Journal of Health Sciences

RESEARCH ARTICLE Open Access

Morphological analysis and clinical significance of the opening of the third coronary artery

Almira Lujinović[1], Lejla Dervišević[1]*, Esad Ćosović[2], Zurifa Ajanović[1], Dina Kapić[2], Esad Pepić[3]

[1]Department of Human Anatomy, Faculty of Medicine, University of Sarajevo, Sarajevo, Bosnia and Herzegovina, [2]Department of Histology and Embriology, Faculty of Medicine, University of Sarajevo, Sarajevo, Bosnia and Herzegovina, [3]Department of Pathophisiology, Faculty of Medicine, University of Sarajevo, Sarajevo, Bosnia and Herzegovina

ABSTRACT

Introduction: The human heart is in most cases vascularized by two coronary arteries, the right coronary artery (RCA) and the left coronary artery. The supernumerary coronary artery, which arises independently from the right aortic sinus and passes through sub-epicardial adipose tissue of the pulmonary conus and anterior side of the right ventricle is called the third coronary artery (TCA).

Methods: This study consisted of 28 formalin-fixed adult human cadaveric hearts. The presence of the TCA was determined. The position of the orifice of the right and excess arteries in relation to the sinotubular junction was determined, and then also the position of the orifice of the excess arteries "on the o'clock level" in relation to the orifice of the RCA. The radius of these orifices and their distance from the orifice of the RCA were measured. The angle between the aorta and TCA, as well as RCA and conus branch, was measured.

Results: A total 11 of specimens had supernumerary arteries. A supernumerary artery was found in two hearts. The angle formed by the aorta with the TCA was 60.09 ± 17.57, while the angle between the aorta and the conus branch had an average value of 89.88 ± 15.92. The orifices of all supernumerary arteries were located below the level of the sinotubular junction. The average diameter of the TCA was 1.49 mm ± 0.41. The average distance between the TCA orifice and the RCA orifice was 2.21 mm ± 1.03. In 45.45% cases, the orifice of TCA was located at the 10 o'clock level.

Conclusion: The present study highlights the presence of the TCA. It may constitute a significant collateral circulation contributing to apical and septal perfusion. Interpretation of signs and symptoms of coronary occlusion should therefore include possible contribution of this vascular channel.

Keywords: Anatomical variations; supernumerary arteries; third coronary artery

INTRODUCTION

The arterial supply of the human heart is provided by the left and right coronary arteries. However, cases of the presence of only one coronary artery originating from the right (1,2) or left aortic sinus (3,4) have been described, which may be associated with congestive heart failure, myocardial infarction, or sudden cardiac death (5).

Supernumerary heart arteries are a common finding. The supernumerary cardiac artery that originates independently from the right aortic sinus and extends through the subepicardial adipose tissue of the pulmonary cone and anterior right ventricle is referred to as the preinfundibular artery, conical artery, delicate Vienssen's artery, or third coronary artery (TCA). Its course and vascularization field often coincide with the distribution of the conical branch of the right coronary artery (RCA) (6-10). Although its distribution is relatively unexplored, TCA may supply various parts of the anterior wall of the right ventricle and the interventricular septum (11,12).

In some cases, the existence of two excessive arteries (third and fourth) has been reported, which originate independently from the right aortic sinus (1,13,14).

Data on the frequency of excess arteries are quite variable and range from 1.5% and 8% according to Lo et al. (15) and Kurjia et al. (16), up to 62% (1). The reason for this probably lies in ethnic or geographical differences based on genetic background (17).

The presence of the TCA is especially important in conditions of coronary insufficiency, which can be mitigated by its existence, as well as by a collateral blood flow, that is, anastomoses that this artery most often forms with the anterior interventricular branch (13,18,19), but also with the diagonal and circumflex branches, as well as with the branches of the RCA (20-22).

*Corresponding author: Lejla Dervišević, Department of Human Anatomy, Faculty of Medicine, University of Sarajevo, Čekaluša 90, 71000 Sarajevo, Bosnia and Herzegovina. E-mail: lejla.dervisevic@mf.unsa.ba

Submitted: 13 July 2022/Accepted: 09 December 2022

DOI: https://doi.org/10.17532/jhsci.2022.1889

UNIVERSITY OF SARAJEVO
FACULTY OF HEALTH STUDIES

Therefore, in persons with occlusive coronary artery disease, it is necessary to perform selective angiography of the TCA and thus establish its presence and course, as well as the possible presence of anastomoses of this artery with branches of other arteries, which remained unnoticed in standard angiographies of the left and right coronary arteries (23-25).

For the correct performance of selective angiography of the TCA, it is very important to know the size of the orifice of the TCA in the right aortic sinus, as well as its position relative to ostia of the RCA and sinotubular junction (10,26,27), which was the aim of this research.

Furthermore, our goal was to determine the size of the angle between the aorta and the TCA, since this information could prevent its damage during ventriculotomy and other heart surgeries (26,28).

METHODS

Twenty-eight formalin-fixed adult human cadaveric hearts, of unknown sex and age, were collected from the Department of Human Anatomy, Faculty of Medicine, University of Sarajevo, over the period of 3 years. The hearts having gross congenital anomalies were excluded. The study was approved by the Local Ethics Committee.

The dissection enabled us to show the coronary arteries, the place of their origin, their course, their way of branching, and their present anastomoses. Hearts were stored for 3–5 days in 10% of formalin. The epicardial and periarterial adipose tissue was removed and coronary arteries and their branches were carefully dissected. In cases where the TCA was found, the aorta was opened along its length at the level of the posterior sinus in order to gain insight into the left and right aortic sinuses and the presence of an appropriate coronary orifice.

The position of the orifice of the right and excess arteries in relation to the sinotubular junction was determined, and then also the position of the orifice of the excess arteries "on the o'clock level" in relation to the orifice of the RCA. The radius of these orifices and their distance from the orifice of the RCA was measured. A digital sliding caliper (Black and Decker, USA) with a measuring range of 0-200 mm was used to measure the aforementioned parameters.

The angle between the aorta and the TCA, as well as the angle between the RCA and the conus branch, was measured using a manual goniometer (GPM Model 117, Switzerland). The angle between the aorta and the TCA was measured by placing the center of the goniometer at the junction of the aorta and the TCA, the fixed arm of the goniometer along the longitudinal axis of the aorta, and the movable arm of the goniometer along the longitudinal axis of the TCA. When measuring the angle between the RCA and the conus branch, the Center of the goniometer is placed at their junction, the fixed arm of the goniometer parallel to the longitudinal axis of RCA, and the movable arm of the goniometer parallel to the longitudinal axis of conus branch. Finally, photographs were made with a high-resolution digital camera.

The obtained data were analyzed using descriptive statistics. The results are presented in form of mean values, maximum and minimum values, standard deviation, and percentages of representation.

RESULTS

Out of a total of 28 hearts, 11 of them (39.29%) had supernumerary arteries starting from the right sinus of the aorta and extending along the pulmonary cone and the front side of the right ventricle (Figure 1).

Two supernumerary arteries originating from the right aortic sinus were present in two hearts (7.14%), that is, along the third and fourth coronary arteries (FCA) (Figure 2).

The angle formed by the longitudinal axis of the aorta with the longitudinal axis of the TCA was 60.09 ± 17.57, while the angle between the longitudinal axis of the aorta and the conus branch was most often obtuse, with an average value of 89.88 ± 15.92.

The orifices of all supernumerary arteries were located below the level of the sinotubular junction.

The average value of the diameter of the supernumerary arteries orifice was 1.49 mm ± 0.41 (0.84 mm to 2.1 mm). The smallest diameters (0.84 mm and 0.87 mm) were found in two cases of FCA.

The average distance from the supernumerary artery orifice to the orifice of the RCA, in the right aortic sinus, was 2.21 mm ± 1.03 (Graph 1).

FIGURE 1. Third coronary artery (TCA) (1. right coronary artery and 2. TCA).

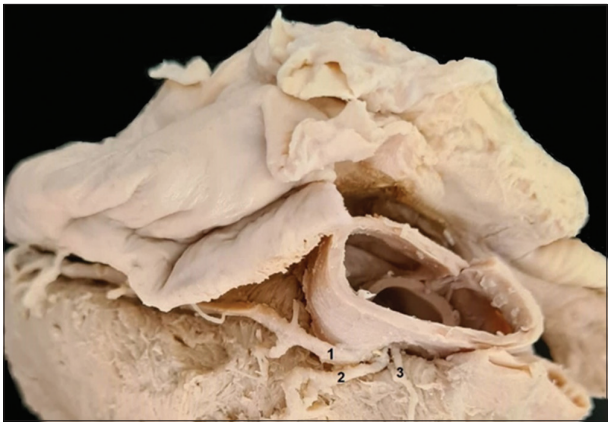


FIGURE 2. Supernumerary cardiac arteries (1. right coronary artery, 2. third coronary artery, and 3. fourth coronary artery).

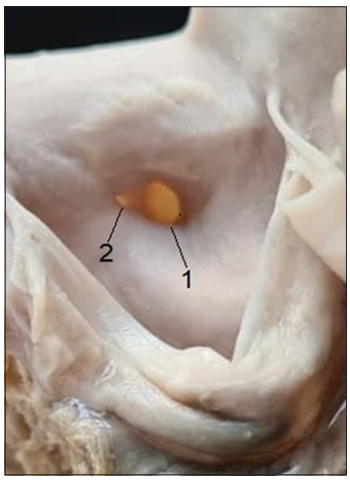


FIGURE 3. Right coronary artery (RCA) and third coronary artery (TCA) orifice in the right aortic sinus (1. RCA and 2. TCA).

FIGURE 5. Third coronary artery (TCA) orifice at the 10 o'clock position (1. right coronary artery and 2. TCA).

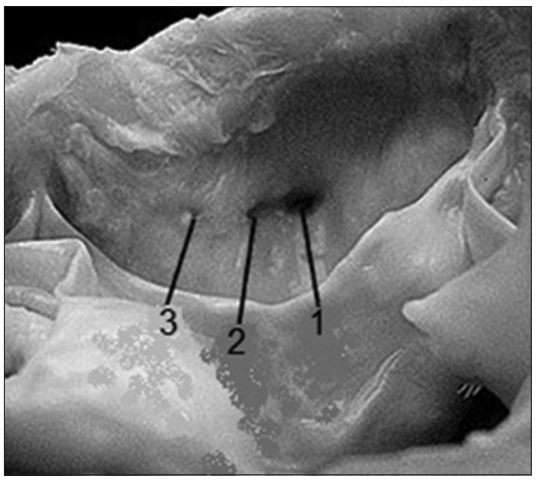
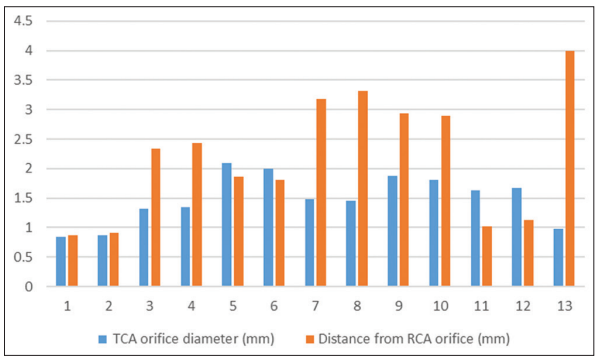
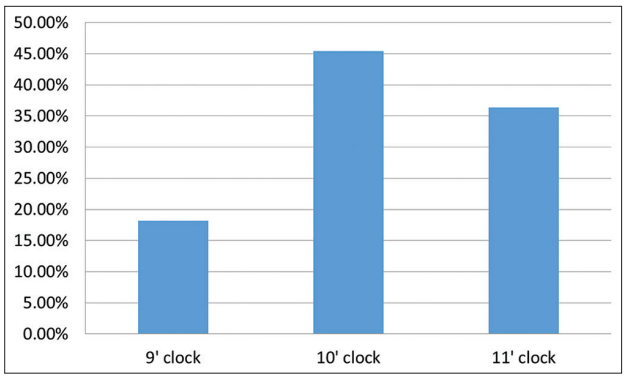


FIGURE 4. Right coronary artery (RCA) orifice and supernumerary artery orifices in right aortic sinus (1. RCA, 2. third coronary artery, and 3. fourth coronary artery).



GRAPH 1. The average distance of the orifice of the supernumerary arteries from the orifice of the right coronary artery.



GRAPH 2. Position of the orifice of supernumerary arteries.

The orifices of all supernumerary arteries were located in the front, to the left, and below the orifice of the RCA (Figures 3 and 4).

When the orifice of the RCA was set at the 12 o'clock level, it was determined that the orifices of supernumerary arteries were located at 10 o'clock (45.45%), 11 o'clock (36.36%), and 9 o'clock (18.18%) (Figure 5 and Graph 2).

DISCUSSION

Considering the clinical importance of the presence of the TCA, numerous authors, both morphologists and clinicians have been interested in this research field. Data on the frequency of the TCA are quite variable in relation to ethnicity, which speaks in favor of a genetic predisposition (17,29,30).

The frequency of the TCA varies depending on the method used for its detection and ranges from 8% and 12% (16,18) on selective coronary angiograms, 17%, 22%, and 29.7% (31-33) on CT coronary angiograms, and 34.8%, 36.8%, and even 68% on dissection preparations of human hearts (26,34,35).

In our study, the frequency of occurrence of the TCA was 39.9%, which coincides with the results of other researchers who used the dissection method as the main research tool, as we did. Wide variation in the prevalence of this artery reported by various authors suggests ethnic variability which may have a genetic basis or it could be due to the inability to selectively cannulate TCA on conventional angiography (10,29,36).

The lowest frequency of TCA on coronary angiograms can be explained by the fact that the TCA often remains undetected. Thus, it is necessary to perform selective coronary angiography of this artery in patients with coronary disease, considering its contribution to perfusion, as well as the importance of collateral blood flow through this artery (3,25,37). In this context, it is also important to determine the size and position of the opening of the supernumerary arteries in the right aortic sinus (10,17).

In our study, the orifices of all 13 supernumerary coronary arteries were localized in the right aortic sinus below

the level of the sinotubular junction, which significantly deviates from the results obtained by Sankari et al. (38), Joshi (39), Manju et al. (40) who found that the location of these orifices was not only below, but also above and at the level of the sinotubular junction.

Data on the localization of the TCA orifice in relation to the RCA orifice are also quite variable. Apsara (41) states that in 98% of cases, the orifice of the TCA is to the left and at the same level as the orifice of the RCA. Stankovic and Jesic (26) found that the TCA orifice is always to the left and above, with a distance of 1.7 ± 0.6 mm from the opening of the RCA (interval 1-2.7 mm), while Maric et al. (17) recorded that it is at the same level and to the left of the RCA opening, from which it is 1–2 mm away.

Our results show that the orifice of the supernumerary heart arteries was in all cases located in front, to the left, and below the orifice of the RCA, from which it was 2.21 ± 1.03 mm away, mostly localized at the 10 o'clock level (45.45%), while the rest was located at the 11 and 9 o'clock levels.

These results are consistent with the study by Míyazaki and Kato (34), who found that the TCA openings were located at 8, 9, and 10 o'clock. In a large study conducted on 550 human hearts, Yadukul et al. (42) the most frequent localization of the TCA orifice was at 10 o'clock (83.15%), but also at 9, 8, and 7 o'clock.

The area of perfusion of the TCA is variable and may be more extensive than usual in some individuals. About 10% of clinical malpractice is due the ignorance of the anatomical variations (43). The size of the coronary arteries typically determines the treatment options in the management of coronary artery disease since small arteries may cause anastomotic difficulties during bypass grafting and can influence the outcome of procedures such as stenting and balloon angioplasty. The possibility of large TCA and myocardial bridges over it should be thought of during various surgical procedures to avoid tissue damage.

Given that the data on the localization of the orifice of the supernumerary cardiac arteries in the right aortic sinus are quite heterogeneous, it is our opinion that this research should be continued on a larger sample and that it is important to determine the most common orifice localization in relation to the sinotubular junction, as well as to the RCA should. This would be of great help to interventional cardiologists for a successful performance of TCA selective coronary angiography.

CONCLUSION

The TCA participates in the perfusion of apical and septal areas by anastomosing with branches of the left anterior descending artery. Hence, the potential presence of the TCA should always be taken into account during diagnostic and therapeutic interventions. The possibility of the existence of a large TCA should not be neglected during various surgical procedures to avoid tissue damage.

COMPETING INTERESTS

There are no conflicts of interest to declare by any of the authors of this study.

REFERENCES

1. Onwuka E, King N, Heuer E, Breuer C. The heart and great vessels. Cold Spring Harb Perspect Med 2018;8(3):a031922.
   https://doi.org/10.1101/cshperspect.a031922
2. Benslimane A, Funck F, Bellorini M, Lefevre T, Guillard N, Jacoly CJ. Single coronary artery arising from the right coronary sinus. Report of two cases. Arch Mal Coeur Vaiss 1998;91(12):1503-7.
3. Takano M, Seimiya K, Yokoyama S, Okamatsu K, Ishibashi F, Uemura R, et al. Unique single coronary artery with acute myocardial infarction: Observation of the culprit lesion by intravascular ultrasound and coronary angioscopy. Jpn Heart J 2003;44(2):271-6.
   https://doi.org/10.1536/jhj.44.271
4. Koizumi M, Kawai K, Honma S, Kodama K. Anatomical study of a left single coronary artery with special reference to the various distribution patterns of bilateral coronary arteries. Ann Anat 2000;182(6):549-57.
5. Silva A, Baptista MJ, Araújo E. Congenital coronary artery anomalies. Rev Port Cardiol (Engl Ed) 2018;37(4):341-50.
   https://doi.org/10.1016/j.repce.2011.12.018
6. Mori S, Tretter JT, Spicer DE, Bolender DL, Anderson RH. What is the real cardiac anatomy? Clin Anat 2019;32(3):288-309.
   https://doi.org/10.1002/ca.23340
7. Wu W, Khan B, Sharzehee M, Zhao S, Samant S, Watanabe Y, et al. Three dimensional reconstruction of coronary artery stents from optical coherence tomography: Experimental validation and clinical feasibility. Sci Rep 2021;11(1):12252.
8. Blessy T, Sumam KS. Blood flow in human arterial system-a review. Procedia Technol 2016;24:339-46.
   https://doi.org/10.1016/j.protcy.2016.05.045
9. Viallonga JR. Anatomical variations of the coronary arteries. I. The most frequent variations. Eur J Anat 2003;7 Suppl 1: 29-41.
10. Yadukul S. Third coronary artery-an autopsy study. Heart 2016;102:A141-2.
11. Sahni D, Jit I. Blood supply of the human interventricular septum in North-West Indians. Indian Heart J 1990;42(3):161-9.
12. Von Lüdinghausen M, Ohmachi N. Right superior septal artery with "normal" right coronary and ectopic "early" aortic origin: A contribution to the vascular supply of the interventricular septum of the human heart. Clin Anat 2001;14(5):312-9.
    https://doi.org/10.1002/ca.1057
13. Lujinović A, Ovčina F, Tursić A. Third coronary artery. Bosn J Basic Med Sci. 2008;8(3):226-9.
    https://doi.org/10.17305/bjbms.2008.2922
14. Fiss DM. Normal coronary anatomy and anatomic variations. Appl Radiol 2007;36(1):14-26.
15. Lo EA, Dia A, Ndiaye A, Sow ML. Anatomy of coronary arteries. Dakar Med 1994;39(1):23-9.
16. Kurjia HZ, Chaudhry MS, Olson TR. Coronary artery variation in a native Iraqi population. Cathet Cardiovasc Diagn 1986;12(6):386-90.
    https://doi.org/10.1002/ccd.1810120606
17. Maric DL, Colic B, Mirovic B, Eric M, Radosevic D, Knezi N, et al. Prevalence of third coronary artery: Variation or constant coronary artery? Int J Morphol 2018;36(4):1241-5.
    https://doi.org/10.4067/S0717-95022018000401241
18. Yamagíshí M, Haze K, Tamaí J, Fukamí K, Beppu S, Akiyama T, et al. Visualization of isolated conus artery as a major collateral pathway in patients with total left anterior descending artery occlusion. Cathet Cardiovasc Diagn 1988;15(2):95-8.
    https://doi.org/10.1002/ccd.1810150207
19. Tanigawa J, Petrou M, Di Mario C. Selective injection of the conus branch should always be attempted if no collateral filling visualises a chronically occluded left anterior descending coronary artery. Int J Cardiol 2007;115(1):126-7.
    https://doi.org/10.1016/j.ijcard.2006.04.012
20. Sharma S, Kaul U, Rajaní M. Collateral circulation to the diagonal artery from the infundibular coronary artery in obstructive coronary arterial disease. Int J Cardiol 1989;25(1):134-6.
    https://doi.org/10.1016/0167-5273(89)90176-9
21. Kerensky RA, Franco EA, Hill JA. Antegrade filling of an occluded right coronary artery via collaterals from a separate conus artery, a previously ™described collateral pathway. J Invasive Cardiol 1995;7(7):218-20.
22. Mishkel GJ, Biagioni E, Stolberg H. Total occlusion of the circumflex artery with collateral supply from the conus artery. Cathet Cardiovasc Diagn 1991;23(3):194-7.
    https://doi.org/10.1002/ccd.1810230311
23. Feld S, Epstein M, Ayzenberg O, Caspi A. Non-visualized left anterior descending artery revealed on selective conus artery catheterization. Clin Cardiol 1995;18(10):597-8.
    https://doi.org/10.1002/clc.4960181014
24. Levin DC, Beckmann CF, Garnic JD, Carey P, Bettmann MA. Frequency and clinical significance of failure to visualize the conus artery during coronary arteriography. Circulation 1981;63(4):833-7.

https://doi.org/10.1161/01.cir.63.4.833

25. Tanigwa J, Petrou M, Di Mario C. Selective injection of conus branch should always be attempted if no collateral fillng visualises a chronical occluded left anterior descending coronary artery. Int J Cardiol 2007;115(1):126-7.

    https://doi.org/10.1016/j.ijcard.2006.04.012

26. Stankovic I, Jesic M. Morphometric characteristics of the conal coronary artery. MJM 2004;8:2-6.

    https://doi.org/10.26443/mjm.v8i1.507

27. Tomar S, Aga P, Sharma PK, Manik P, Srivastava AK. Frequency and clinical significance of conus artery and its variant third coronary artery in North Indian population: A 64-slice CT angiographic study. Int J Sci Res Publ 2014;4(9):2250-3153.

28. Gouda HS, Mestri SC, Aramani SC. Third coronary artery-boon or bane? J Indian Acad Forensic Med 2009;31(1):62-4.

29. Olabu BO, Saidi HS, Hassanali J, Ogeng'o JA. Prevalance and distribution of the third coronary artery in Kenyans. Int J Morphol 2007;25(4):851-54.

    https://doi.org/10.4067/S0717-95022007000400027

30. Garg N, Tewari S, Kapoor A, Gupta DK, Sinha N. Primary congenital anomalies of the coronary arteries: A coronary: Arteriographic study. Int J Cardiol 2000;74(1):39-46. \

    https://doi.org/10.1016/s0167-5273(00)00243-6

31. Erol C, Seker M. The prevalence of coronary artery variations on coronary computed tomography angiography. Acta Radiol 2012;53(3) 278-284.

    https://doi.org/10.1258/ar.2011.110394

32. Kosar P, Ergun E, Ozturk C, Kosar U. Anatomic variations and anomalies of the coronary arteries: 64-slice CT angiographic appearance. Diagn Interv Radiol 2009;15(4):275-83.

    https://doi.org/10.4261/1305-3825.DIR.2550-09.1

33. Ritu M, Sanjeev A. Frequency and clinical significance of the conus artery as third coronary artery on 64-slice computed tomography angiography (CTA). IJCRR 2013;5(12):72-6.

34. Míyazaki M, Kato M. Third coronary artery: Its development and function. Acta Cardiol 1988;43(4):449-557.

35. Fazliogullari Z, Karabulut AK, Dogan NU, Uysal II. Coronary artery variations and median artery in Turkish cadaver hearts. Singapore Med J 2010;51(10):775-80.

36. Schlesinger MJ, Zoll PM, Wessler S. The conus artery: A third coronary artery. Am Heart J 1949;38(6):823-38.

    https://doi.org/10.1016/0002-8703(49)90884-4

37. Lakshmi GL, Vineesh V, Mathew D. Third coronary artery: A cadaveric study. Int J Anat Res 2017;5(1):3410-4.

    https://doi.org/10.16965/ijar.2016.491

38. Sankari TU, Kumar JV, Saraswathi P. The anatomy of right conus artery and its clinical significance. Recent Res Sci Technol 2011;3(10):30-9.

39. Joshi SD, Joshi SS, Athavale SA. Origins of the coronary arteries and their significance. Clinics (Sao Paulo) 2010;65(1):79-84.

    https://doi.org/10.1590/S1807-59322010000100012

40. Manju M, Kaur D, Nair N. Morphology and morphometry of coronary ostia in adult human cadaveric hearts. J Anat Soc India 2006;56(1):110-3.

41. Apsara MP. The third coronary artery: Lessons revisited. J Evol Med Dent Sci 2014;3(43):10704-10.

    https://doi.org/10.14260/jemds/2014/3396

42. Yadukul S, Sumangala CN, Chandragirish C, Chandrashekar TN. Third coronary artery-an autopsy study. IJHRMLP 2015;1(2):46-8.

43. Ajayi NO, Lazarus L, Vanker EA, Satyapal KS. Anatomic parameters of the left coronary artery: An angiographic study in a South African population. Int J Morphol 2013;31(4):1393-8.