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Right coronary artery anatomy: anatomical and morphometric analysis

Anatomia da artéria coronária direita: análises anatômicas e morfométricas

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Abstract

Background: **It is necessary knowing the large variability of right coronary (RCA) artery specialty for its implications in surgical procedures and clinic events. This variability is usually related to the length, branches quantity, origin and irrigated territories.**

Objective: **To evaluate by direct examination the morphologic expression of RCA in Colombian people.**

Methods: **RCA were measured in 221 fresh hearts by RCA ostium canalization with polyester synthetic resin that was injected in their branches.**

Results: **The caliber of the RCA proximal segment and at the level of the acute angle of the heart was 3.42 ± 0.66 mm and 2.9 ± 0.50 mm, respectively. It ended between crux cordis and the left margin in 75.6% of specimens. Posterior interventricular artery (PIA) reached the inferior third, or the apex, or the anterior interventricular sulcus in 149 (67.4%) cases. Sinoatrial node artery (SNA) originated in the right coronary in 134 (60.6%) cases, 77 (34.9%) from circumflex artery (CxA) and from both in 10 (4.5%). Posterior right diagonal artery (PRDA) was noted in 38 (17.2%) hearts, but only 6% of the sample with long PIA, concomitantly presented the PRDA (*P* = 0.001). In right dominance SNA were originated from RCA in 54.7% and form CxA in 46.3% (*P* = 0.06).**

Conclusions: **Caliber of the RCA and its branches is lesser than the majority of previous studies, while the PRDA frequency is slightly higher than the reported in literature. Clinical and pathological scenarios by these variations should be taken into account: hemodynamic procedures, cardiac surgery and arrhythmias from coronary occlusive disease.**

Descriptors: **Coronary Vessels. Coronary Circulation. Atrioventricular Node. Sinoatrial Node.**

Resumo

Introdução: **É necessário conhecer a grande variabilidade da artéria coronária direita (ACD), especialmente por suas implicações nos procedimentos cirúrgicos e eventos clínicos. Esta variabilidade está geralmente relacionada à extensão, à quantidade de ramos, à origem e aos territórios irrigados.**

Objetivo: **Avaliar por exame direto a expressão morfológica da ACD em sujeitos colombianos.**

Métodos: As ACD foram medidas em 221 corações frescos pela canalização do óstio da ACD com uma resina de poliéster sintético que foi injetada em seus ramos.

Resultados: **O calibre do segmento proximal da ACD e ao nível do ângulo agudo do coração foi de 3,42 ± 0,66 mm e 2,9 ± 0,50 mm, respectivamente. A ACD terminou entre a *crux cordis* e a margem esquerda em 75,6% da amostra. A artéria interventricular posterior (AIP) atingiu o terço inferior, o ápice ou o sulco interventricular anterior em 149 (67,4%) casos. A artéria do nó sinoatrial (ANS) surgiu da artéria coronária direita em 134 (60,6%) casos, 77 (34,9%) da artéria**

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circunflexa (ACx) e de ambas em 10 (4,5%) amostras. A artéria diagonal posterior direita (ADPD) foi observada em 38 (17,2%) corações, mas apenas 6% da amostra com uma AIP longa, apresentaram a ADPD (*P*=0,001). Em corações com dominância direita, a ANS surgiu da ACD em 54,7% e da ACx em 46,3% dos casos (*P*=0,06).

***Conclusões:* O calibre da ACD e seus ramos é menor do que o relatado na maioria de estudos anteriores, enquanto que a frequência da ADPD é ligeiramente superior ao relatado na literatura. Cenários clínicos e patológicos por estas variações devem ser levados em conta: procedimentos de hemodinâmica, cirurgia cardíaca e arritmias de doença coronária obstrutiva.**

***Descritores:* Vasos Coronários. Circulação Coronária. Nó Atrioventricular. Nó Sinoatrial.**

INTRODUCTION

Right coronary artery arises from the anterior sinus of Valsalva and courses through the right atrioventricular groove between the right atrium and right ventricle to the inferior part of the septum. The right coronary artery (RCA) presents a wide morphological expression especially for its length, size, and number of branches, emergence sites and irrigated territories. The RCA has different architectural expressions that classified it as long or short. In the long configuration and after taking a trajectory into the atrioventricular groove it is divided, near or at the level of the Crux cordis, in posterior interventricular artery (PIA) and left retroventricular artery. The short configuration of RCA ends as posterior branch of the right ventricle in 7-20% [1-3].

An additional irrigated territory supply is given by two additional arteries when is necessary: Circunflex artery branches (CxA) and the anterior interventricular artery (AIA) coming from the sterno-costal surface. Great variability has been reported at the end site of the PIA. It is frequently observed at the inferior and apex segment of the posterior interventricular groove. In a minor incidence is noted in the superior and middle segments of this groove [1,2,4,5].

Several RCA branches have anatomical and clinical importance: right branch of the arterious conus (RBAC), sinoatrial node artery (SNA), right marginal artery (RMA), right diagonal posterior artery (RDPA), and atrioventricular node artery (ANA). Each of these arteries has special characteristics that make them different. A branch of the RCA, RBAC is considered classic and can result in nearly one-third of the aorta (third coronary). In these cases larger caliber and length is observed irrigating upper and middle anterior surface of the right ventricle [6,7]. SNA is part of the atrial arteries' group usually arising from the anterior segments of both coronary arteries, although is more frequent emerging from RCA in 55%-73% [8,9]. RMA originates before or at the level of the sharp edge of the heart and can reach the heart apex. This determines the branches number and size reduction for the right ventricle anterior surface supply [1].

The RDPA (infrequently pattern), originates from the RCA near of the acute margin of the heart and adopt an oblique path on the posterior wall of the right ventricle to reach the middle third of posterior interventricular groove contributing to the irrigation of the lower segment of the diaphragmatic heart face [10-13]. The branch of the ANA start in the "inverted U" segment of the RCA located in the crux cordis (73%-85%) and the rest coming from the terminal branch of the CxA [14,15].

The importance of the cardiac irrigation variability in special the RCA is supported by several clinical and pathological scenarios: hemodynamic procedures, cardiac surgery in heart trauma and arrhythmias from coronary occlusive disease management [1,7,15].

Expression of the ACD has been reported with different methods: classical dissection, corrosion injection techniques and imagenology studies [1,7,12,14]. Research on this topic on Colombian samples is absent, consequently this study attempts to determine the anatomical features of these arteries in a fresh cadaveric material sample. Equally, additional interesting information is the correlation of the SNA branch origin and the coronary dominance type.

METHODS

Hearts of this study were 221 fresh samples of not reclaimed Colombian mixed race individuals without signs of heart's disease or trauma from the Forensic Medicine Institute in Bucaramanga, Colombia. The sample was obtained by convenience during three years. Ethic committee approved this investigation. Through its ostium, RCA were injected with synthetic resin polyester (palatal GP41L 80% and 20% styrene) at a pressure of 120 mmHg.

Samples with third coronary presence were injected in its own ostium. Hearts were left in KOH solution to 15% for five minutes under direct observation to release and debride visceral epicardium and epicardic fat [16,17]. After this step, both anatomical structures were also carefully dissected and removed to clean and expose mycardical surface and extramyocardial courses of RCA and branches. RBAC, SNA, ANA, RDPA, RMA morphological characteristics were observed and registered.

RCA long and short configurations were registered. Calibers (Mitotuyo's Electronic Gauge) of the RCA were taken 5 mm from its origin and in several locations: in the acute margin of the heart and in the proximal and middle segment of the PIA. Caliber of RCA collaterals were also measured 5 mm from its origin. Moreover, trajectories and frequencies were recorded. According Ortale et al. [5] and DiDio et al. [18], criteria were used to determine coronary dominance. A correlation of the SNA branch origin and the coronary dominance type were done.

Photographic records were obtained for each evaluated samples. Data analysis continuous variables were described with their mean and standard deviation, also nominal variables with its proportions. Chi (X^2) statistical tests were performed with an alpha error of 5%. Excel database were analyzed in STATA 8.0.

RESULTS

In this study, 221 hearts were assessed of which 181 (81.9%) were male and 40 (18.1%) female. The average age of individuals was 32.9 years (range 16-77). Average weight of the pieces was 294.3 ± 45.9 gr (male 304.6 ± 58 gr; female 250.6 ± 60.7 gr). The caliber of the RCA proximal segment was 3.42 ± 0.66 mm and of the left coronary artery (LCA) was 3.77 ± 0.61 mm (P = 0,107). The caliber of the RCA at the level of the acute angle of the heart was 2.9 ± 0.50 mm. The measures of the RCA were not significantly higher in men than in women (P = 0.23).

In the majority of anatomical specimens (75.6%), the RCA ended between the crux cordis and the left margin irrigating some segments of the diaphragmatic surface of the left ventricle. With a lesser frequency (2.2%) it ended in the left margin (Table 1).

The calibers of the PIA in the proximal and middle segments were 2.04 ± 0.46 mm and 1.7 ± 0.52 mm, respectively. Short expression of the PIA (Figure 1) reached the homonimus sulcus in proximal and middle segments in 72 (32.6%) hearts. Long expression finished in the inferior third, in the apex, or in the anterior interventricular sulcus in 149 (67.4%) specimens (Table 2). Long PIA was found more frequently in women (70%) than men (67.5%) without significance (P = 0.87).

Conus arteriosus' artery (CAA) originates from the RCA in 164 (74.2%) and the aorta (third coronary) in 57 (25.8%) cases (Figure 2). Right ventricular upper heart surface was irrigated by CAA in 66.4%. The third coronary arteries (generally larger), that irrigate conus arteriosus' anterior wall, also supply the superior and middle ventricular surface in 87%, while 13% reached the inferior ventricular segment. It was noted that third coronary was present in 50 (27.6%) males and seven (17.5%) female without significant difference (P = 0.22).

Table 1. Right coronary artery´s territory finalization.

RCA finalization	Number	Percentage
Between Right Margin and Crux Cordis	19	8.6
Into Posterior Interventricular Sulcus	30	13.6
Between Left Margin and Crux Cordis	167	75.6
Into Left Margin	5	2.2
Total	221	100

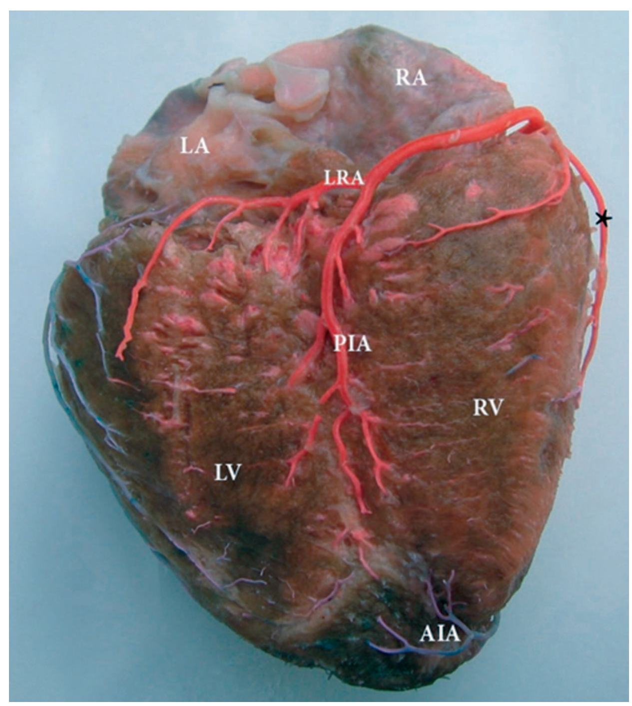

Fig. 1 *- Posterior-inferior heart view. PIA: Short posterior interventricular artery. Right marginal artery (*). AIA: Anterior interventricular artery. LRA: Left retroventricular artery. RV: Right ventricule. LV: left ventricle. RA: Right atrium. LA: Left atrium*

Table 2. Posterior interventricular artery´s site finalization by gender. PIS: Posterior interventricular sulcus.

	PIS Superior third n (%)	PIS Middle third n (%)	PIS Inferior third n (%)	Apex n (%)	Anterior Intervent. Sulcus n (%)
Male	20 (11)	40 (22.1)	85 (47)	35 (19.3)	1 (0.6)
Female	4 (10)	8 (20)	23 (57.5)	4 (10)	1 (2.5)
Total	24 (10.9)	48 (21.7)	108 (48.9)	39 (17.6)	2 (0.9)

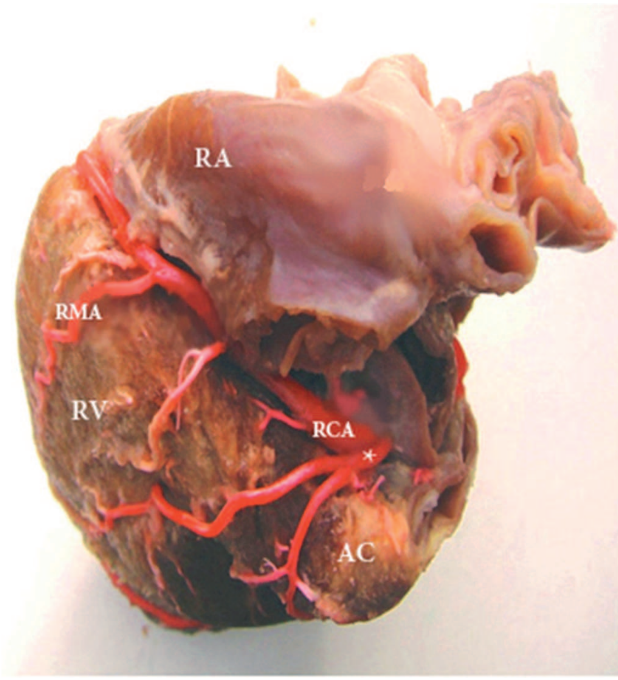

Fig. 2 *- Antero-superior heart view. Conus arteriosus' artery originated from aorta (third coronary) (*). RCA: Right coronary artery. AC: Arteriosus conus. RMA: Right marginal artery. RV: Right ventricule. RA: Right atrium*

SNA was originated in the RCA in 134 (60.6%) cases, from the CxA in 77 (34.9%) cases and from both in 10 (4.5%). Proximal caliber of the SNA was 1.27 ± 0.28 mm that can be compared with caliber from different arteries coming from RCA that have in average 1.22 ± 0.28 mm while those arising from the CxA were 1.39 ± 0.30 mm ($P < 0.038$). Distance from SNA to the ostium of the RCA was 15.5 ± 10.42 mm. It was observed 94 (65.3%) samples with a SAN origin in the proximal 20 mm of the RCA (Figure 3). The SNA originated in a major proportion from the antero-medial segment of the RCA (57.6%) followed by the intermediate-anterior segment with 41 cases (Table 3).

Right dominance in 168 (76%) hearts were present, also, circulation balanced in 38 (17.2%) samples and left dominance in 15 (6.8%) samples. Hearts with right dominance present a SNA originated from the RCA in 94 (54.7%) specimens and from the CxA in 78 (46.3%) cases without statistical difference ($P = 0.06$). The ANA caliber was 1.04 mm ± 0.21 and was originated from retroventricular left artery (RCA branch) in 198 (89.6%) cases and from the CxA in 15 (6.8%) cases. Eight cases observed two arteries originating both from the CxA and the retroventricular left artery. The distance from the origin of the ANA to the division site of the RCA in subsequent PIA and retroventricular left branch site was 10.21 ± 4.27 mm.

Table 3. Sinoatrial node artery originated from different segments of RCA.

Arterial segments	Right Coronary Artery n (%)
Antero-Medial	83 (57.6)
Intermediate-Anterior	41 (28.5)
Antero-lateral	14 (9.7)
Lateral	5 (3.5)
Posterior	1 (0.7)
Total	144 (100)*

** Include 10 cases originated from both the right coronary artery and circumflex artery*

It noted the presence of the RDPA in 38 (17.2%) hearts of the total sample and in 22.1% of the specimens with right dominance. From this presence 33 (86.8%) originated from the RCA and five (13.2%) from the RMA (Figure 4). The distance between origins of the RMA and RDPA was 12.6 ± 5.3 mm. Caliber of RDPA was 1.98 ± 0.51 mm. The length of the first segment of the RDPA with an oblique trajectory on the posterior face of the right ventricule (up to PIS) was 50.8 ± 12.3 mm. Its course over the PIS was 28.7 ± 16.2 mm and ended 19.7 ± 6.3 mm before cardiac apex.

Cases with short PIA have the presence of RDPA in 40.3% (18 samples with PIA finishing in the superior third and 11 cases in the middle third of the PIS). Moreover, 6% of the samples with long PIA concomitantly presented the RDPA ($P = 0.001$).

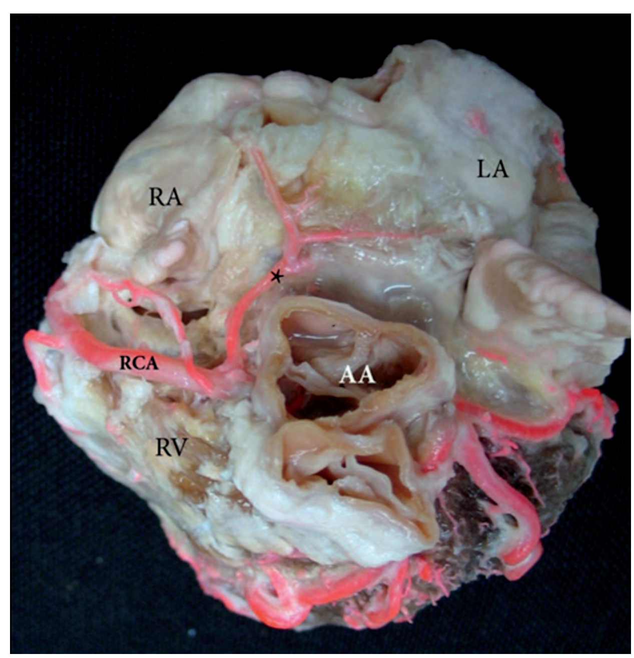

Fig. 3 *- Superior heart view. Sinoatrial node artery originated from right coronary's proximal segment (*). RCA: Right coronary artery. RV: Right ventricle. RA: Right atrium. LA: Left atrium. AA: Aortic artery*

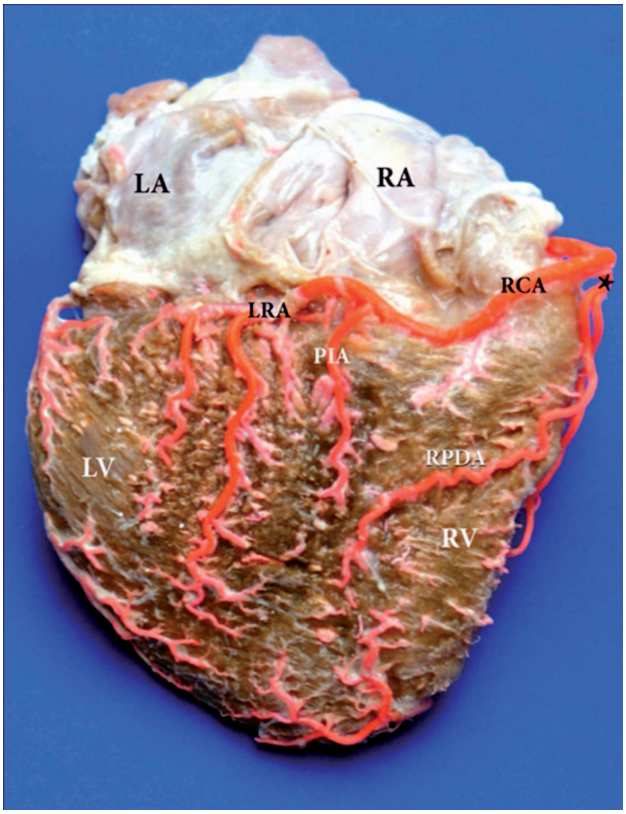

Fig. 4 - *Posterior heart view. RDPA: Right posterior diagonal artery originated from right marginal artery (*). RV: right ventricle. LV: Left ventricule. RA: Right atrium LA: Left atrium PIA: Posterior interventricular artery. LRA: Left retroventricular artery. RCA: Right coronary artery*

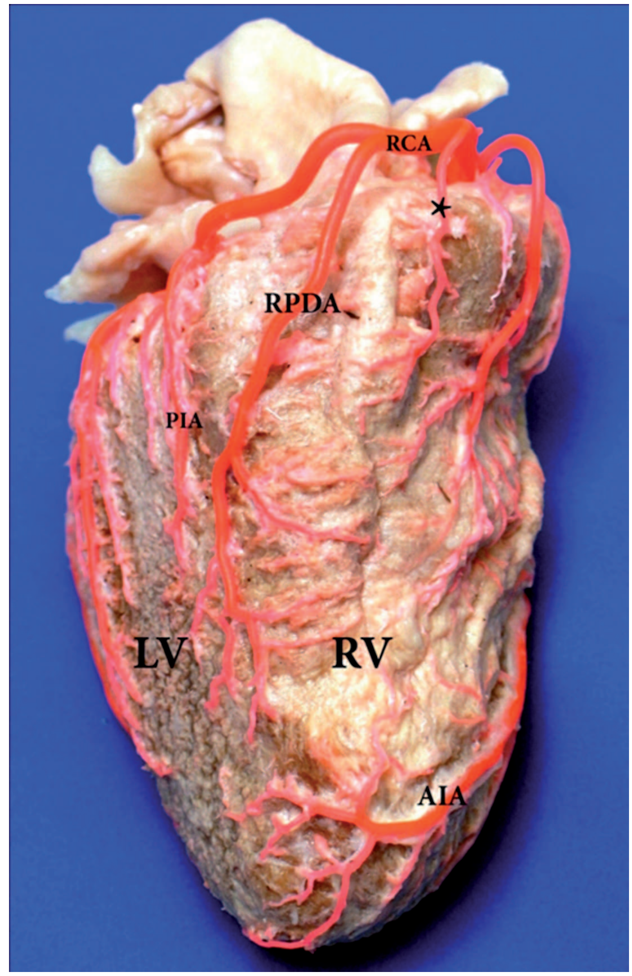

Fig. 5 - *Posterior view and acute margin of the heart. Right marginal artery (*). RDPA: Right posterior diagonal artery. RV: right ventricle. LV: Left ventricule. PIA: Posterior interventricular artery. AIA: Anterior interventricular artery. RCA: Right coronary artery*

RMA was presented in 211 hearts (95.5%) with an average diameter of 1.55 ± 0.43 mm. This ended in the superior or middle third of the acute margin of heart in the 58.9% (Figure 5) and in the lower third in 33.4%. RMA only reached the apex in the 7.7% of cases.

DISCUSSION

RCA proximal caliber found in our results (3.42 mm) is smaller than anterior reports (3.5-4.1 mm) [19-22]. Curiously, Lip et al. [23] found in indoasian people a narrower caliber of 2.98 mm. Equally with our results, Dodge et al. [21] and Kaimkhani et al. [24], found a correlation between coronary dominance and caliber, being higher in hearts with right dominance. We found larger calibers in LCA than RCA. These findings are consistent with angiographic and post-morten measurements [19-24].

We attribute the coronary low caliber related to the weight of the specimens (male 304 gr/female 250 gr). Taking into account that the heart´s weight is 0.45 to 0.5% of the subject´s weight [25]; male and female studied was on average 60-66 kg and 50-56 kg respectively.

Cardiac artery bridge grafts outcome (poor perfusion, anastomosis, increased inhospital deaths) depends in great manner of the coronary calibers. Similarly, procedures as stenting and balloon angioplasty could present complicatedness related to smaller calibers that can be associated with repetitive revascularization and higher risk of restenosis [8].

Left retroventriculars branches were the most frequent finalization of the RCA (75.6%) and is in agreement with previous reports [1,3,26] and disagreement with Baroldi et al. [27], and James [2] with higher incidences (81 and 88%). Equally, we noted a RCA short finishing as subsequent branch of the right ventricle in the 8.6% similar to other works [1-3]. We consider that a vascular compensation is inferred when RCA finish in short branches on the diaphragmatic face of the hearth and additional supplies from CxA and AIA trespassed the cardiac apex territory to be distributed in the postero-inferior and middle segments.

In line with Nerantzis et al. [13] and Margaris et al. [11] we do not observe RDPA in hearts with left dominance; however Ortale et al. [12] reported it in three types of coronary circulations. Our frequency of RPDA is slightly higher than that reported in previous studies [7,11,13]. When there is no RPDA, the posterior wall of the right ventricle is irrigated by small branches arising from the RCA. Remarkably, in angiographic studies RPDA can be confused with an accessory interventricular branch [11].

Nerantzis et al. [13] reported a distance range of 3-28 mm between RPDA and RMA origins, similar to our findings (12.6 mm). There are other findings with light differences with this author as the path and distance from the RPDA. At this respect the distance from its origin to the PIS from our findings against Nerantzis (50.8 vs. 61 mm) and the sulcus course length (22 vs. 28.7 mm) show it. Finally, RPDA never finished in the apex in accordance with others [11-13].

The origin of the RDPA observed in our study is coming from the RCA in 86.8% and from RMA in 13.2% that is consistent with other reports [11-13]. The fact that the range reported by others (10-16%) that RDPA originates or is a continuation of the RMA, lets understand why Smith [10], named it as a posterior reflection of the RMA. Due to RDPA's high absence (80-85%) and low caliber, the judge expressed by James [28] in relation to consider RDPA as a RCA final trunk division (inferior and minor from the acute heart margin) we consider has not weight.

We saw a long expression of the PIA in the 67.4% that is slightly minor than other reports [11,13,28]. It must be emphasized that in these studies is established a compensate territory situation when a short expression of the PIA is completed by RPDA (39-40%) and contrasting a small number of cases (6-8%) with a long expression of the PIA concomitant with the presence of RDPA. These observations are of practical importance due to the RDPA along with the AIA irrigate together the inferior zone of the PIS and its adjacent area. In the presence of an occlusive event of the AIA, RDPA represent a bridge that can irrigate the inferior third of the heart diaphragmatic area limiting the possibility of ischemic processes.

This study found that SNA originated mainly from RCA (59.1%) in agree with other reports [14,29,30]. There are differences reported: a minor incidence (50%-54%) [9,31,32] and a major one (65-79%) [7,8,33,34], possibly due to ethnical and methodological differences. In this sense low incidences in SNA's origin from RCA can be highlighted in the works of Ramanathan [32] in Indian population, Zangh [31] in Chinese, and Krupa [9] in Polish. Additionally, in our series we found a double SNA origin (3.4%), which is consistent with reports of Ramanathan [32] and Ortale [33] and slightly lower than Saremi et al. [8] and Cademartiri et al. [34]. Futami [35] also reported a double origin in 23% of Japanese population. SNA dual irrigation from coronary system becomes a protective anatomical substrate for any atheromatosisprocesses involving these vessels that can alter sinus rhythm. Equally, surgical approaches on atrial walls (atriotomy, valvular correction and congenital malformation) may injure sinoatrial node [30,36]. In this sense, the existence of another artery can ensure an adequate blood flow.

The proximal caliber of SAN observed in this study is similar to the reported by Zangh et al. [31], but slightly minor than others [8,14,30,33] reporting a caliper of 1.4-1.7 mm. These differences may be given by preparation and measuring methods, also in the height-weight people's characteristics.

There is agreement that ANA origin is influenced by coronary dominance [8,14,15,30,32,35,37]. In right dominance, ANA originates from the left retroventricular branch. ANA emergence from the RCA (85-92%) has been reported profusely [8,14,15,29] agreeing with our results. However, a minor range (70-84%) have been identified by other authors [15,32,37]. ANA has also been reported originating from the CxA in a range of 10-15% [8,14,29,30,34,35,37]. Curiously, we found a limited number of samples (2.3%) with ANA dual origin (RCA or CxA) and agreeing with Saremi et al. [8] and Hadziselimovic [29]. There are several reports [14,15,30,32,37] in which there are no findings for this dual irrigation.

ANA damage risk is high (20%-40%) in procedures involving the mitral valve. This can occur when artery originate from CxA, because the close relationship between arterial structure and the mitral valve's fibrous ring that can results in atrioventricular block [15,39].

Incidence of CAA (originated from aorta) was observed in 25.8% in agree with Kalpana [3], Edwards et al., [39] and Koºar et al. [7]. A higher incidence was reported (34-36%) by Olabu et al., [43] and Miyazaki et al., [6]; and also, a lesser incidence (8-11%) [34,42,44]. This CAA has an anastomosis expression with neighbor arteries like AIA that is perceived as an isquemia morphologic protector factor originated in the right anterior ventricular wall. Finally, there was no significative gender difference among this vascular expression [5,7].

CONCLUSIONS

- Frequency of SNA originated from right coronary's proximal segment is in agreed with the data reported previously. In a similar way, long posterior interventricular artery is similar with other reports.
- RPDA frequency is greater to the reported in previous works that make us to consider this finding as an ethnic characteristic.

• In a significative number of cases, RMA finalized in the superior and middle third of the acute margin of the heart.

• CAA derived from aorta is located in a middle range compared to other studies.

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