1 cm above the commissures of the aortic leaflets. The aorta was then opened up longitudinally at the level of the posterior aortic sinus so as to properly visualize the ostium of the coronary arteries and of the Third coronary artery if present. The most representative preparations were photographed. Relevant data were recorded and analyzed statistically by Z-test (manual method).

Observation:

The conus artery was present as the first ventricular branch of the RCA and was seen in 62 specimens (88.57%). The TCA was seen in 8 specimens (11.43%). Of these, in 6 cases (8.57%), it arose as a separate branch from the Right Aortic sinus while in 2 specimens (2.86%), it arose together with the RCA in funnel shaped common ostium. No specimen with more than 3 coronary arteries were seen in this study.

The origin of the TCA was found at the Right Anterior Coronary Sinus, arising left and usually at the same level as the orifice of the RCA. The orifice was smaller compared to that of the RCA. The distance of the orifice of the TCA from that of the RCA was 0.8 mm to 4.2 mm.

After its origin, the TCA pass left towards the infundibulum of the right ventricle through the subepicardial adipose tissue (Fig: 1). Alternately it may run downward for a very short distance in the right coronary sulcus and then turn left, leaving the sulcus to reach the pulmonary infundibulum.

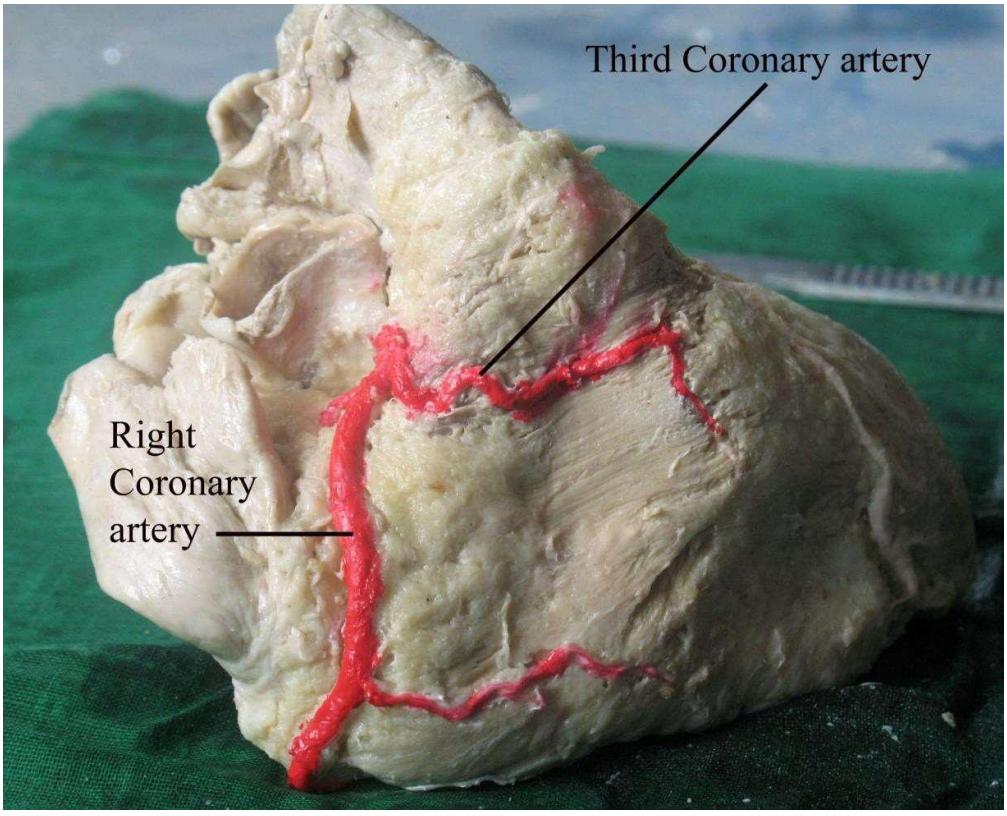

Figure 1: TCA running along infundibulum of the right ventricle

The number of terminal branches of the TCA was usually two: an upper and a lower branch. Along its course, it sometimes gave off a few small side branches. Out of the 8 hearts with TCA, 5 supplied the Pulmonary infundiculum only while 3 supplied the infundibulum and the anterior wall of right ventricle as well. None of the arteries reached the inferior border or apex of heart.

In certain specimen, the TCA was joined by analogous small branches of the left conus artery, which was found to arise from the proximal part of the anterior interventricular artery. Together they seemed to form an arterial circle or ring at the pulmonary infundibulum which has been referred to by various authors as the Annulus of Vieussens'. This was seen in 3 specimens only.

Discussion:

Angelini P [(1)] differentiated 'Anomaly' or 'Abnormality' as forms observed in less than 1% of the population while 'Variation' as forms that are not commonly observed yet are present in more than 1% of the population. A review of literature shows a wide variation seen in coronary arteries (Table 1). Thus while some authors [(6),(7),(8),(10), (14),(17),(19),(20)] described the TCA as a variation, some authors[(1), (15),(16),(21)] would see it as an abnormality (Table 1).

Table 1: Frequency of Third coronary artery

Type of study	**Author**	**Region**	**Sample Size**	**Separate Conus Artery/ Third Coronary artery**
Dissection/ Autopsy	Present study	Guwahati, India	70	11.43 %
	Bianchi A, 1904 [(2)]	Italy	100	33%
	Symmers WSC, 1907 [(18)]	United Kingdom	100	38%
	White NK and Edwards JE, 1948 [(15)]	United States	600	0%
	Alexander RW and Griffith GC, 1956 [(16)]	California, USA	18950	.03%

study	Edwards BS, et al, 1981[12]	Minnesota, USA	305	39%
	Kurjia HZ et al, 1986 [10]	Iraq	119	7.6%
	Stankcovic I & Milika J, 2004 [6]	Belgrade	23	34.8%
	Lujinovic A, et al, 2008 [7]	Bosnia	25	32%
	Dhobale MR, et al, 2015 [14]	Pune, India	150	32%
	Lakshmi GL, et al (2017) [19]	Karnataka, India	50	30%
	Maric DL, 2018 [8]	Serbia	55	52.7%
In-vitro injection study	Schlesinger MJ, et al., 1949 [17]	United States	1000	51 %
	James TN, 1961 [20]	New York	106	50%
In- vivo injection study	Donaldson RM, et al,1982 [21]	United Kingdom	8000	0.15%
	Angelini P, et al, 1999 [1]	Texas	1950	0%

This extreme variation (0%-52.7%) in the occurrence of the TCA across the world is quite significant. Method of study has been suggested as a cause of this variability as the inability to selectively cannulate the TCA on conventional arteriography may be a factor [14]. However, this is not a fully satisfactory explanation as wide variability was seen both in dissection method as well as in injection studies. While injection studies showed variation from 0% to 51%, dissection studies showed a range from 0% to 52.7% as well (Table 1). This suggests that the TCA may show wide ethnic or racial variations [10]. Most of the studies deal with the American or the European population, some of which may contain a mixture of Caucasian, Negros, Hispanic and Orientals. Asian authors [10] found an occurrence of 7.6% among Iraqis while some Indian authors [19],[14] found it in 30% and 32% respectively in some Western Indian population. However, the Indian population is quite diverse with a mixture of Aryans, Dravidians and Mongoloids population. Unlike the West Indian population, North East India consists of a mixture of Mongoloid and Aryan races. Hence a study in this region assumes importance as it

can help give a better estimate of the Indian Subcontinent and also give some idea regarding the occurrence of the artery in the mongoloid race.

The occurrence of the TCA in the present study was compared to findings by other authors (Table 2) using Z-Test. The present study showed significant differences ($p<0.05$) with most authors except a few [10]

Three types of TCA depending on the number of orifices [22] have been described. 1º - TCA with common orifice with RCA (Fig: 2), 2º - Single orifice of TCA, separate from RCA (Fig: 3), 3º - Two or more orifices for TCA. Variations in the origin of the conus artery found in the present study have been compared with those of other authors (Table 2).

Table 2: Comparison of mode of origin of the Third coronary artery

Author	Common ostium with RCA (1º)	Separate ostium in anterior aortic sinus (2º)	Multiple orifices of TCA (3º)	Total percentage of Third coronary artery
Olabu BO, et al, 2007 [22]	16.21 %	17.56%	0%	33.77 %
Dhobale MR, et al, 2015 [14]	2%	26.67 %	3.33%	32%
Lakshmi GL, et al, 2017 [19]	26%	4%	0%	30%
Maric DL, et al, 2018 [8]	0%	41.8%	10.9%	52.7%
Edwards BS, et al, 1981 [12]	28.52%	8.52%	1.96%	39%
Present study	2.86%	8.57%	0 %	11.43%

When the results of mode of origin of the TCA was compared with other authors (Table 2), the occurrence of 1º pattern showed significant differences with the findings of some authors [12], [19], [22] but insignificant differences with some [8], [14]. 2º pattern showed significant differences with

the some authors [14], [8] but insignificant differences with some others [12], [19], [22]. Likewise, 3º pattern showed insignificant differences from most authors [12], [14], [19], [22] except one [8].

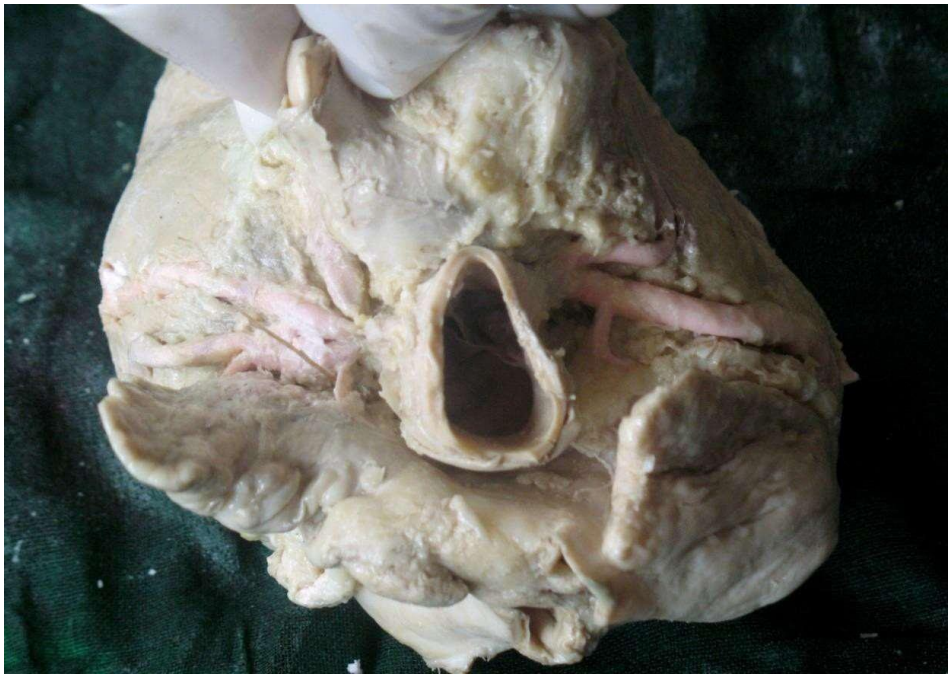

Figure 2: Common ostium of TCA with RCA (1º)

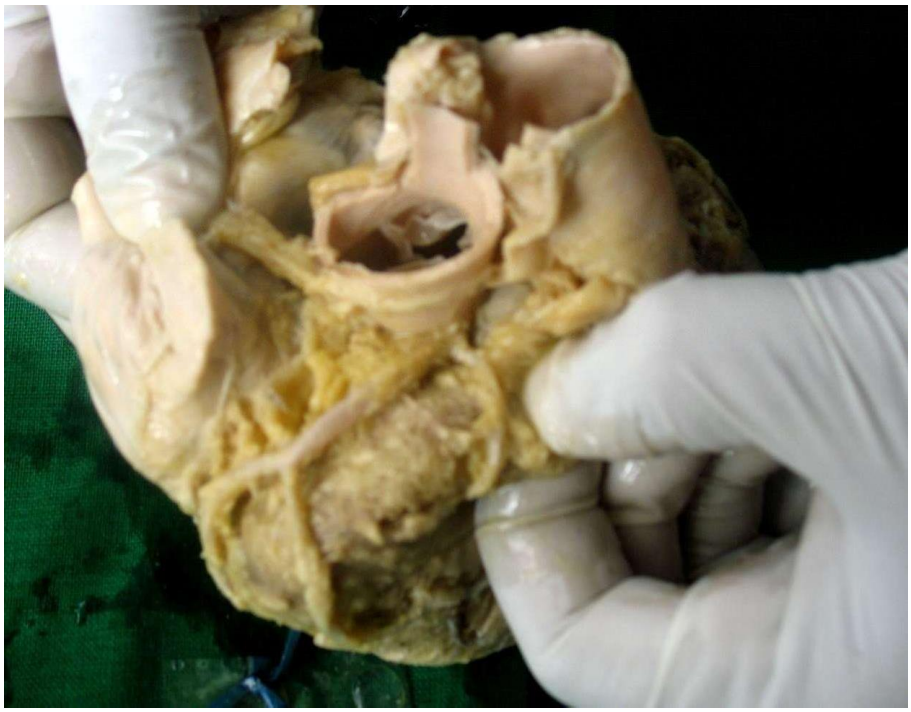

Figure 3: Separate ostium of TCA in anterior aortic sinus (2º)

The ostium of the TCA lies in the right aortic sinus, superior and left to the ostium of the RCA[6]. The TCA ostium lies at the same level as the RCA ostium [8]. The distance between the TCA and RCA ostium has been variably reported by different authors as 1.0 mm - 2.7 mm, 1- 4 mm and 1.5 - 4.5 mm respectively [6], [7], [8] . The present study found the distance as 0.8 mm to
4.2 mm.

The number of branches (side and ending) of the TCA varied from two to seven [11]. The number of branches (side and ending) of the TCA were two (62.5%), three (25%) or seven (12.5%)[6]. The TCA usually divides into 2 branches: a smaller and shorter upper and a longer lower branch
[19]. The upper branch usually ended by supplying the pulmonary infundibulum while the lower branches extended variably to the infundibulum, anterior wall of right ventricle or inferior border of right ventricle. A similar path and branching pattern was also observed in the present study. Sometimes the TCA branches extensively to supply not only the pulmonary conus, but also the anterior wall of right ventricle till the inferior border and apex, interventricular septum and conducting system. Angelini[1] noted that the artery supplied the anterior free wall of the right

ventricular outflow tract, which refers to the segment of myocardial territory upto 3-5 cm below the Pulmonary valve. Hence TCA need to be considered during the management of arrhythmias and myocardial ischemia [19]. Some authors have reported TCA supplying the conducting system and hence suspected that TCA dysfunction may be involved in right ventricular outflow tract arrythmogenesis [14]

Large TCA has also been reported [14], [19]. However, no such specimen was found in the present study. Such vessels may give a false better report in cases of left anterior descending artery occlusion. These also poses a risk during cardiac surgeries and this variant should be kept in mind in surgical interventions involving infundibulum or anterior wall of right ventricle (right ventriculotomy) [14] .

The TCA assumes importance in collateral circulation in case of blockage of any one of the

main coronary arteries [13]. Some authors [6] observed that the TCA and the conal branch of the RCA formed Vieussens' arterial ring in 50% and 63% cases respectively. They concluded that the presence of TCA reduces the anastomotic potential of the RCA. Anastomosis between right and left coronary arteries are abundant during fetal life. However they reduce a lot by the end of first year of life. Anastomosis prove more effective in slowly progressive pathological conditions. Well developed collateral circulation through TCA may allow diagnostic and therapeutic interventions in CAD patients [19]. Hence awareness of this artery is necessary for proper interpretation of coronary angiograms and management of patients with coronary insufficiency.

Physiological significance of the conal artery was determined by the length of the conal artery rather than by the origin [6]. Absence of ST segment elevation in V1 lead of ECG in acute anterior myocardial infarction might suggest that the interventricular septum was protected by a large conal branch in addition to the septal branches of the left anterior descending artery [23]. This was also angiographically proved. This artery also has forensic implication as it may help in identification of an individual if ante mortem records show the presence of the TCA [24] .

Conclusion

Occurrence of TCA has shown wide variations across different regions and races. This artery forms an important anastomotic channel in the heart with several clinical implications. As such,

knowledge of the TCA assumes significance as to the understanding of the regional and ethnic variations, which would be helpful for not only for anatomists, but also for cardiologists, radiologists and forensic medicine specialists.

Acknowledgement:

We thank Dr. Deepika Phukan, Statistician cum Lecturer of Community Medicine, Jorhat Medical College & Hospital, Jorhat, Assam, India for her guidance and help in carrying out this research. We thank the Department of Anatomy, Gauhati Medical College and the Department of Forensic Medicine, Gauhati Medical College for the technical and infrastructural support in carrying out this research.

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