ANATOMY OF THE THIRD CORONARY ARTERY IN KENYANS

A dissertation submitted in partial fulfillment of the requirements of the intercalated Bachelor of Science, in Anatomy Degree of the University of Nairobi

By

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DECLARATION

I hereby confirm that this dissertation represents my original work and has not been presented elsewhere for examination.

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DEDICATION

I would like to dedicate this work to my friends Ezekiel Mutai, David Tarus, Blastus Kakundi, George Otieno, Victoria Mueni and Josephine Mutisya. Special dedication to my brother Kennedy Odhiambo, sister Monica Awour and aunt Safina Omar.

ACKNOWLEDGEMENTS

I would like to acknowledge the following people for working hand in hand with me thereby contributing to its successful completion:

My supervisors: Dr. Hassan Saidi, Prof. Jameela Hassanali and Dr. Julius Ogeng'o for their constant guidance in the writing of this dissertation. Dr. Kirsteen Awori for accepting to edit the final write-up. The late Prof. James Kimani, Dr. Paul Odula, Dr. Joseph Githaiga and Dr. Gichambira Gikenye for their help in definitions of terminologies. Acleus Murunga and Boniface Miring'u for helping in fixation of the gross specimens and photography. Technicians for providing the necessary materials in histology and photography. Finally, my classmates: Anne Pulei, Peter Kitunguu and Duncan Anangwe their moral support.

LIST OF CONTENTS

LIST OF ABBREVIATIONS

1.	AMI	- Acute myocardial infarction
2.	AVG	-Atrioventricular groove
3.	AVN	-Atrioventricular node
4.	ECG	- Electrocardiography
5.	EEL	- External elastic lamina
6.	ID	- Internal diameter
7.	IEL	- Internal elastic lamina
8.	IVG	-Interventricular groove
9.	IVS	- Inter-ventricular septum
10.	LAD	- Left anterior descending
11.	LAS	- Left aortic sinus
12.	LCA	- Left coronary artery
13.	LCX	- Left circumflex artery
14.	LV	- Left ventricle
15.	PAS	- Posterior aortic sinus
16.	PIV	- Posterior interventricular
17.	RAS	- Right aortic sinus
18.	RCA	- Right coronary artery
19.	RV	- Right ventricle
20.	SNA	- Sinus node artery
21.	SPSS	- Statistical Package of Social Sciences
22.	TCA	- Third coronary artery

SUMMARY

Background: The heart is usually supplied by the right and left coronary arteries from their respective sinuses in the ascending aorta. The infundibulum of the right ventricle is usually vascularized by conal branches of the right coronary and left anterior descending arteries. The third coronary artery (TCA), which has been defined as a direct artery from the right aortic sinus towards the infundibulum, may also contribute to the supply of this territory when it is present. Knowledge of the anatomy of the TCA including its distribution to the anterior wall of the right ventricle and the interventricular septum may be important in understanding the progression of acute myocardial infarction involving these regions. Its course and extent could be important in surgical procedures around the aortic root and anterior wall of the right ventricle. There is evidence that the prevalence of this artery shows age and ethnic variability.

Aim of the study: To determine the prevalence and anatomy of the third coronary artery in a Kenyan population.

Study design: Descriptive cross-sectional study.

Materials and methods: One hundred and sixty four cadaveric and postmortem human hearts of different ages were obtained from the Department of Human Anatomy, University of Nairobi and the Chiromo and Nairobi city mortuaries. Ethical approval was sought from the Kenyatta National HoSpital Ethical Review Committee. The hearts were studied by gross dissection for the prevalence and topographical anatomy of the third

coronary artery. The structure of the artery was studied by light microscopy and morphometric analysis carried out on the histological slides prepared then compared for age and sex. The data obtained was coded and analyzed using SPSS.

Results: The third coronary artery was present in fifty seven (34.8 %) heart specimens. This artery arose either from two orifices, single separate or common orifice with the right coronary artery in the right aortic sinus. These were located to the left of the orifice for the right coronary artery in all the cases. Most of the arteries had an epicardial course in the entire length but three had myocardial bridges extending for a variable distance across the vessel. The TCA was variably distributed to the conducting system, anterior wall of the right ventricle, interventricular septum and apex of the heart. Microscopically the TCA was, like the right and left coronary arteries, a typical muscular artery. The artery displayed intimal hyperplasia which showed proximodistal decrease in prominence. There was more intimal hyperplasia in adult specimens than in the paediatric specimens. Longitudinal smooth muscles were a prominent feature in the intimal zones. The wall of the TCA was thicker and the luminal diameter wider in specimens from the male subjects compared to those from the female subjects.

Conclusion: The third coronary artery is present in a third of Kenyans with a variable region of distribution. A long TCA may provide collateral pathway for apex or septal perfusion in blockages involving the left anterior descending artery. Interpretation of symptoms and signs of coronary occlusion should therefore consider possible contribution of this coronary channel especially when extending to the interventricular

septum and the apex of the heart. TCA is a muscular artery and exhibits microscopic features similar to that of the other coronary arteries including intimal hyperplasia. The TCA thus appears to have similar predisposition to coronary artery disease as the left and right coronary artery. Despite having a third coronary artery, the total amount of coronary blood flow is fairly maintained.

INTRODUCTION

The heart is usually vascularized by right and left coronary arteries which arise from respective aortic sinuses at the beginning of the ascending aorta.[1] The right coronary artery (RCA) from the right aortic sinus (RAS) runs between the right auricle and the infundibulum of the right ventricle (RV). It gives off the right conal artery and the sinus node artery (SNA) to the infundibulum and the sinoatrial node respectively then descends in the atrioventricular groove. Other atrial and ventricular branches including the right marginal artery are given off here before the artery turns at the inferior border of the heart to run posteriorly, eventually giving the atrioventricular node (AVN) artery and the posterior interventricular (PIV) artery in a right coronary dominance.[1,2] The left coronary artery (LCA) arises from the left aortic sinus (LAS) behind pulmonary trunk and runs between the left auricle and the infundibulum of the RV. It then divides into left circumflex (LCX) and left anterior descending (LAD) arteries. The LAD also gives off a left conal branch to the infundibulum near its origin then runs in the anterior interventricular groove (IVG) to anastomose at the apex of the heart with the posterior interventricular (PIV) branch of RCA. The infundibulum of the right ventricle is thus supplied by conal branches of both RCA and LAD.[1,3] In some individuals the right conal artery is absent and instead, an artery may arise directly from the RAS, without any observable common trunk with RCA. This has been named the third coronary artery (TCA).[1,2,4]

The reported prevalence of the TCA ranges from 33-51% with evidence of age and ethnic variability.[4, 5, 6, 7] The vessel arises from the aortic sinus through single or multiple

orifices and there seems to be an association between multiplicity of orifices and pathology.[5, 6] Miyazaki and Kato (1988) have found their more frequent occurrence with pathological hearts than normal hearts.[6] These orifices may have clinical implications during cannulation of coronary arteries through their ostia.

In terms of distribution, this artery supplies a variable part of the anterior wall of the RV and may reach the inter-ventricular septum (IVS).[8, 9, 10] This may be important in providing collateral circulation to the IVS when the LAD or its septal branches are occluded.[9] Indeed there are reports that electrocardiographic (ECG) evaluation during the diagnosis of LAD occlusions may not detect any ischemic change in these regions of collateral flow hence giving a 'false better' report.[9,11] A morphometric study by Ivan and Milica (2004) revealed that the TCA has a wider lumen compared to that of the right conal artery suggesting that having a TCA may be advantageous[7]. In spite of the importance of the TCA and the possibility of age and ethnic variations in prevalence, there is scarcity of data on the TCA among the Kenyans.

Microscopically, the coronary arteries have been described as muscular over their entire length.[12] The tunica intima comprises endothelial lining (typically simple squamous) and several layers of collagen fibres in the subendothelium. The tunica media is composed of smooth muscle cells and a network of elastic fibres while circumferentially organized collagen fibres constitute the adventitial[3, 14, 15] Structural differences between the right and left coronary arterial trees have however been described[12] and is thought to contribute to the disparity in incidence of coronary artery disease in the two vessels. This

is because development of atherosclerotic plaques is related to the underlying histological structure.[16,17,18] Further, structural organization of the coronary systems are reported to show gender differences - results that also explain gender prevalence of coronary

disease. The present study asked the question whether the histological structure of the third coronary artery is different from the two coronary arteries to suggest different predisposition to disease.

STUDY JUSTIFICATION

There is evidence of age and ethnic variation in the existence of the third coronary artery yet no study has focused on this in the Kenyan population. Knowledge of the course and distribution of third coronary artery may be necessary in surgical procedures around the anterior wall of the right ventricle and the aortic root. The branching pattern and distribution of the TCA are relatively understudied yet this information may be necessary in the interpretation of the electrocardiographic findings in the diagnosis of acute myocardial infarctions in the clinical practice. Pathologic hearts have been found to have a higher incidence of multiple orifices for the TCA that also tend to be larger compared with those of normal hearts. These observations suggest that TCA has a physiological role in development of coronary pathology.

It is widely recognized that hemodynamic forces are involved in the initiation and development of atherosclerosis. In the coronary vasculature these forces could be mediated by arterial dynamics and geometry which may not be similar in the three coronary arteries. Knowledge of the structural organization of TCA is essential in understanding its predisposition to coronary artery disease. This is important since coronary atherosclerotic lesions are not only limited to the large arteries but may also include even the small vessels supplying the conducting system such as the sinoatrial node (SAN) and atrioventricular (AV) node arteries. This may also add to the pattern of classification or quantification of coronary atherosclerosis which is currently done in relation to three vessels (LCX, LADjfnd RCA).

HYPOTHESIS:

The prevalence, morphology and distribution of TCA among Kenyans resemble those in other populations and its micro structure is similar to that of the other coronary arteries.

OBJECTIVES:

a) Broad objective:

To determine the prevalence of the third coronary artery in a Kenyan population and to describe its topographic, morphometric and structural organization in comparison with the right and the left coronary artery.

b) Specific objectives:

1. To determine the prevalence of the third coronary artery in the Kenyan population in the paediatric and adult age groups.
2. To demonstrate the pattern of branching, distribution and the extent of the third coronary artery.
3. To describe the light microscopic structure of the third coronary artery in comparison to the right and left coronary arteries.
4. To determine the luminal diameter and medial-intimal ratios of the third coronary artery and compare between age and sex.

MATERIALS AND METHODS:

Materials

One hundred and sixty four human hearts from both sexes with an age range of 4-55 years obtained from the cadavers in the Department of Human Anatomy, University of Nairobi and postmortem materials from Chiromo and Nairobi city mortuaries were used in the study. These were sorted into two groups as pediatric (4-12 years, 16 hearts) and adult (18-55 years, 148 hearts). The hearts from male subjects were 91 in total (9 from paediatric and 82 from adult age groups) while those from female subjects were 73 (7 from paediatric and 66 from adult age groups). Twenty histological specimens of hearts with the TCA were systematically sampled from the postmortem materials for light microscopy. Specimens were also obtained from twenty hearts of postmortem subjects without the third coronary artery for morphometric comparisons with the above.

Ethical approval

Ethical approval was obtained from the Kenyatta National Hospital Ethical Review Committee for the use of postmortem materials. The relatives of the deceased consented to the use of the heart of the subjects following postmortem.

Selection criteria:

Exclusion criteria

Heart specimens with observable cardiac defects were excluded from the study.

Gross dissection

The chest cavity was opened during postmortem along the costal cartilages to expose the middle mediastinum. The pericardium was incised longitudinally to expose the heart, which was then harvested by dividing it at the origin of the great vessels. The hearts were dissected to display the right and left coronary arteries and the presence of the TCA was noted. This was done by cleaning around the aortic root by blunt dissection. The aortic root was split from the posterior side of the left ventricle (LV) to enable a better view of the RAS with the orifices present. By use of dissecting lenses, the number and pattern of branching of the third coronary artery was displayed and traced to confirm the course. Observations made were recorded on data sheets.

Measurements

Sections for histological study of the TCA, LCA and RCA were sequentially taken 1 Omm apart from their origin from the ascending aorta and to their various terminations using Vernier calipers. The lengths of the myocardial bridges observed were also measured.

Light microscopy

Twenty heart samples were selected by systematic sampling from the postmortem materials for microscopic study (ten from each age group, male and female equally). Histological sections were taken sequentially (10mm apart beginning from the ascending aorta) by cutting in a plane perpendicular to the axis of TCA, RCA and LCA up to the termination of each vessel. The specimens were fixed by immersion in 10% formal saline; then dehydrated in increasing grades of alcohol from 70% to absolute alcohol each for one hour. They were prepared for paraffin wax embedding by clearing in toluene for 2 hours and infiltrated in wax for 12 hours each. After being embedded in fresh molten wax overnight, seven |am thin sections were cut using Leitz Wetzlar® sledge microtome. The sections were then floated in warm water and thereafter mounted then dried in a hot air oven at 40 °C. The sections were stained with the Weigert resorcin - fuchsin stain then counterstained with Van Gieson stain to demonstrate the elastic fiber component of the vessels. Mason's trichrome stain was also used to demonstrate the general structure of the vascular tunics. Slides were examined under the magnification X40, XI00, X250 and X400 on a Leica light microscope®. The structure of the TCA was compared with that of the other coronary arteries at proximal, middle and distal portion of each vessel. In addition, age and sex differences were noted. Observations made were recorded on data sheet.

Stereology

a) Luminal dimensions

Slides were mounted on the light microscope and the images projected to the screen with a mounted transparent counting grid. A scaled transparent grid was also mounted on the light microscope with the slide to help determine the magnification on the screen. Absolute measurements of the internal diameter of the vessel were made by taking the average of three measurements in three planes (Figure la). These measurements were used to compare blood flow when there was a TCA and when there was none, by adding the average diameters of TCA, RCA and LCA, and then compared with the average of RCA and TCA when there was no TCA.

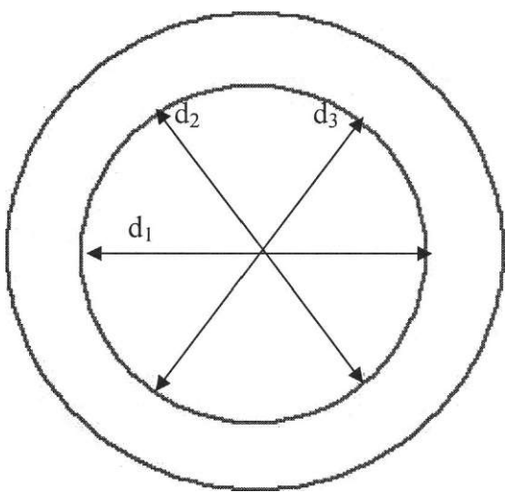


Figure 1a: An illustration of the cross section of coronary artery showing how the internal diameter was measured

b) Medial-intimal ratios

Medial-intimal ratios were determined by counting the number of points falling on the media and intima (Figure lb). These were compared between the coronary arteries and also between age and sex.

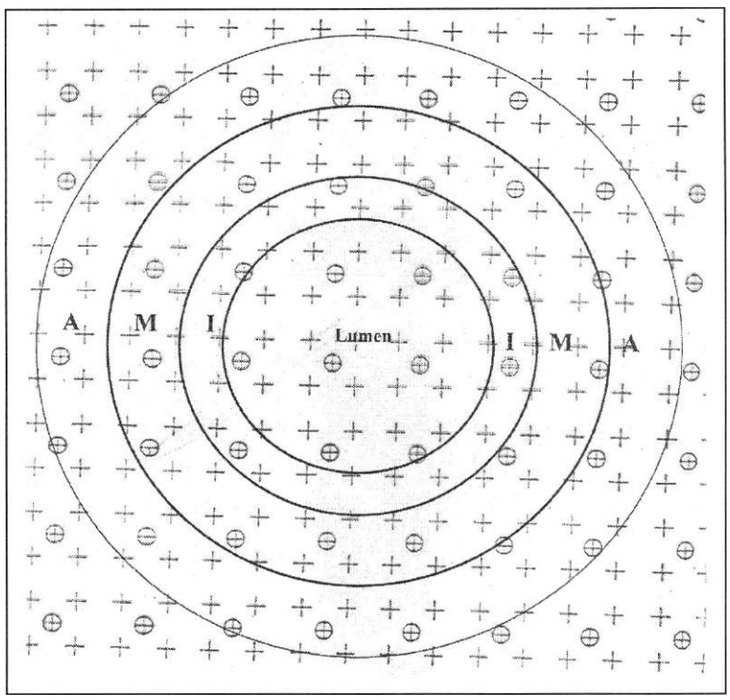


Figure lb: An illustration of the cross section of coronary artery showing how points were used to determine wall to lumen ratio. I = Intima; M = Media; A =- Adventitia.

Photography

Photographs demonstrating the origin, course and branches of TCA and photomicrographs of histological slides demonstrating the structure of the arterial wall were taken from gross dissection and light microscopes respectively by a digital camera (Sony Cybershot® P200, 7.2Megapixels).

Data management

The results of measurements were coded, tabulated and analyzed using a computer software and statistical package of social sciences (SPSS) for windows version 11.5.0 Chicago, Illinois, 2002. Means and standard deviations were determined. The One-Way ANOVA was used to compare the mean dimensions across the vessels. The results obtained are presented using tables and charts.

RESULTS

The present study found a variable presence, pattern of origin and distribution of the TCA. The structure of the TCA was that of a typical muscular artery. Morphometric analysis revealed sexual dimorphism in the TCA luminal diameter and medial-intimal ratios.

Prevalence of the third coronary artery

The third coronary artery was present in 57 of all the cases (34.8 %). Among the adults the prevalence was 35.1% (52/148) and in the paediatric age group 31.3% (5/16). The difference was statistically insignificant (p = 0.36). The difference in prevalence of the TCA between the sexes was also not significant [32/91 in males (35.2%) and 25/73 in females (34.2%); p = 0. 51]. These TCAs originated either from two orifices (3 cases), single orifice separate from that of the RCA (28 cases) or from a common orifice with the RCA (26 cases) (Figures 2; 3a - 5b).

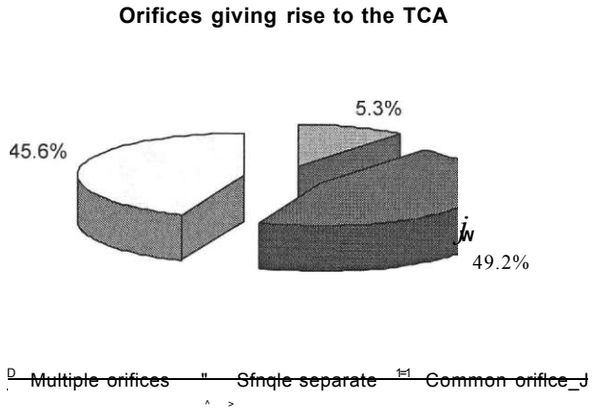


Figure 2: Pie chart showing the number of orifices in the RAS that give rise to the TCA.

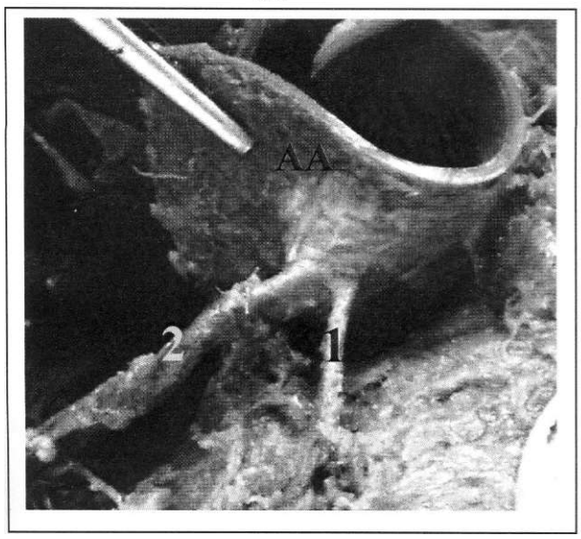
Figure 3a: Photograph of the root of the ascending aorta from the anterior view showing the origins of the third coronary artery (1) and the right coronary artery (2) from the ascending aorta (AA).

Figure 3b: Photograph of the internal part of the ascending aorta of the specimen in figure 3a from the posterior view showing the right aortic sinuse (RAS). Note the three orifices in the RAS labeled 1 (for right coronary artery), 2 (for third coronary artery) and 3 (for a direct branch towards the AV node of the conducting system).

Figure 4: Photograph of the internal part of ascending aorta showing the right and left aortic sinuses, with the RAS having two orifices for the right and third coronary arteries.

Figure 5 (a) and (b): Photographs showing a common origin of the RCA **(1)** and the TCA (2) with their orifices from a single ostium in the right aortic sinus. Note also a myocardial bridge (MB) along the course of the TCA on the wall of the pulmonary trunk.

3a



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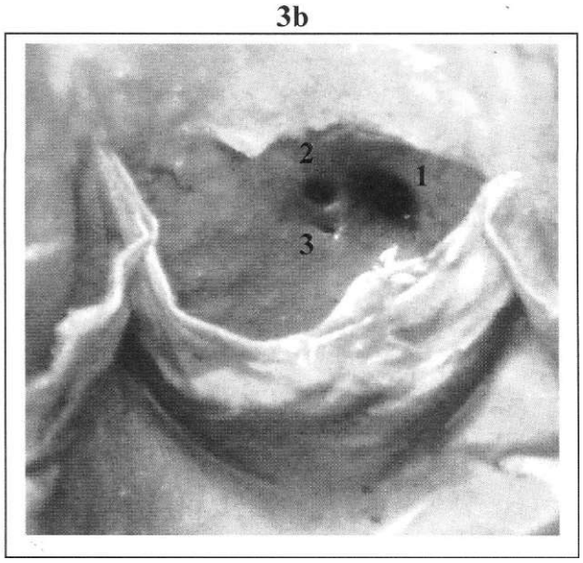

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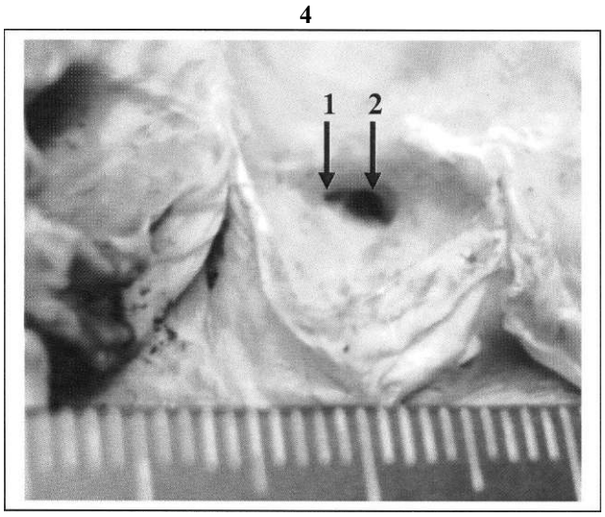

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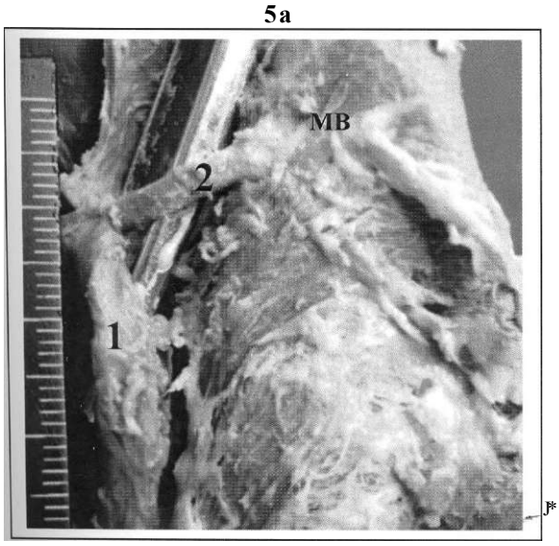

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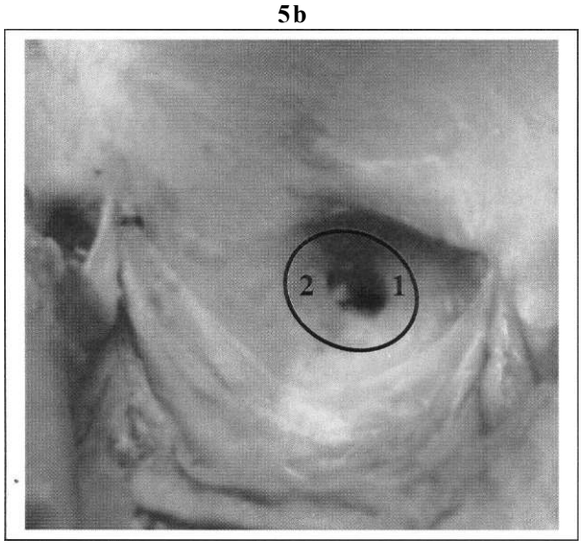


Orifices within the RAS

Majority (76.8%) of the heart specimens had only one orifice in the RAS (115 and 11 adult and paediatric hearts respectively). This single orifice was for the RCA only in most of the cases (101). In 25 cases it served as a common origin for both the RCA and the TCA without any observable common trunk (Figures 5b and 6a). Two orifices were present in the RAS in 28 of the heart specimens observed. These were for both RCA and TCA in 27 of the cases and for the RCA and the sinus node artery (SNA) in one case (Figure 4).

Three separate orifices were observed in four hearts where in two hearts they were for independent origins of the RCA, TCA and SNA artery; in one heart they gave rise to RCA, TCA and AVN (Figure 3b); and in one case for origin of the RCA and TCA which had two orifices. The RAS had four orifices in two heart specimens where the TCA had two orifices and the other orifices were for the RCA and the SNA artery.

In one case there was no orifice in the RAS. Here the RCA originated from an ostium separate from that of left coronary artery (LCA) within the left aortic sinus (LAS) (Figure 6b). This artery then took an interarterial course, with the ascending aorta behind and the pulmonary trunk in front to reach the right atrioventricular groove.

Branches and termination of the third coronary artery

The number of branches of the third coronary artery varied from none to four. In 6 cases there was no branch from the parent artery, while it gave two branches in 10 cases (17.5%), three in 29 cases (50.9%) and four in 12 cases (21.1%) (Table 1). The artery terminated as a single trunk in 32 of the cases (56.1%) while other modes of termination involved bifurcation in 18 cases (31.6%) and trifurcation in 7 cases (12.3%) (Figure 8a).

Table I: Number of TCA branches

Number of branches of TCA	Frequency		Total
	Adult	Paediatric	
None	4	2	6
Two	9	1	10
Three	27	2	29
Four	12	0	12
Total	**52**	**5**	**57**

Course and distribution of the TCA

Most of the third coronary arteries studied (54 of the cases) were epicardial throughout their entire length. In three hearts from adult subjects however the TCA had a variable number and extent of myocardial bridges in the anterior wall of the right ventricle

(Figures 5a; 7a & b). The lengths of the myocardial bridges ranged between 5-11mm and depth between 1-2mm.

Most of the proximal branches of the TCA supplied the anterior wall of the right ventricle (in 34 adult and 3 paediatric hearts) (Figure 8a) while in some subjects these initial branches were distributed towards the region of the conducting system (14 cases, all were hearts from adult subjects) (Figure 8b). In six cases (2 paediatric and 4 adult hearts), there was no branch given by the TCA from the parent trunk.

Figure 6a: Photograph of the root of the ascending aorta (AA) from the inside showing single orifice for the right coronary artery (arrowed) within the right aortic sinus.

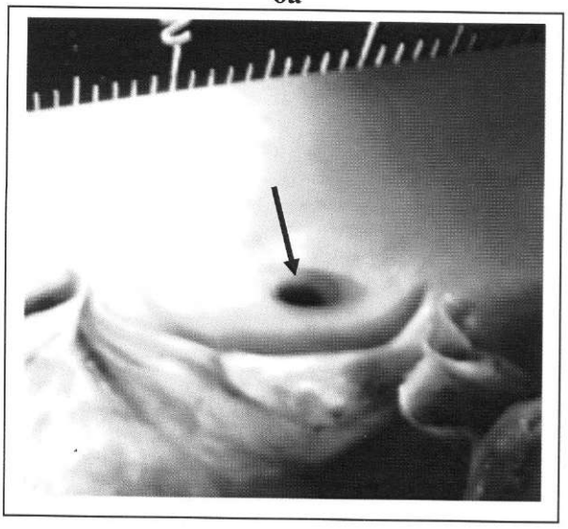
Figure 6b: Photograph of the right and left aortic sinuses showing the orifice of the right coronary artery (labeled 2) within the left aortic sinus together with the orifice of the left coronary artery (labeled 1). The right aortic sinus (RAS) did not have any orifice within it.

Figure 7a and b: Photograph of the front of the right ventricle (RV) showing a third coronary artery (TCA) with myocardial bridges (MB). AA = Ascending aorta; RA = Right auricle.

Figure 8a: Photograph of the right side of the infundibulum of the right ventricle (RV) showing the distribution of the third coronary artery (TCA) to the anterior wall of the right RV. This is an example of a terminal trifurcation.

Figure 8b: Photograph of the right side of the pulmonary trunk (PT) showing the branches of the third coronary (labeled 1; reflected) towards the conducting system (arrows). 2 = Right coronary artery.

6a



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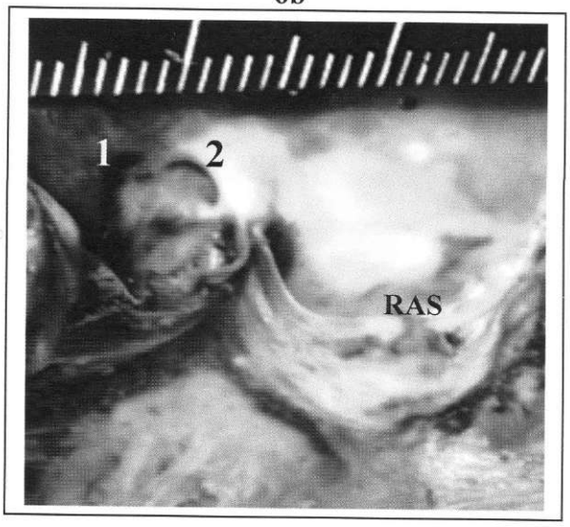

7a

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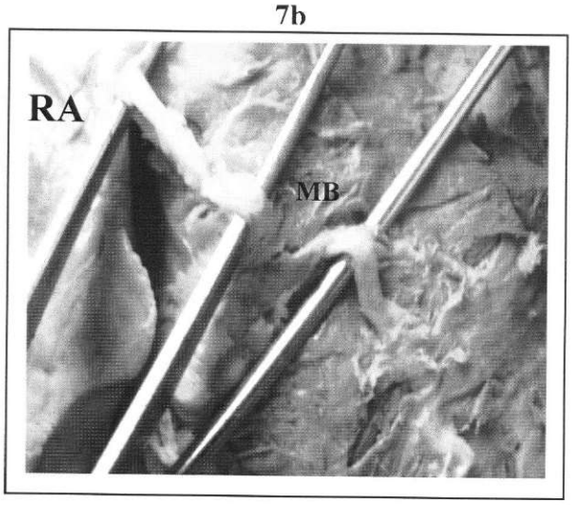

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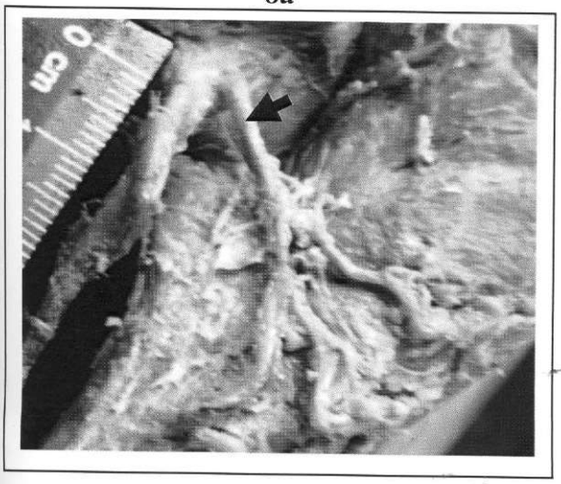

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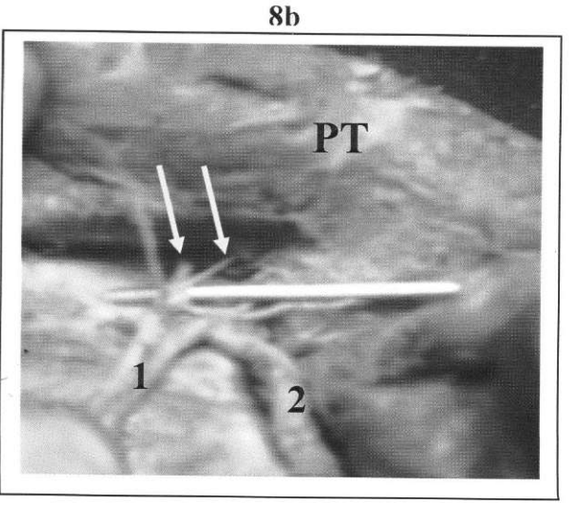


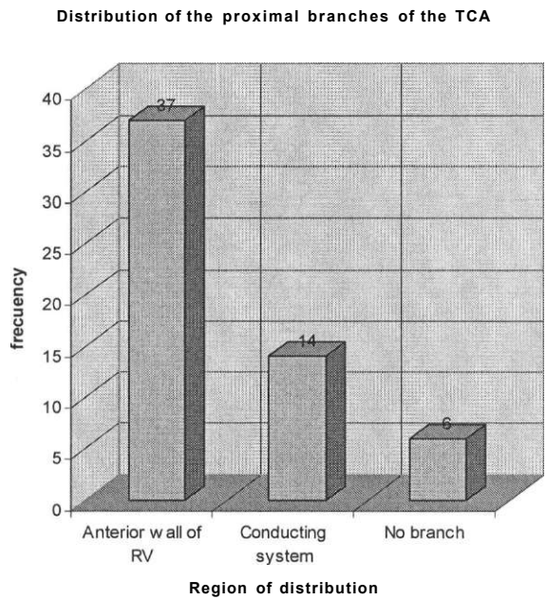


Figure 8c: Bar chart showing the distribution of the proximal branches of the third coronary artery. The parent artery did not give any observable branch in 6 of the cases.

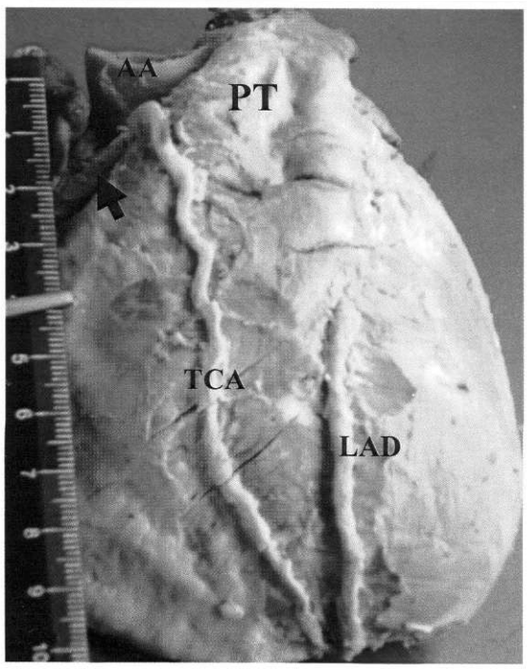
The terminal branch/branches of the TCA reached the interventricular septum (IVS) in 50.9% of the cases (2 paediatric and 27 adult hearts), while these branches terminated in the anterior wall of the right ventricle in 43.9% of the cases (3 paediatric and 22 adults). Three of the TCAs observed (5.3%) terminated at the apex of the heart after coursing in front of the right ventricle (all from heart of adult subjects). One out of these three arteries formed a cruciate anastomosis with the left anterior descending (LAD) and the posterior interventricular artery (PIV) at the apex of the heart (Figure 9a and b). In another case the TCA reaching the apex of the heart was larger than the RCA (Figure 9c).

Figure 9a and b: Photograph of (a) the anterior surface and (b) the apex of the heart showing a long third coronary artery (TCA) reaching the apex of the heart together with the left anterior descending (LAD). Both the TCA and the LAD anastomosed (inset) at the apex of the heart together with the posterior interventricular artery (PIV). The LAD had a myocardial bridge on its proximal part in this specimen. PT = Pulmonary trunk; AA = Ascending aorta.

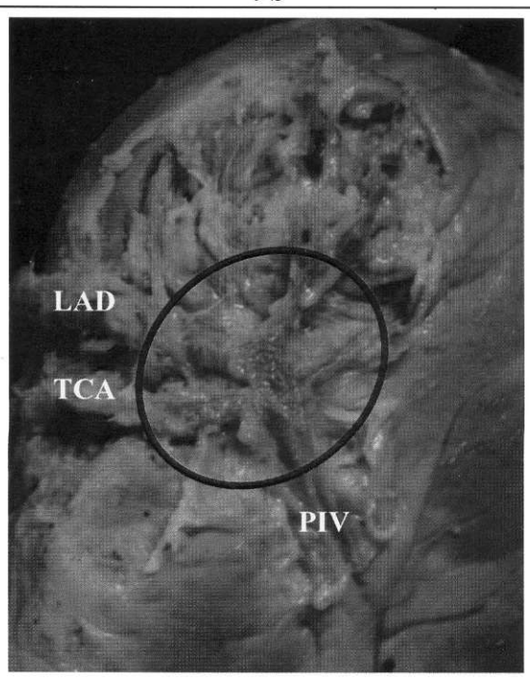
Figure 9c: Photograph of the aortic root showing the origin of the third coronary artery (TCA) and the right coronary artery (RCA) from a common trunk. Note that in this specimen the TCA was larger than the RCA and it passed epicardially in front of the right ventricle (RV) to the apex of the heart. SNA = Sinus node artery.

Figure 10: Photograph of the right coronary artery (RCA) within the right atrioventricular groove showing the sinus node artery (SNA) and the right conal artery (R Conal) as they branch from the RCA. The SNA was given proximal to the branching of the right conal artery from the RCA. Note that in this specimen the right conal artery is almost the same size as the RCA.

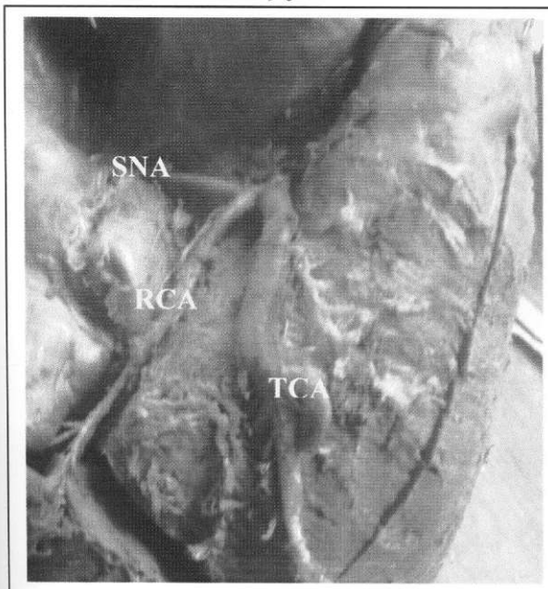
9a



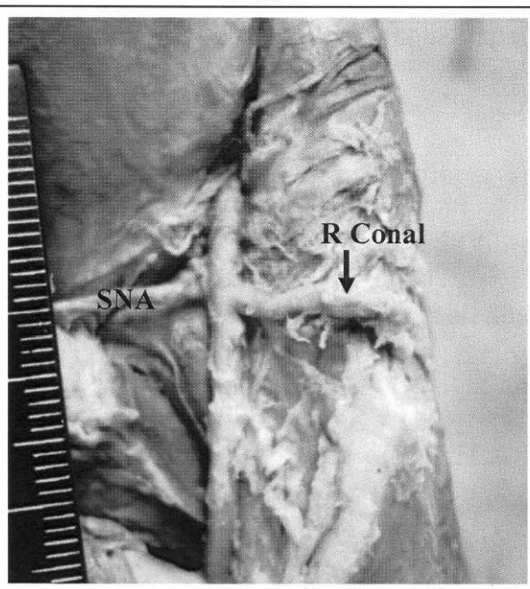
9b



9c



10



Light microscopy

The wall of the third coronary artery showed the typical three-layered structure of a muscular artery with an intima, muscular media and a collagenous adventitia (Figure 11a). There is a gradual proximodistal change in the vessel wall such that elastic fibres reduce both in the intima and media, thinning of the subendothelial space and reduction in size of the tunica media. Apart from the size of intimal thickness in relation to the media, the microscopic structure of the TCA resembles that of right and left coronary arteries.

The tunica intima

The endothelial layer of the tunica intima of the TCA is predominantly formed of squamous epithelium lining the vessel wall (Figure lib). The subendothelial space contained variable amount of collagen and elastic fibres and smooth muscle cells. This was variable depending on the age and sex of the subject. Collagenous fibres are concentrically arranged and intermingle with elastic fibres. The amount of elastic fibres within the subendothelium increases with age, and they tend to be more in the male than in the female specimens of the same age. The same trends are also seen in the right and the left coronary arteries, but in the same individual the subendothelium of the TCA is thinner compared with that of the RCA and LCA (Figure 12a - c).

The relative size of the subendothelial space of the specimens from adult subjects was greater compared to those from paediatric age groups. This is due to the presence of more elastic fibres and also due to the presence of longitudinally oriented smooth muscle fibres

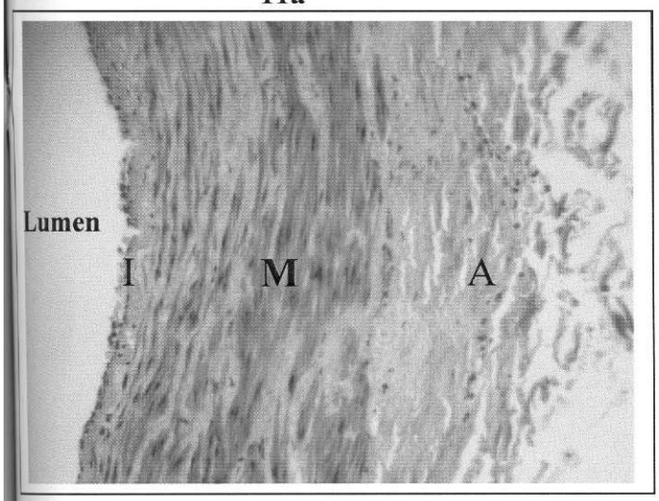
adjacent to the internal elastic lamina on the intimal side. This was observed more in the adult than paediatric specimens (Figure 13a & b). In addition to the uniform intimal thickening around the vessel wall, focal regions of intimal cushions were observed in the TCA of two adult male subjects (Figure 14a & b). The internal elastic lamina of the TCA was thin and continuous in the specimens from the paediatric subjects but it was relatively thicker and interrupted at some regions in the specimens from older subjects (Figure 15a & b).

Proximodistally, the TCA decreased in its intimal thickness due to reduction in the amount of both connective tissue fibres and the subendothelial smooth muscles. The internal elastic lamina also becomes less prominent further distally (Figure 16a & b; Figure 17a & b).

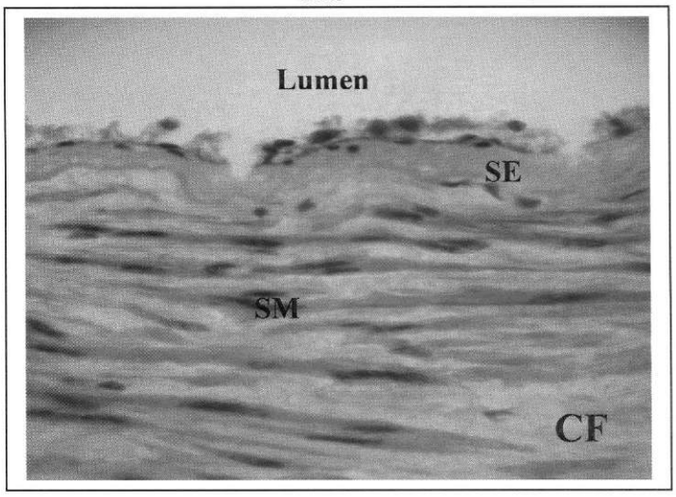
Figure 11 (a) and (b): Photomicrographs of the proximal TCA wall of a 7-year old pediatric heart showing the three tunics of a typical muscular artery. Note that the tunica media (M) consists of concentric smooth muscle cells (SM) with intervening collagen bundles (CF) while the adventitia (A) is collagenous. The endothelial lining consists of a continuous layer of squamous epithelial cells. The subendothelial space (SE) is relatively uniform and is predominantly collagenous. Stain = Mason's Trichrome; Magnification = (a) XI00 and (b) X400.

Figure 12 (a), (b) & (c): Photomicrographs of the proximal part of the TCA obtained from an adult female (a) compared with LCA (b) and RCA (c) of the same individual where all the sections were taken 10mm away from the ascending aorta. Note the relative size of the subendothelial space (SE) of the tunica intima. Intimal hyperplasia is more prominent in the LCA, followed by the RCA then TCA. L = Lumen; M = Media; Stain = Weigert's stain; Magnification = X100.

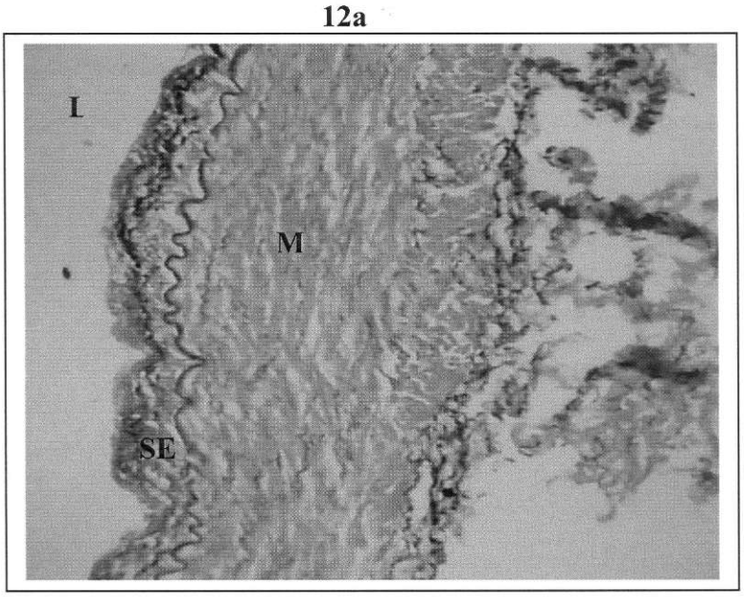
11a



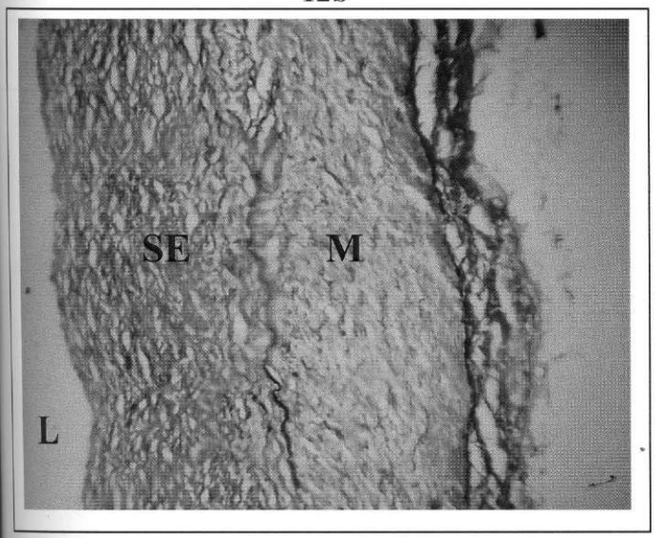
11b



12a



12b



12c

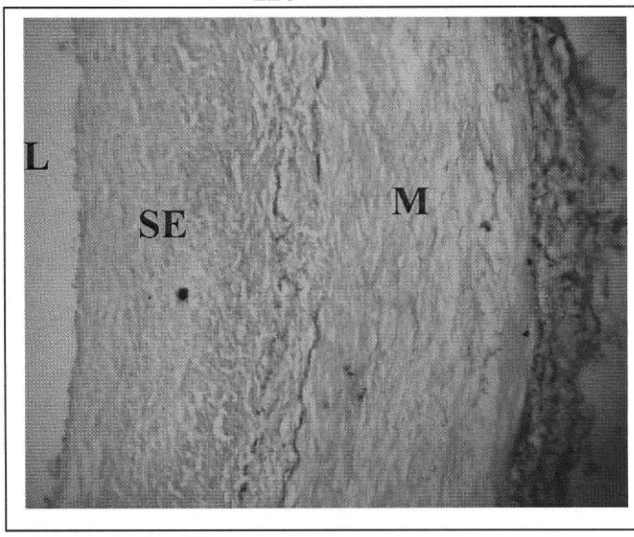
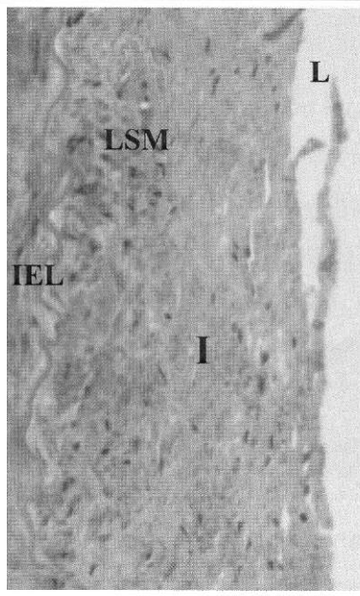


Figure 13 (a) and (b): Photomicrographs of the proximal part of the TCA wall of an adult heart showing the tunica intima (1) and part of the tunica media (M). Note the longitudinal bundles of smooth muscles (LSM) in the subendothelium, a finding observed more in the adult coronary arteries. L = Lumen; IEL = Internal Elastic Lamina; Stain = Mason's Trichrome; Magnification = XI00 and (b) X400.

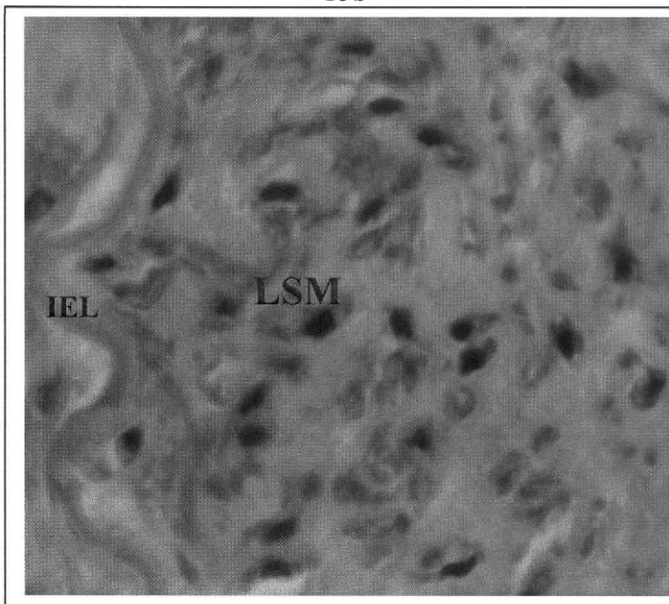
Figure 14 (a) and (b): Photomicrographs of the proximal adult TCA showing intimal cushions (IC) in the arterial wall. Note the larger and elastic tunica intima and a thinner tunica media (M) in this region of intimal cushioning. Magnification = XI00: Stain = Weigert's Stain (a) and Mason's Trichrome (b).

Figure 15 (a) & (b): Photomicrographs of the proximal TCA wall from the heart of a 54-year old male adult showing the tunica intima (I) and part of the tunica media (M) with an intervening internal elastic lamina (IEL). Note that the internal elastic lamina is thicker but interrupted in the adult specimens (compare with fig. 16 below from a 21-years old male). Stain = Weigert's Stain; Magnification = (a) XI00 and (b) X400.

13a



13b



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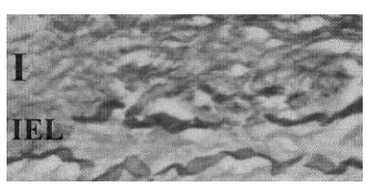

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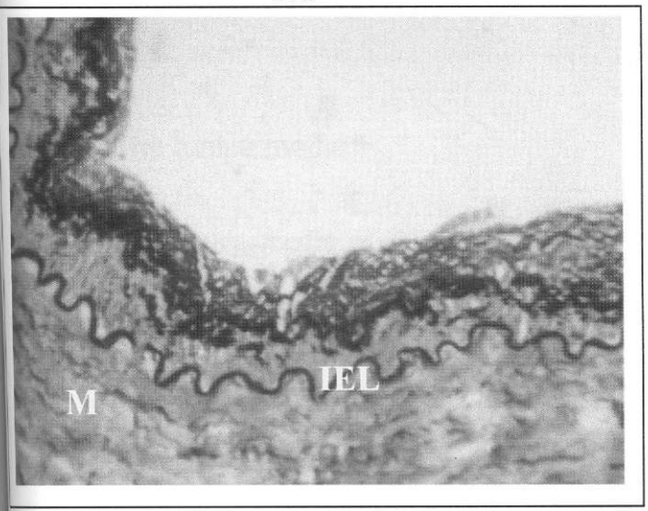
Figure 16 (a) & (b): Photomicrographs of the proximal portion of the TCA wall from the heart of a 21-year old subject showing the tunica intima (I) and the media (M). Note the continuous internal elastic lamina (IEL) [compared with the IEL in a 54-year old male adult in Fig. 15 above]. Fig. 16b also shows longitudinally oriented smooth muscle cells (LSM) in the adventitial zone of the tunica media, an observation made only in this specimen. Magnification = X100; Stain = (a) Weigert's and (b) Mason's Trichrome.

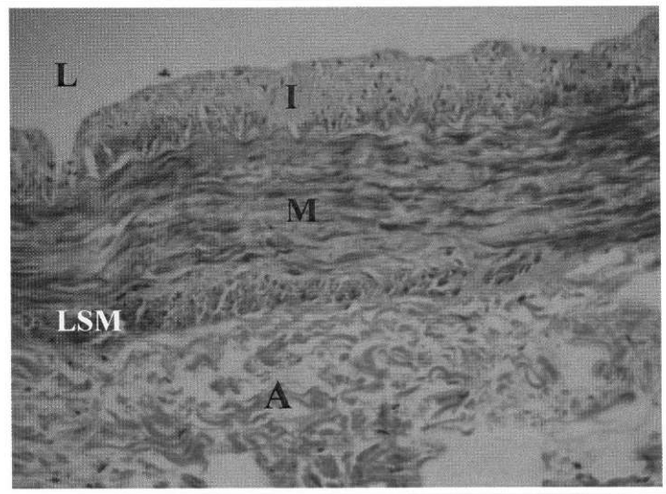
Figure 16 (c) & (d): Photomicrographs of the proximal portion of the TCA wall from the heart of a 21-year old subject showing the tunica intima (I) and part of the media (M). Note the more elastic and thicker tunica intima compared with the specimen from the distal portion of the same vessel (Fig. 17) in the same individual. The tunica media contains strands of elastic fibres (16c) intervening between concentric smooth muscle cells and collagen fibres (16d). Magnification = X400; Stain = (a) Weigert's and (b) Mason's Trichrome.

Figure 17 (a) & (b): Photomicrographs of the distal portion of the TCA wall from the heart of a 21-year old subject showing the tunica intima (I) and part of the media (M). Note the less elastic and thinner tunica intima in the distal portion compared with that from the proximal (Fig. 16 above). Magnification = X400; Stain = (a) Weigert's and (b) Mason's Trichrome.

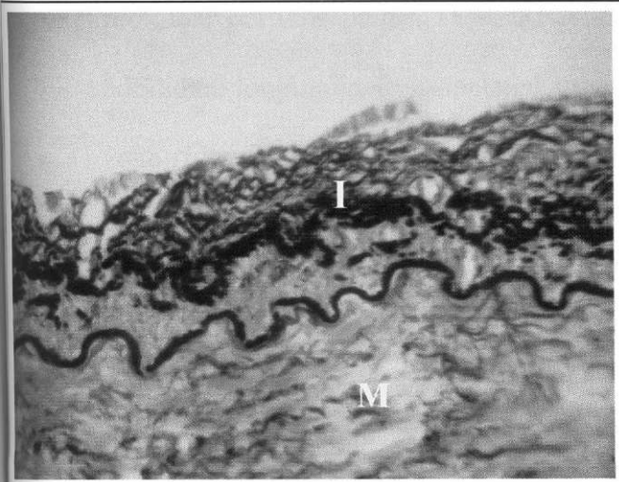
16a



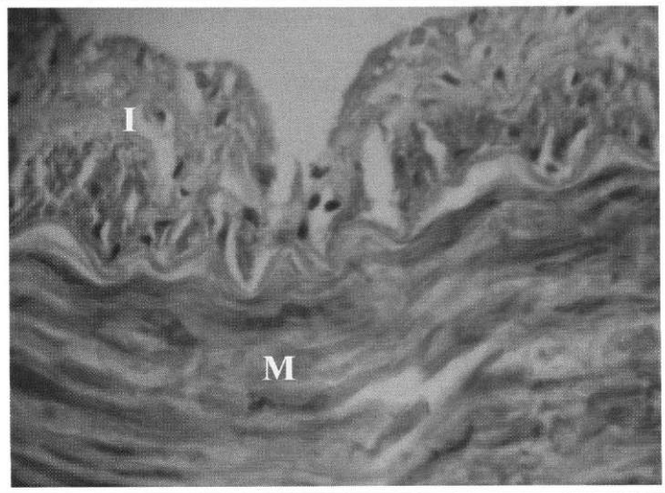
16b



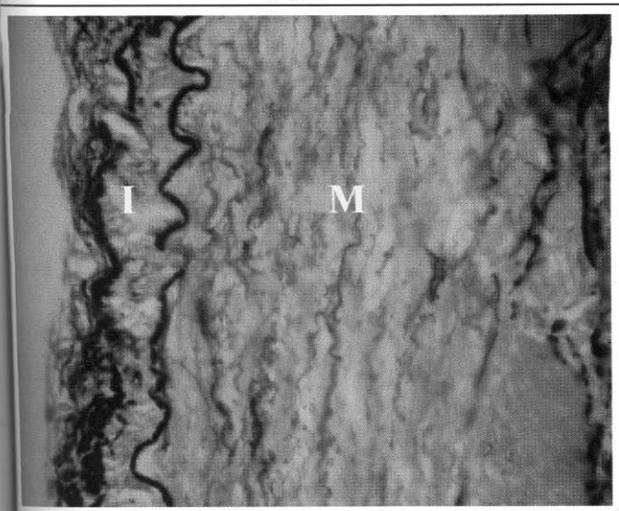
16c



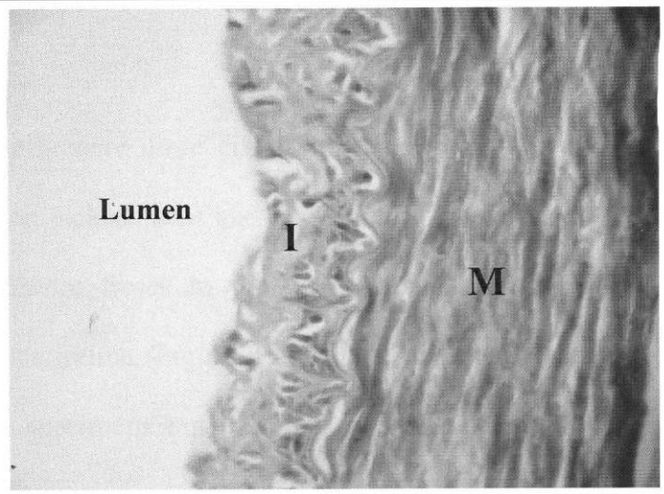
16d



17a



17b



The tunica media

The tunica media of the TCA consisted mainly of concentric smooth muscle cells in association with bundles of collagen fibres and fine strands of elastic fibres that ran in the same direction as the smooth muscle cells (Figure 1 la & b; Figure 16c & d). The media however showed both proximodistal and age variation in its structural organization and components. In addition to the concentric smooth muscle layer, the tunica media of the proximal portions of the TCA, RCA and the LCA from hearts adult subjects had an additional longitudinally orientated smooth muscle cells within the media in the luminal zone (Figure 18a - c). This longitudinal bundle had variable thickness in these vessels where in some specimens it was almost half of the media. The elastic fibres associated with this muscle layer also seem to follow this orientation, with most of them merging with the internal elastic lamina (Figure 18c). In some specimens there were also longitudinal smooth muscles observed in the adventitial zone of the tunica media (Figure 16b) and in one heart the media of the LCA was three-layered while that of the TCA and the RCA consisted of two layers (Figure 19a & b).

The different orientation of smooth muscle cells were more elaborate in the proximal portion of these vessels while the distal portion lacked them and had thinner intima in relation to the media (Figure 20a & b). Elastic fibres in the TCA media reduce proximodistally just like the elastic fibres in the intima (Figure 21a & b). The external elastic lamina (EEL) was ill defined in most specimens but in some cases the elastic fibres in the adventitia merged with it (Figure 22).

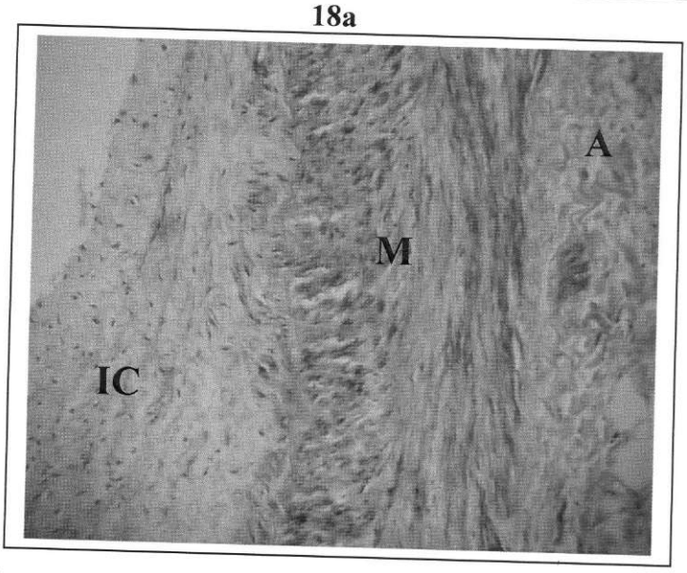
The tunica adventitia

The adventitia of the TCA is extensively collagenous same as the adventitia of the RCA and the LCA. The inner zone of the tunica adventitia of the three arteries contains dispersed strands of elastic fibres merging with the external elastic lamina (Figure 22). This finding was more in the adult than in the paediatric specimens. The elastic fibres are also reduced in the distal segments. The tunica adventitia of the proximal portion of the TCA may also contain vasa vasora as observed in some adult specimens (Figure 23).

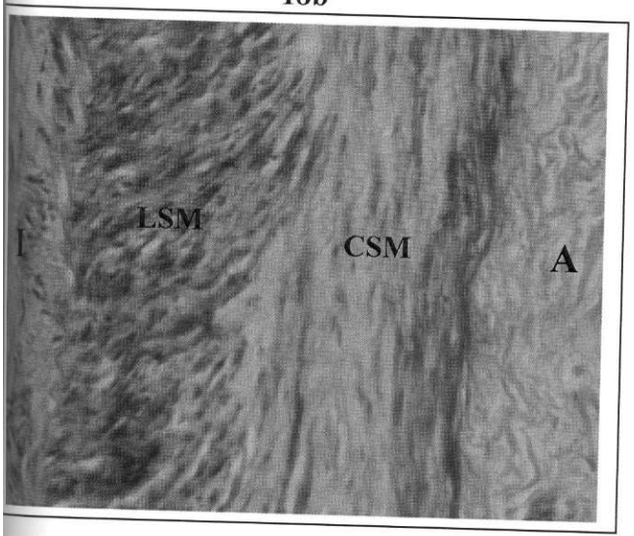
Figure 18 (a), (b) and (c): Photomicrographs of the proximal portion of adult TCA showing the three tunics. Note the concentric layer of smooth muscles cells (CSM) in the adventitial zone of the tunica media and the longitudinal layer in the luminal zone (LSM). This section also shows intimal cushion (IC) and an elastic inner zone of the tunica adventitia. The elastic fibres in the luminal zone of the tunica media merge with the internal elastic lamina (IEL). A = Adventitia; M = Media; I = Intima. (a) Magnification = X40; Stain = Mason's Trichrome; (b) Magnification = XI00; Stain = Mason's Trichrome; (c) Magnification = XI00; Stain = Weigert's stain.

Figure 19 (a) and (b): Photomicrographs of the proximal part of the LCA from a male adult heart showing the tunica media. Note the three smooth muscle orientation in the media, with an inner circular, middle oblique and outer longitudinal layer. L = Lumen; M = Media; Stain = Mason's Trichrome; Magnification = (a) X40 and (b) XI00.

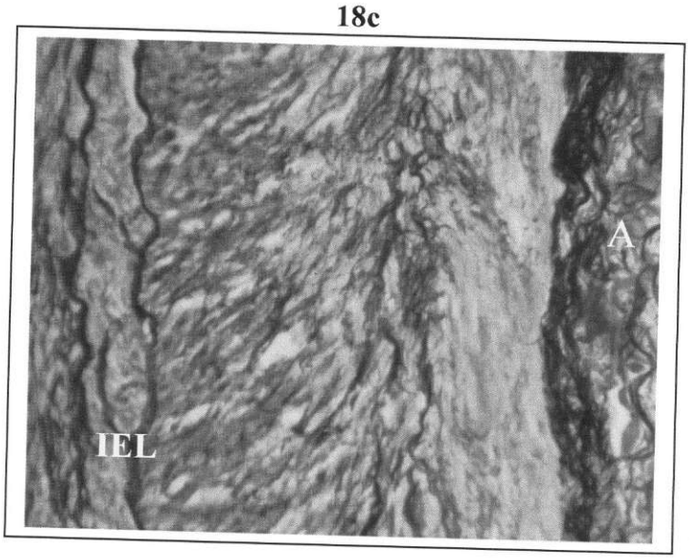
18a



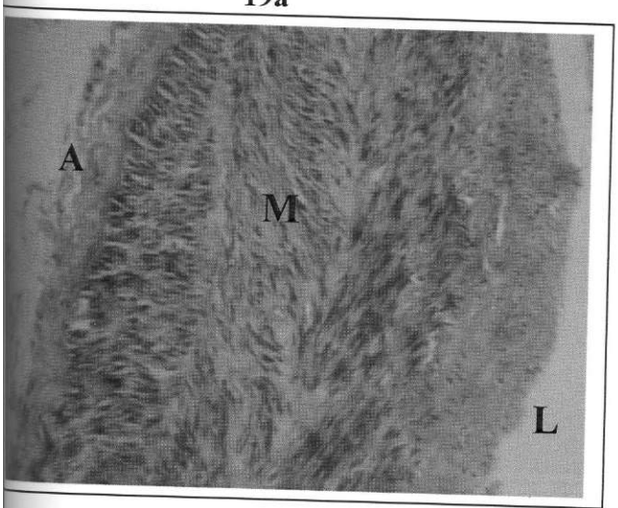
18b



18c



19a



19b

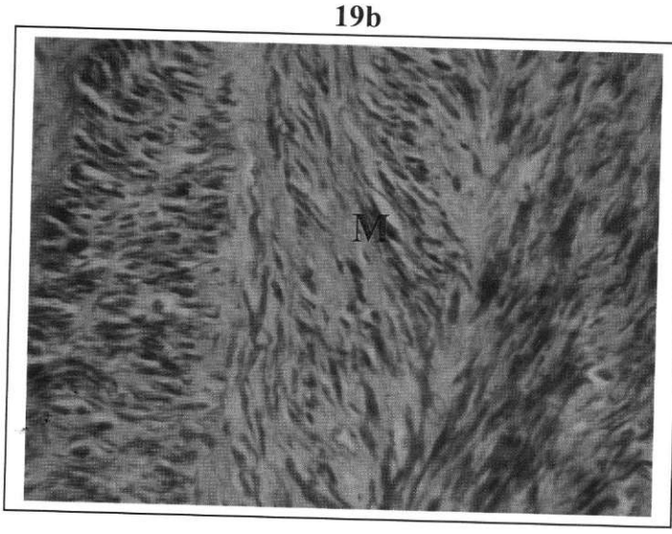


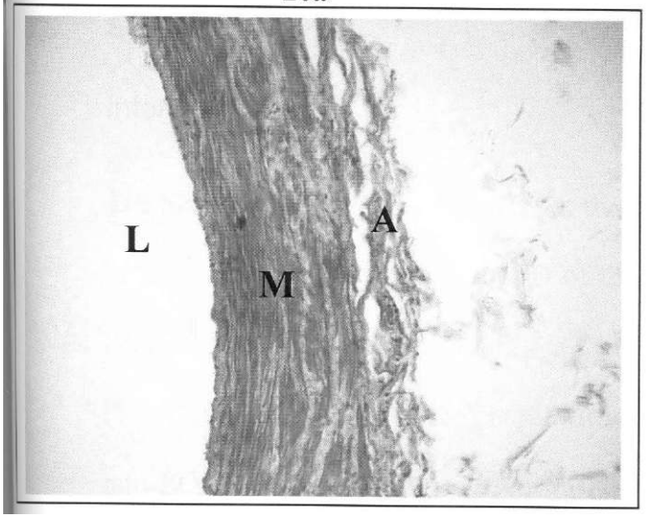
Figure 20 (a) and (b): Photomicrographs of the distal portion of the TCA from an adult heart showing the three tunics. Note the thin tunica intima (I) concentric smooth muscle (CSM) cells in the tunica media but absence of the longitudinal muscular layer in both the luminal tunica media and the subendothelial tunica intima. The tunica adventitia (A) is also less extensive (Fig. 20a). L = Lumen; M = Media; Stain = Mason's Trichrome; Magnification = (a) X40 and (b) X400.

Figure 21 (a) and (b): Photomicrographs of the proximal (a) and distal (b) parts of the TCA wall from the heart of a 37-year old female adult showing the difference in the intimal size (I) and elastic fibre content of both the intima and the media (M). Note that the proximal portion (a) has a thicker intima and contains more elastic fibres both in the intima and the media than the distal portion (b) of the same vessel. Magnification = XI00.

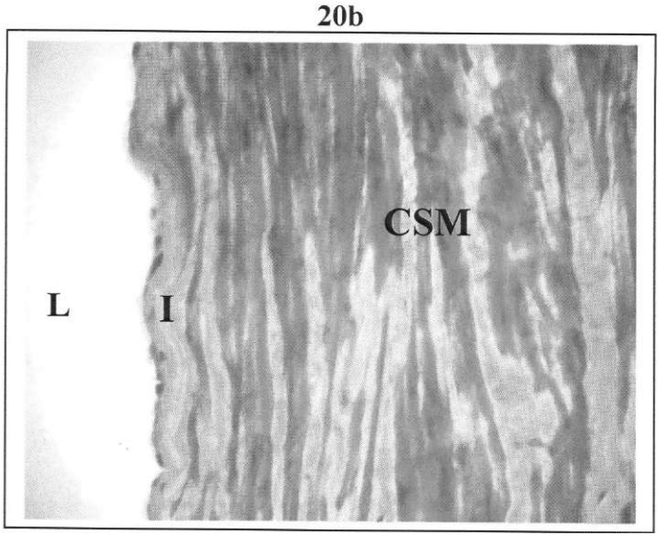
Figure 22: Photomicrograph of the proximal portion of the adult TCA showing the tunica adventitia and part of the tunica media. Note the highly collagenous adventitia with an elastic inner zone. The elastic fibres in the inner zone of the tunica adventitia (A) merge with the external elastic lamina (EEL). M = Media; Stain = Weigert's Stain; Magnification = XI00.

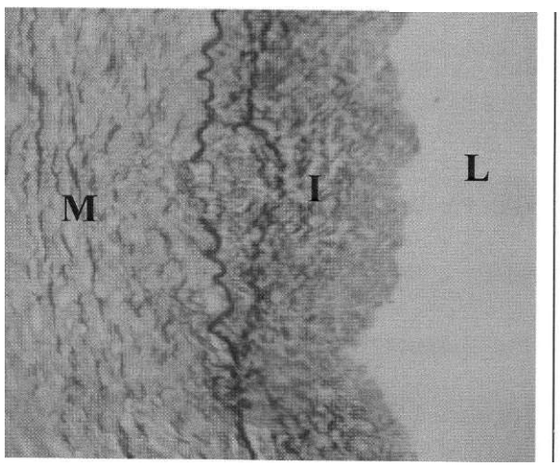
Figure 23: Photomicrograph of the proximal portion of an adult TCA showing vasa vasorum in the tunica adventitia. Stain = Mason's Trichrome; Magnification = (a) X100 and (b) X400.

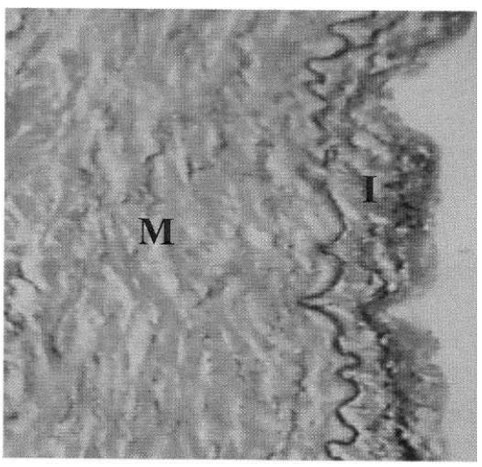
20a



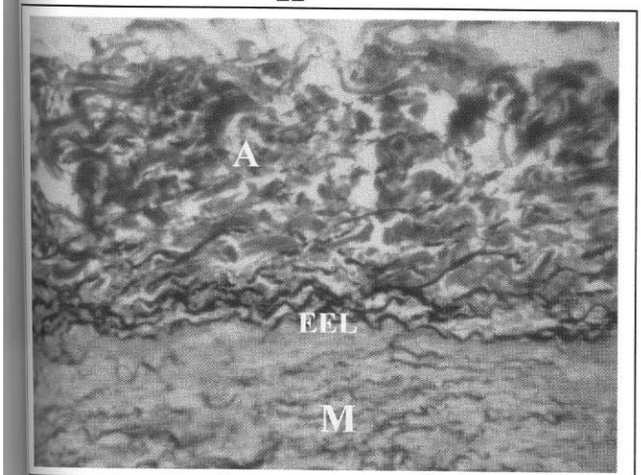
20b



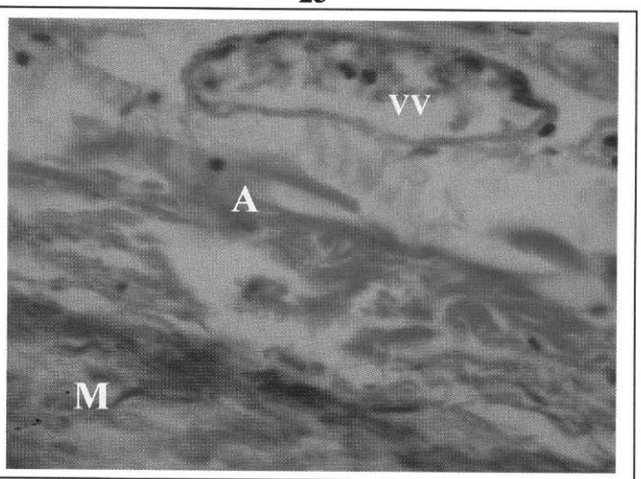




22



23



Stereology

Internal diameters

The average internal diameter (ID) of three measurements across the lumen of the vessel in three planes was taken as the ID of the vessel and these were compared between the hearts with a TCA and hearts without the TCA (Table 2). The total ID of the three vessels (TCA, RCA and LCA) in the hearts with a TCA was greater than the total ID of the RCA and LCA when the TCA is absent (10.01mm and 8.94mm respectively; $p = 0.44$). The luminal cross sectional diameters (CSA) of these vessels in the two situations were however the same (127.1mm and 126.5mm respectively; $p = 0.62$).

When the ID of the three vessels was compared between the two sexes using the specimens from the adult subjects, males were found to have a wider luminal diameter than the females in all the coronary arteries, which also accounted for the larger CSA seen in the males ($133.33mm^2$) than in the females ($123.51mm^2$) (Table 3). Statistical tests did not show significance in these variables however ($p = 0.12$).

Table 2: Table showing IDs of the coronary arteries both in hearts with and hearts without the TCA. TCA = Third Coronary Artery; RCA = Right Coronary Artery; LCA = Left Coronary Artery; ID = Internal Diameter; CSA = Cross Sectional Area.

	In hearts with TCA				In hearts without TCA		
Vessel	TCA	RCA	LCA	Total	RCA	LCA	Total
ID (mm)	1.22	3.98	4.81	10.01	4.08	4.86	8.94
CSA (mm')	4.68	49.76	72.68	127.1	52.30	74.20	126.5

Table 3: Table showing luminal diameters (ID) and the corresponding cross sectional area (CSA) of the three coronary vessels compared between males and females.

	Males				Females			
Vessel	TCA	RCA	LCA	Total	TCA	RCA	LCA	Total
ID (mm)	1.24	4.11	4.90	10.25	1.21	3.91	4.75	9.87
CSA (mm')	4.83	53.07	75.43	133.33	4.60	48.03	70.88	123.51

Medial-intimal ratios

Medial-intimal ratio was done by point counting and the ratios worked out by dividing the number of points falling on the media by the number of points falling on the intima (Table 4). The males were found to have a lower medial-intimal ratio compared with the females ($p = 0.08$). The ratio was also observed to decrease with age, with the paediatric specimens having a higher medial-intimal ratio than the adult specimens. However, sexual dimorphism was more in the adult than in the paediatric age groups. In all the cases, the LCA showed a greater intimal thickening, followed by RCA and then TCA.

Table 4: Table showing the medial-intimal ratios of the coronary arteries in the males and the females in both adult and paediatric age groups.

		Males				Females			
Vessel		TCA	RCA	LCA	Total	TCA	RCA	LCA	Total
Adults	Media	144	198	223	565	138	183	215	536
	Intima	32	50	64	146	29	45	58	132
	Ratio	4.23	3.96	3.48	3.87	4.76	4.06	3.71	4.06
Paediatric	Media	89	143	166	398	84	139	158	381
	Intima	17	29	35	81	16	28	33	77
	Ratio	5.23	4.93	4.74	4.91	5.25	4.96	4.79	4.95

DISSCUSSION

Prevalence of the third coronary artery

The present study revealed a prevalence of 34.8% of the third coronary artery in the Kenyan population, a figure that falls within an earlier described range of 33-51%. The reported prevalences in dissection studies in different populations are shown in table 5. The adult prevalence of TCA in the current study (35.1%) is similar to the data by both Miyazaki and Kato (36.8%)[5] and Ivan & Milica (34.8%)[7] including that which has been described in textbooks[1] (36%). The Kenyan prevalence is however higher than populations studied by Von Ludinghausen et al (7.1%),[10] Kurija et al (8%)[19] and Kalpana (24%)[20] but much lower than 50% as documented Waller and Schlant (1986).[21]

Table 5: Table showing the prevalence of the TCA in various populations

Author	Population	Incidence
Miyazaki and Kato (1986)[5]	Japanese	36.8%
Ivan and Milica (2004)[7]	Bulgarians	34.8%
Von Ludinghausen & Ohmachi (2001)'°	Germans	7.1%
Kurjia et al (1986)'y	Iraqi	8%
Kalpana (2003)™	Indians	24%
Turner and Navaratnam (1996) [22]	English	15.8%

Kurjia et al (1986), due to his very low finding (8%) suggested that the occurrence of a separate TCA is an anomaly rather than normality as widely reported in the literature.[19]

Observations of the present study together with others[7, 10, 20] suggest that there may be ethnic variation in the occurrence of the TCA. Pertinent to this suggestion is the proposal by Garg et al (2000) that there exist geographical differences in coronary variations and these may probably have a genetic background.

The prevalence of the TCA in the paediatric age group in the present study was found to be similar to that of adult age groups (33.3% and 34.7% respectively). Although there is no available data on the prevalence of the TCA in paediatric age groups to the best of our knowledge, Miyazaki and Kato (1986) reported TCA in 20.6% of fetal hearts in contrast with 36.8% seen in the adult hearts in the same study.[5] Based on their findings, these workers postulated the possibility that the third coronary artery may develop after birth. Although fetal hearts were not studied in the present work, the present finding is at variance to this view and holds that the TCA occurs with the same prevalence in the paediatric age group as in the adult in the same population unless it is an early postnatal development. Pertinent to this view is the suggestion that there is no or only unremarkable new development of coronary artery during physiologic growth as proposed by Reinecke and Hort (1988; 1992).[24, 25]

Orifices within the right aortic sinus

There were a maximum of two orifices for the TCA in the present study, while the RAS had a maximum of four orifices. The existence of multiple orifices within the RAS has also been documented by previous studies and it is well known that the RAS usually have

more multiple ostia than the LAS.[2, 6, 22, 26, 27, 28, 29, 30] The separate orifices for the TCA and RCA in the RAS can be explained by insufficient unification of the RCA with the TCA during their growth towards the ascending aorta. These multiple orifices including those of the TCA have been shown to have a higher incidence in pathologic hearts than in normal hearts.[6]

Taking the orifice of the RCA as the reference point, the TCA has been described to display three types of origin according to the orientation of the orifice. The orifice may be at eight, nine and ten o'clock but there is no significant difference in the occurrence of the 3 types.[6] The present finding that in all the cases the TCA orifices were to the left of the RCA orifices supports and extends this concept by Miyazaki and Kato (1986).[6]

The current study observed two orifices within the RAS in 28/164 hearts, similar to the findings of Saidi et al (2002)[29] in the same setting (17% of the hearts in both cases). Muriago et al (1997)[34] however reported a higher incidence (74%) of an accessory coronary artery in London compared to the findings in Kenya. While this study found three orifices in the RAS in four hearts (2.4%) and Saidi et al (2002)[29] documenting an almost similar incidence (2%), Muriago et al (1997)[34] observed three orifices in the RAS in 22% of heart specimens although all were gross dissection studies. Although this study found lower counts of orifices in the RAS compared to the majority cited in the literature,[27,34] other studies have reported much lower values[35] (Table 6).

Table 6: A table showing the incidence of multiple orifices in the RAS as reported in various studies.

Author	Population or Country	Percentage of multiple orifices observed	
		Two orifices	Three orifices
Present study	Kenya	17%	2.4%
Wolloschek et al (2001)[27]	Germany	60%	-
Saidi et al (2002)[2y]	Kenya	17%	2%
Muriago et al (1997)[34]	London	74%	22%
Cavalcanti et al (2003)[35]	Brazil	none	-

According to Miyazaki and Kato (1986, 1988),[5 6] the existence of multiple orifices for the TCA suggests that this artery may develop after birth. They arrived at this conclusion based on their findings where pathological hearts were found to have a higher incidence of these multiple orifices in addition to their wider ostia compared with the normal hearts[6]. Moreover, prevalence of the TCA was more in the adult than fetal hearts^. Based on these observations, the functional significance of the TCA may include provision of collateral circulation. Since pathological hearts have a wider TCA orifice than the orifice for the TCA in the normal hearts, this artery may have a physiological role in the development of coronary pathology.[6' 9] Although not considered in the present study, variations in positions, angles of arterial take-off, initial arterial courses through the aortic adventitia and presence of ostial ridges or membranes that may result in significant compromise of blood flow are also important in determining the physiological role of coronary arteries.[36]

Absence of ostium in the RAS was observed in one case where the RCA arose from the LAS independently then took an interarterial root to reach the right atrioventricular groove. This anomaly has been reported with an incidence of 0.17% - 0.38% in angiographic series and 0.03% in a necropsy studies.[23,37] There are 3 subtypes based on the anatomic course of the artery: the aberrant vessel may course (a) as retroaortic; (b) as interarterial or; (c) pass anterior to the pulmonary trunk. The interarterial subtype has been reported to be associated with angina pectoris, myocardial infarction and to the extreme sudden death even in the absence of atherosclerosis.[38,39,40,41]

Branches of the TCA

In the majority of cases there were three branches (48.7%) from the parent TCA. Ivan and Milica (2004) found 2-7 branches of the TCA given from either side or as end branches with a mode of 2 branches (62.5%).[7] Termination of the TCA was observed to display three patterns, with single trunk termination as the most common form (56.1%). This is at variance with Ivan and Milica (2004), in which all of the TCA bifurcated

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terminally. In this study, bifurcation was seen only in 28.2% of all the cases. This difference may be due to ethnic variation which is contributed by genetic and environmental influences such as activity.

The observation that TCA from the paediatric subjects had less number of branches than those from the adults subjects may be related to gradual opening up of collateral circulation with age as proposed by Miyazaki and Kato (1988)[6] and confirmed in other studies.[42, 43] It has been shown that the constitutive number and density of collateral

vessels in an individual is likely to be under genetic control, with the capacity and number of channels varying between individuals.[44] This collateral circulation has however been shown to reduce in some pathological conditions such as diabetes and hypertension.[45,46,47,48,49]

Course and distribution of TCA

Most of the TCA observed in the present study had an extramural (epicardial) course in their entire lengths. In three cases however a segment or some segments of the TCA were intramural for a variable length and depth. Such myocardial bridges across some segments of the TCA had also been observed by Ivan and Milica (2004) in one out of eight TCAs.[7] Apart from being associated with myocardial ischemia, infarction, tachycardia induced ischemia, conduction disturbances and even sudden deaths,[50, 51, 52] these myocardial bridges may constitute risk factors such as perforation of the submerged portion during the process of identifying the artery in a surgical procedure.[9]

Most of the proximal branches of the TCA were distributed to the anterior wall of the right ventricle. This is consistent with what has been described by various investigators.[7,9,53] The anterior wall of the right ventricle is usually supplied by the right and left conal arteries, ventricular branches of LAD and RCA and the right marginal artery.[1] Since all these branches are either from the right or left coronary arteries, it is possible that the anterior wall of the right ventricle may be partially sheltered in cases of right or left coronary artery occlusions when a TCA is present. Depending on the size of

this TCA, this may have some implications in evaluation of the extent of right or left coronary artery occlusions using the electrocardiograph (ECG).[9,11]

To the best of our knowledge, this is the first report of three cases of TCA extending epicardially to the apex of the heart. The apex is usually supplied by the LAD and PIV

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arteries. ' Based on this anatomical finding, it is plausible that this artery may provide a form of collateral circulation to the apex of the heart and even to the adjacent regions through this anastomosis in cases of either the LAD or PIV occlusions. Extreme caution must however be taken during surgical procedures around the anterior wall of the right ventricle and the infundibulum such as in the repairs of Tetralogy of Fallot since a large TCA may present a surgical hazard.[23,54,55,56] In addition, a large TCA reaching the apex of the heart may protect this region hence giving a 'false better' ECG report in the diagnosis of myocardial ischemia related to LAD occlusions using this region.[9,11]

In 24.6% of the cases the proximal segment of the TCA gave branches towards the atrioventricular (AV) node. Although such branches from the TCA have not been described, several studies have reported the presence of an anastomotic artery from either the proximal right coronary or left circumflex (LCX) arteries to the conducting system, usually anastomosing with the atrioventricular node (AVN) artery and occasionally with the sinus node artery (SNA).[57,58,59] This has been named by some authors as the "arteria anastomotica auricularis magna" or the "Kugel's artery".[1,60,61]

Although this study did not look into the anastomoses made by this artery, it is possible from the course taken that when present the TCA may supply the conducting system including the AV node through these branches. This is concordant with the finding of Ovcina et al (2002) that the AV segment of the conductive heart muscles in human hearts has an abundant vascularization from many arteries.[62] Even though individual variability exists, the AV nodal artery is usually derived from the RCA or LCX that reach the crux of the heart, with the RCA contributing a greater percentage.[2, 58, 59, 63, 64, 65] These variations may be of major significance both in analysis of coronary angiographic and ECG findings and in cardiovascular surgery.[9, 11, 58, 66] Although they may play an important role in the blood supply to the conduction system, these arteries are vulnerable to injury during surgical procedures around the aortic root. It is plausible that the branches of the TCA to the AV node are equally important during surgical procedures and in provision of collateral blood flow to the conducting system.

The IVS was supplied by at least one terminal branch of the TCA in 51.3% of the cases. Although Sahni and Jit (1990) did not specifically consider the TCA, they reported an 85% participation of the RCA or its conal branch in supplying the IVS.[8] An angiographic study by Ben-Gal et al (1997) also showed that the TCA has variable morphological sizes and that this is important in providing blood flow to the IVS in form of collateral circulation.[9] Since vulnerability of myocardial segments decreases in those segments which have collateral supply,[68] this can protect and preserve myocardium around the time of coronary occlusion, contribute to better residual myocardial contractility and even lessen other presenting symptoms.[44]

Coronary collateral circulation involving the third coronary artery

Observations of the pattern of distribution of the TCA in the present study suggest its participation in the blood supply to the conducting system, anterior wall of the right ventricle, the interventricular septum and the apex of the heart. This extensive distribution is imperative in the provision of collateral flow, and may be vital when the parent arteries which usually supply these regions are occluded. This may have a role in slowing the onset cardiac failure caused by myocardial hypoperfusion of some heart segments.[44] At the anterior wall of the right ventricle the TCA usually anastomoses with the left conal artery from the LAD to form the arterial circle of Vieussen's[1] although even the left conal artery may be absent in some individuals.[20] Ivan and Milica (2004) found TCA participation in this anastomosis in 50% of the cases.[7] The TCA may also anastomose with the vasa vasorum of the pulmonary trunk and the aorta.[1]

These coronary collateral circulations have been shown to form both pre- and postnatally.[69] The channels can be formed in three basic ways: (a) by sprouting from an established vessel; (b) by endothelial cells growing and dividing a 'mother' channel and; (c) by intussusception, where the vessel is infiltrated by matrix followed by vessel growth.[44,71] The functional advantage of these anastomoses varies and appears to become more effective in slowly progressive pathologic conditions and also seems to improve during individual's life.[1] This can be explained in terms of opening up of collateral flow and due to increased demand with age.[5, 44] It has been suggested that some coronary arterial patterns may not be fully established at the time of birth and so they form postnatally.[5,44,71,72]

Light microscopy

Observations of the present study have revealed that like the right and left coronary arteries, microscopic organization of the TCA displays the typical three-layered structure of a muscular artery. Although limited studies had focused on the microscopic structure of the TCA, the structures of the LCA and RCA have been extensively described, both in humans and other animals and have shown that they are generally muscular. [12, 18, 73, 74]

The vascular wall of the TCA was observed to show proximodistal variation, with proximal portions having a larger tunica intima with more elastic fibres than the distal portions. This implies that the artery is more elastic close to its origin but as it moves further away this elasticity decreases. The larger intima of the proximal portions was also contributed by the longitudinal smooth muscle cells which were observed more in the subendothelial space of the coronary arteries from the adult subjects. These are probably adaptation to bear more hemodynamic stress which may be higher proximally. Intimal hyperplasia however is associated with luminal constriction of the coronary arteries and this may lead to decreased blood flow or contribute to retention of atherogenic molecules. [75, 76, 77, 78, 79] Though it may be considered as an adaptive response, this intimal hyperplasia of the coronary arteries including the TCA may lead to the development of clinical conditions associated with increased cardiovascular morbidity and mortality.[80] The distal portions of the TCA together with the RCA and the LCA have thinner intima with less elastic fibres and no or reduced subendothelial smooth muscle cells. This is expected of these parts of the arterial wall since" the parent artery now changes to become an arteriole which has a thin tunica intima and media.

The present study has shown that intimal hyperplasia is more prominent in the adult than in the paediatric age groups. According to previous studies, intimal formation appears during normal development and aging as well as in the response of arteries to injury such as atherosclerosis, long-standing hypertension, atherosclerosis and angioplasty.[76,78,81,82] With the consistency to which intimal hyperplasia was observed even in the paediatric specimens, it is unlikely that these findings were pathological, but rather a normal anatomy of the coronary arteries. The diverse cellular origin of this neointimal formation includes inflammatory processes in the media and adventitia leading to proliferation of adventitial and medial smooth muscle cells. The cells may however come also from circulating smooth muscle progenitors, poorly differentiated vascular fibroblasts or even from nonvascular sources.[78,80]

Since intimal hyperplasia was observed in all the three coronary arteries, it is possible that the TCA is also subjected to the same hemodynamic stress as the right and left coronary arteries. One such stress is the effect of cardiac motion which makes coronary arteries to undergo large displacements due to their attachment to the moving myocardium hence resulting in appreciable changes in curvature and torsion of the vessels.[83,84,85] Based on the view of cardiac motion, the TCA probably undergoes more displacement than the right and left coronary arteries since unlike the RCA and LCA which follow regions with minimal displacement during cardiac motion (atrioventricular and interventricular grooves), the TCA passes in front of the RV close to the pulmonary root. The relative extent of intimal hyperplasia in the current study was however not reflective of this proposed differential hemodynamic stress.

With age the subendothelial zone of the tunica intima of the TCA seems to acquire a longitudinal layer of smooth muscle cells. This is similar to what was observed in the right and the left coronaries in the present study and concurs with previous literature reports on the coronary arteries.[1, 86] Such longitudinal smooth muscles have also been observed in other vessels like the pulmonary arteries[88] and the sheep common carotid[00] where they are said to add to the mechanical properties of these vessels. In some vascular systems like the rat portal vein however, this longitudinal smooth muscle layer has been shown to form prior to the concentric layer where they function in the early control of portal blood flow.[89] In the present study, these longitudinal muscles were observed more in the adult hearts than in the paediatric hearts. It therefore appears like they form postnatally, probably as an adaptation to overcome more work load rather than in controlling blood flow as in the rat portal vein.

Longitudinal smooth muscles were also observed in the luminal zone of the tunica media but more from the adult than the paediatric specimens. Although it may also be taken as an adaptive response since it was more developed in the proximal than the distal portions of all the three coronary arteries, formation of this second medial layer has been frequently described as a characteristic feature of advanced atherosclerotic lesion.[90]

Morphometry

The findings of the present study in the ID of coronary vessels closely resemble what has been described in the literature. Ivan and Milica (2004) measured the external diameters

of the TCA and the RCA and found that the TCA ranged between 1.2mm-2.1mm with an average of 1.7±0.3mm.[7] In their case the RCA measured 4.7±1.2mm in specimens with the TCA and 5.5±1.2mm in specimens without the TCA. These values appear to be higher than the findings of the present study. The difference may be due to several factors namely that the present study considered internal diameters and not external diameters. Secondly, it may be due to the difference in the distance from the ascending aorta from where the sections were taken. While this present study took these sections 10mm away from the ascending aorta, it is not clear at which level Ivan and Milica (2004)[7] took their specimens. Thirdly, minor dissimilarities may also result from the differences in fixatives used during tissue preparation.

Studies of the coronary artery dimensions using angiographic methods have reported slightly higher values than the values reported in the postmortem materials. [11] [q1] [q0] This difference may be due to tissue shrinkage in postmortem materials. Although there were differences in the total ID of the TCA, RCA and LCA in hearts with a TCA compared to the total ID of the RCA and LCA in hearts without the TCA, the cross sectional area of these arteries did not show variation. This may mean that the TCA increases flow only to the region it is distributed at the expense of other regions, but does not necessarily increase the overall coronary blood flow.

The intimal-medial ratio of the three coronary arteries in the paediatric hearts was less than what was seen in the adults. Pertinent to this observation is the fact that after birth, replication in the outer media gradually declines as the intima retains their cell replication

rates, so that intima to media ratio increases with age.[90] This is supported in the present study where intimal hyperplasia was observed to be more pronounced in the adult than in the paediatric specimens. Although chronic conditions like diabetes are however also associated with increased intimal thickening in the blood vessels,[93] the consistency of the present observations excludes pathology.

Generally, coronary arteries have been shown to be atherosclerotic since the beginning of life while in other vessels like the hepatic artery intimal thickening may only be incidental during the first four decades of life.[94] This is in agreement with the present findings where the coronary arteries from adult subjects displayed extensive intimal thickenings. Although this was seen in all the three coronary arteries, the intima to media ratio of LCA was the greatest followed by RCA then TCA in the same individual. This may have the implication that the LCA is the most prone to atherosclerotic lesions, followed by RCA and lastly the TCA. These findings therefore suggest that the anterior wall of the right ventricle and the interventricular septum may be less prone to ischemic attack following atherosclerotic lesions of the LAD in case there is TCA reaching these regions.

The present study observed sexual dimorphism of the coronary vessel wall in the adult more than the young age groups. These differences involved the medial-intimal ratio, the absolute intimal thickness and the luminal diameters. This may be an expected finding with the knowledge that although there are. genetic links to the coronary pathologies, some of these factors, together other acquired factors show gender disparity and manifest

with age. Gender differences in the coronary size (internal diameters and cross sectional area) has also been reported in a number of previous studies, with the females having lower values than males as in the current study.[12, 9>] However, studies have shown that the females have smaller hearts than males and so they have a better coronary flow than

the males, thus making them less prone to ischemic diseases. Hormonal difference between males and females has also been implicated to this differential predisposition to coronary disease.[96]

Sexual dimorphism was observed in the intimal-medial ratios in the TCA, LCA and the RCA. In this context specimens from male subjects had lower media to intima ratios than specimens from female subjects although the media was still greater in the males (Table 5). Previous studies have also shown sexual dimorphism in the coronary arteries, with the males having a higher intimal-medial ratio than the females. This disparity has been inferred to the difference in the incidence of coronary artery disease which is much higher in men than in women until the fourth-fifth decades of life.[94,96,97,98,99] In addition, Dhall et al (2003) compared lumen size of the coronary arteries between the sexes with relation to the heart weight and observed that all the coronaries are wider in relation to heart weight in women more than men indicating better coronary flow in females.[12] Thus, although luminal diameters were relatively larger in the males compared with the females, in the present study this may not be an indicator of better flow in the males. Dhall et al (2003)[12] concluded that the better flow in the females may also be one of the factors contributing to lower incidence of coronary artery disease in women.

Conclusion

The third coronary artery is present in about a third of Kenyans, a prevalence that is within the range documented in the literature, and shows neither sex nor age disparity in its occurrence. Knowledge of its variable distribution and extent is necessary in the interpretation of signs and symptoms of coronary artery occlusion since it may provide collateral blood flow to regions such as the conducting system, inter-ventricular septum and the apex of the heart. In addition, the presence of a large TCA or its branches may be a surgical hazard. The TCA is a muscular artery and displays features similar to that of the right and left coronary arteries suggesting that it may also be subjected to the same hemodynamic forces hence can also be affected in coronary artery disease. The total cross sectional area of the three vessels combined in hearts with the TCA is similar to that where the TCA is absent. This implies that despite having a TCA, coronary blood flow is fairly maintained.

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CONSENT FORM:

Aim and benefit of the study:

To study a particular vessel of the heart that may have an effect on the pathogenesis of heart diseases and helps in successful surgical procedures.

Confidentiality:

The identity of the deceased will be concealed and no information concerning him/her will be published. The specimens taken from the deceased will be safely incinerated or buried in Lang'ata cemetery after being used for this study, and there will be no mutilation of the body parts taken.

I hereby humbly request the next of kin to allow the data be collected from the deceased and recorded during the post mortem. Denial of consent by the next of kin will be respected.

Signature:

Date:

I the undersigned have been explained to and understood the above and willingly accept to let the deceased participate in the study. I understand that privacy of the data recorded shall be maintained by the researcher and will reveal no other details apart from those related to the study. I also understand that the organs used in this study will be honorably disposed after use.

jo

Name_____Signature / Thumbprint:

DATA SHEET:

Specimen number:

Age_____years

Age group: [1] Paediatric [2] Adult

Gender: [1] Male [2] Female

Third coronary artery: [1] Present [2] Absent

Orifices within the RAS [1] [2] [3] [4]

Orifices for the TCA [1] One orifice [2] Multiple orifices [No____J

[3] Common orifice with the right coronary artery

Course: [1J Entirely epicardial

[2] With myocardial bridge [Length_____mm]

Distribution of proximal branches of the TCA [1] Conducting system

[2] Anterior wall of right ventricle

[3] No observable branches

Region of termination of the TCA [1] Anterior wall of the right ventricle

[2] Inter-ventricular septum

[3] Apex of the heart

Type of termination of the TCA [1] Single trunk

[2] Bifurcation

[3] Trifurcation

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Ret: KNH-ERC/ 01/ 3560 **Date: 7th June 2006**

Beda Otieno
3rd Year Medical Student
Dept. of Human Anatomy
University of Nairobi

Dear Beda

RESEARCH PROPOSAL: "ANATOMY OF THE THIRD CORONARY ARTERY IH KENYANS (UP62/3/2006)

Refer your above proposal.

This is to inform you that permission has been granted by the KNH-Ethics & Research Committee to conduct research on study tit!ed"Anatomy of the third coronary artery in Kenyans".

By a copy of this Setter the relevant persons are requested to avail the relevant information and materials that you will require.

Yours sincetely,

PROF A N GUANTAI
SECRETARY, KNH-ERC

C.C. Prof. K.M. Bhatt, Chairperson, KNH-ERC
The Deputy Director CS, KNH
The Chairman, Department of Human anatomy, UON.
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