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Biometric Analysis of Healthy Coronary Arteries in a Chilean Population: An Angiographic Study

Análisis Biométrico de Arterias Coronarias Sanas en Población Chilena: Un Estudio Angiográfico

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SUMMARY: Thorough knowledge and understanding of coronary arteries and their anatomy is essential when performing cardiac surgery such as a coronary bypass. Coronary angiography is a minimally invasive method used to evaluate the anatomy and obtain different measurements of the coronary arteries. This study was designed to evaluate the endoluminal diameter, trunk length and anatomical distribution of coronary arteries in Chilean subjects without apparent angiographic lesions. Measurements were carried out by 3 trained examiners using Leonardo® software program in 238 Chilean subjects of both sexes with an age-range of 45 to 78 years. Ostium and the distal luminal segments diameters were measured, as well as trunk length of both right and left coronary arteries. Ostium of the anterior interventricular artery, dominance and tortuosity were also registered. In the right coronary artery, the diameters (3.8 ± 1.2 mm and 3.6 ± 1.0 mm) differed according to sex and dominance, and the length (35.2 ± 12.5 mm) differed according to age. In the left coronary artery, the diameters (4.9 ± 1.1 mm and 4.7 ± 1.0 mm) were greater in males than in females. The left coronary artery showed greater diameters and length than the right coronary artery. The prevalence of right arterial dominance was 88.0 %. Patients with right arterial dominance presented greater distal caliber in the right coronary artery than those with left arterial dominance ($p<0.05$), especially in older patients. Significant arterial tortuosity was observed in seven subjects.

KEY WORDS: Angiography; coronary arteries; biometry; Chilean population.

INTRODUCTION

Globally, coronary heart disease is one of the most common causes of premature death (GBD 2015 Eastern Mediterranean Region Cardiovascular Disease Collaborators, 2018).The disease also has a significant impact in developing countries (Zhu *et al*., 2105). In Chile´s Maule Region, located in the central area of the country, mortality rates due to coronary heart disease were 10 points higher in comparison than the national average (51.8 x 100,000) and (41.7 x 100,000) respectively (Ministerio de Salud, 2018). This unique disparity with the rest of the country has not been researched, although specific aspects of coronary artery anatomy may play a role.

Information about the morphology, length and lumen diameters in normal healthy coronary arteries is scarce. Nevertheless, thorough knowledge and understanding of these parameters is critical. Indeed, coronary artery dimensions may vary based on sex, age, and ethnicity as well as body surface area and body weight (Leung *et al*., 1991; Dodge *et al*., 1992). Thus, interventional cardiac procedures and factors adjusted for age, sex, body surface area and ethnicity, in small populations as is the case of this study, may be useful for comparison with other populations. (Skowronski *et al*., 2018). In recent years, the biometric characteristics of coronary arteries in particular countries or ethnic groups, have been studied and compared with other populations i.e. India, Turkey or Iraq (Shukri *et al*., 2014; Turamanlar *et al*., 2016; Özdemir & Sökmen, 2020). However, to our knowledge there are no studies regarding normal anatomical characteristics of coronary arteries in the Chilean population.

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Currently, coronary angiography (CA) is considered the gold standard and an essential technique to evaluate these arteries, despite the potential risks such as ionizing radiation, invasiveness and a small associated risk of morbidity (Wielopolski *et al*., 2000). On the other hand, since visual estimation of arterial stenosis may vary between operators, automated measurement systems have been introduced. In a recent study Sen *et al*. (2018), analyzed both inter-observer variability and consistency between operator estimation and quantitative coronary analysis measurements. They concluded that visual assessment may overestimate a coronary lesion and thus lead to unnecessary interventions. Therefore, automated systems have been developed to accurately evaluate normal and pathologic morphology in coronary arteries and avert needless procedures.

The present study was designed to evaluate length and endoluminal diameter of selected segments of coronary arteries and their main branches. The analysis was carried out in a sample of Chilean subjects without coronary angiographic lesions, residing in an area with high rates of coronary disease. It is proposed that the study may serve as a baseline for comparison with other populations, and establish clinical standards for procedures in accordance with the characteristics of local patients.

MATERIAL AND METHOD

This is a retrospective clinical study in a sample of 402 patients who were referred to the hospital with symptoms of coronary heart disease, between 2015 and 2018. Subjects underwent coronary angiography at the Haemodynamic Unit of the Regional Hospital in Talca, Chile. Diagnosis revealed no significant angiographic lesions. This research was approved by the Ethics Committee on Human Research of the Maule Health Service, Chile (2018).

Respecting their anonymity, baseline clinical status of patients, socio demographic information and other data were obtained for participating subjects. Clinical records were retrieved from the Talca Regional Hospital through FileMaker Pro Advanced 8.5v2 pProgram® for Windows. The selection of patients did not consider co-morbidity. The inclusion criteria were as follows: subjects without significant angiographic lesions, angiographic projections not exceeding 3º of dispersion in the angulation, and imaging examination always performed by the same operator. The exclusion criteria were those proposed by Leung *et al*. After applying inclusion and exclusion criteria the final sample consisted of 238 patients.

Selection of images and Measurement: The measurements on left coronary artery were carried out in a 45º left /25º caudal projection (Spider). Since measurements were concentrated in the proximal portion of the trunk, measurements for the right coronary artery were in a 45º left/0º projection.

Clinical Procedure: Coronary artery images were captured with an angiograph Axiom Artis® (Siemens AG, München, Germany) following Seldinger's radial access technique (Seldinger, 1953; Campeau, 1989). Data were collected in IMA format, and the images analyzed with Leonardo® program (Siemens, München, Germany) (U. S. Food & Drug Administration, 2020).

Parameters for measurement design. The following parameters were considered:

a) demographic variables, sex and age of patients.

b) Coronary dominance is defined as the emerging side of posterior interventricular branch and is classified as, a) right dominance, b) left dominance and c) co-dominance (Saikrishna *et al*., 2006);

c) Coronary artery tortuosity is classified as normal and sinuous. Sinuosity was identified by presence of three or more folds (defined as a change of 45º in the direction of the vessel) along the main trunk, of at least one coronary artery (Davutoglu *et al*., 2013);

d) Internal diameter of the vessels was measured using a 6 French catheter.

e) Biometric analysis that includes three measurement for right coronary artery (RCA) and four measurements for left coronary artery (LCA) at different points in the coronary arteries (Fig. 1a). At RCA the following measurements were performed: e.1) ostium diameter (R1): endoluminal diameter (mm) of the emerging point of the coronary artery; e.2) arterial trunk length (R2): distance (mm) between the ostium of the artery and the emerging point of the first marginal artery; e.3) end-trunk diameter (R3): endoluminal diameter (mm) of the end segment of the trunk just before the emerging point of the first marginal artery. At LRA the measurements were: e.4) ostium diameter (L1): endoluminal diameter (mm) of at the emerging point of the artery; e.5) artery trunk length (L2): distance (mm) between the artery ostium and bifurcation; e.6) end-trunk diameter (L3): endoluminal diameter (mm) of the final segment of the common LCA; e.7) diameter of the anterior interventricular artery (L4): endoluminal diameter (mm) estimated at 2 mm distal to its emerging point.

Angiographic images meeting the pre-established inclusion and exclusion criteria were used for calibration, and results obtained by an expert were considered as reference values. Reliability of biometric analyses was calculated for inter- and intra-examiner values using infraclasses correlations (ICC) giving an average value of 98.0 %.

Thereafter, a descriptive analysis of the sample obtained was performed according to sex, age (over 61 years and under 62 years) and dominance (right; left, excluding the codominance of bivariate analysis, since it occurred in two subjects only). Central trend and dispersion measures were obtained from all measurements.

Statistical analysis. To compare the average measurements t-test were performed for independent samples, and Mann-Whitney U test, selected according to the normality obtained in the data distribution. Wilcoxon signed rank (W) test was used to compare paired samples. Furthermore, the ostium diameters and end-trunk diameter of both arteries were related visually related by point graph and statistically by Pearson correlation test. Values of $p \leq 0.05$ were considered as significant.

RESULTS

A total of 402 subjects were initially recorded, however 162 patients were excluded for not meeting the inclusion criteria, and 2 were excluded for showing statistically extreme values. Therefore, the final number of subjects studied was 238 individuals. Figures 1b to 1f illustrate several cases in which measurement points chosen in the Leonardo ® program are identified. Most of the patients were male (55.9 %; n =133), under 62 years of age (51.7 %; n =123) and in nearly 90 % (n = 211) of cases there was right dominance (Table I).

For right coronary arteries (Table I) the average value at R1 was 3.8 mm (SD 1.2). Moreover, statistically significant differences were observed between sexes, with higher average values in males (3.9 mm vs 3.5 mm; U = 5243; p = 0.001). For the right trunk length (R2) average value was 35.2 mm (SD 12.5) and showed statistically significant differences between age groups: values from younger subjects were higher than subjects over 62 years (36.9 mm vs 33.3 mm); t (236) -2.23; p = 0.03). The end-trunk diameter (R3) averaged 3.6 mm (SD 1.0) showing statistically significant differences by sex and dominance. Males had a thicker caliber relative to women (3.7 mm vs 3.3 mm; U = 5125, p = 0.001), and subjects with right dominance showed a higher diameter than those with left dominance (3.6 mm vs 3.1 mm; U = 1827, p = 0.01) (Table I).

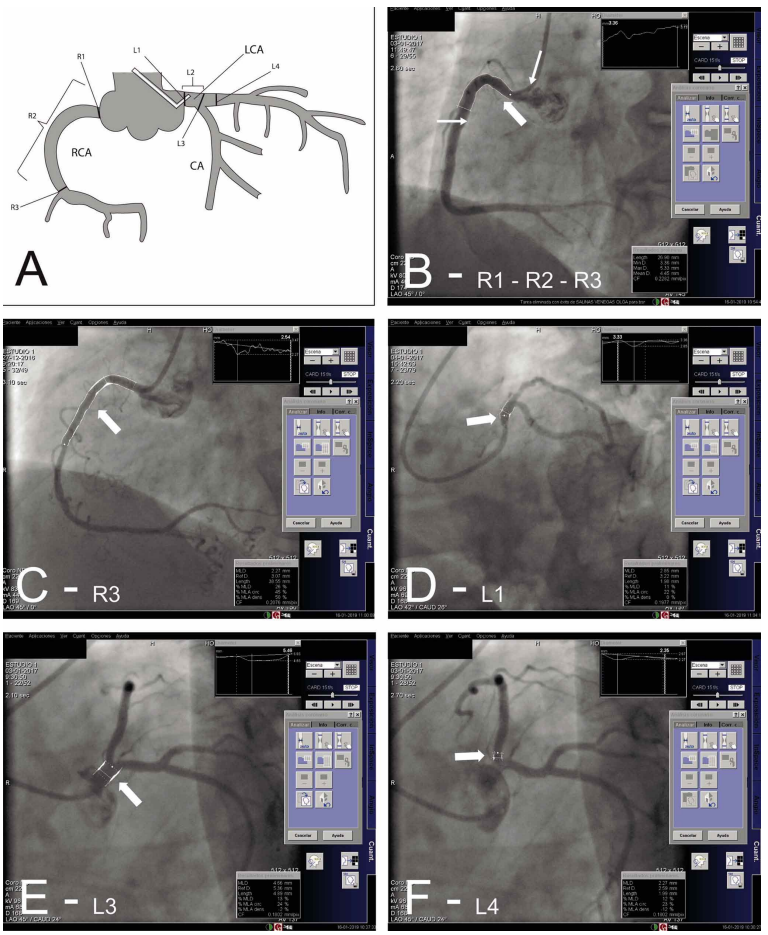

Fig. 1. (A) Coronary angiography scheme showing the measurement points chosen (R: right, L: left) AIA: anterior interventricular artery. CA: circumflex artery, LCA: left coronary artery, RCA: right coronary artery. (B) Measurement in RCA, the right marginal branch (main) is observed originates in the middle third of the right coronary artery right at the measurement endpoint. There are also some marginal vessels that emerge from the main trunk regarded as minor marginals vessels. (C) Measurements in right coronary artery (45º/0º) at R1, R2 and R3. The absence of minor marginal branches makes measurement easier (end-to-end pointed lines define arterial trunk length). (D) Measurement at L1 in a left coronary artery with a slight angulation deviation (note the visibly decreased gauges). (E) Measurement at L3, where the pointed line is observed to detect a diameter of 5.46 mm. (F) Measurement at L4. Note that there is a distance of 1.99 mm to detect the measuring point. In some cases, the exact distance 2 mm from the start of the anterior ventricular branch cannot be obtained. The discontinuous line shows a diameter of 2.35 mm.

Table I. Summary of mean values of biometric measures performed in the coronary arteries.

		Right coronary artery			Left coronary artery			
		R1	R2	R3ˆ	L1	L2	L3ˆ	L4
Average values (SD)		3.8 (1.2)	35.2 (12.5)	3.6 (1)	4.9 (1.1)	7.9 (3.6)	4.7 (1)	4.7 (1)
Sex	Males (SD)	3.9 (1.3)Δ	35.9 (13.2)	3.7 (1) Δ	5.1 (1.1) Δ	7.9 (3.9)	4.9 (1) Δ	3.4 (0.8) Δ
	Females (SD)	3.5 (1) Δ	34.2 (11.5)	3.3	4.7 (0.9) Δ	7.8 (3.3)	4.5 (1) Δ	3.2 (0.8) Δ
Age	< 61 years (SD)	3.7 (1.2)	36.9 (11.8)*	3.5(0.9)	4.9 (1.1)	7.6 (3.7)	4.8 (1.1)	3.3 (0.8)
	> 62 years (SD)	3.8 (1.2)	33.3 (12.9)*	3.6 (1.1)	4.9 (1)	8.2 (3.6)	4.6 (1)	3.3 (0.8)
Dominance	Right	3.8 (1.2)	35.6 (12.6)	3.6 (1) Δ	4.9 (1.1)	7.9 (3.7)	4.7 (1)	3.3 (0.8)
	Left	3.5 (1.2)	31.3 (11.2)	3.1 (1) Δ	4.8 (1.1)	7.3 (2.5)	4.6 (1.2)	3.1 (0.8)

*p value significant (<0.05) using t-test statistics. Δp value significant (<0.05) using Mann-Whitney U test. ˆp value < 0.001 using Wilcoxon signed-rank (W) for dependent sample. Note: Numbers may not round due to missing values. RCA right coronary artery, LCA left coronary artery, AIA anterior interventricular artery.

For left coronary arteries, ostium diameter (L1) indicated an average value of 4.9 mm (SD 1.1) with statistically significant differences (U = 5631, p = 0.01) between male (5.1 mm; SD 1.1) and female (4.7 mm; DS 0.9). Length of the arterial trunk (L2) and lumen at the end of the trunk (L3) showed on average, values of 7.9 mm (SD 3.1) and 4.7 mm (SD 1.0), respectively. Lumen diameter at the end-trunk of the artery (L3) was 4.7mm, and statistically significant differences were observed between for sex (4.9 mm in male vs 4.5 mm in female; U = 5551, p = 0.007). The same was true for the diameter of the anterior interventricular artery (L4) which had an average value of 3.4 mm (SD 0.8) in males and 3.2 mm (SD 0.8) in females (U = 5355, p = 0.003), with an average values of 3.3 mm (SD 0.8) (Table I).

Regarding tortuosity factor, 7 subjects were considered sinuous, and the average values of end-trunk diameters statistically differed between right and left arteries (3.6 vs 4.7; W = 11.23; p < 0.001) (Table I). Figure 2a shows the scatter plot between the left and right ostium, showing a positive and statistically significant linear relationship (r = 0.21; p = 0.001). Finally, the diameter of the ending of both arteries showed positive and statistically significant relationship (r = 0.21; p = 0.001; Fig. 2b).

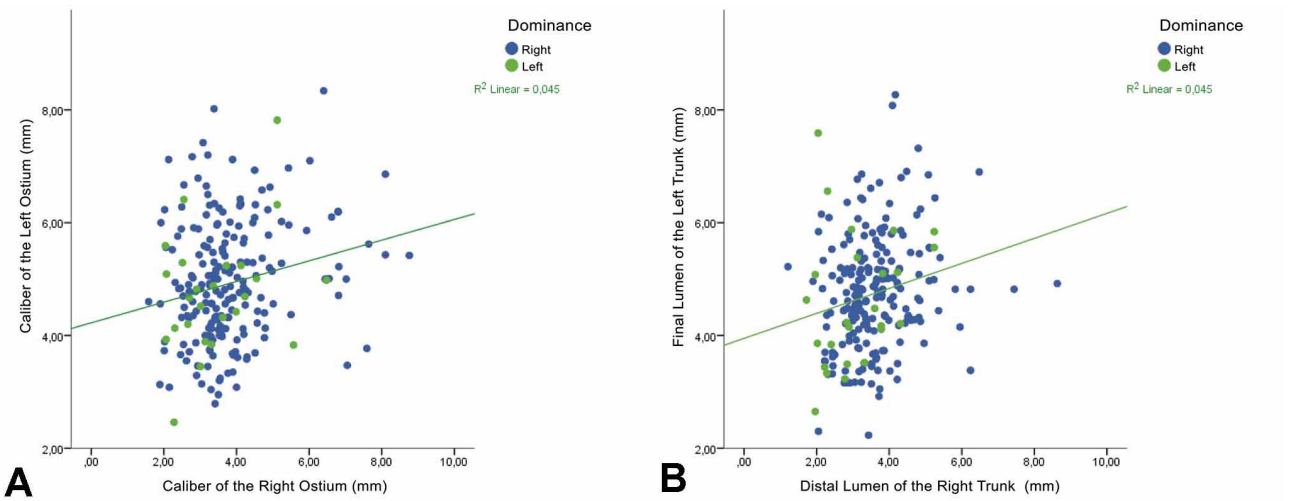

Fig. 2. A. Linear relationship between the left and right ostium of the coronary arteries. B. Linear relationship between the end-trunk caliber.

DISCUSSION

A retrospective imaging study was conducted through coronary angiography, using Seldinger's radial technique in a sample of 238 patients that meet the inclusion and exclusion criteria. To our knowledge no similar studies have been carried out locally in a Chilean population. The size of the sample and internal characteristics of the group (age and sex distribution) give rise for comparison of these results with previous studies. These may be considered

proportionate in relation to studies published in smaller population samples in the past (Leung *et al*.; Saikrishna *et al*.; Shukri *et al*.; Raut *et al*., 2017) and larger samples (Vasheghani-Farani *et al*., 2008; He *et al*., 2017). These studies demonstrate significantly reduced caliber of the left main trunk, anterior ventricular branch, circumflex branch and right trunk in Asian-Indian subjects compared to the North American Caucasian population (Makaryus *et al*., 2005).

The present study shows that there is a significant difference ($p = 0.001$) for average caliber between the right and left coronary trunks (3.6 mm and 4.7 mm, respectively). These results coincide with Vieweg *et al*. (1976), in reference to normal measurement values of human coronary arteries. Our results on the other hand, are in contrast with data reported by Latarjet & Ruiz Liard (2006) who considered the average coronary trunk diameter similar to (3 to 4 mm). It should be noted however, that they did not take into consideration demographic factors. For instance, ethnicity, dominance, tortuosity or cardiovascular risk, all of which can influence the biometric values of coronary arteries (Makaryus *et al*.; Vasheghani-Farahani *et al*., 2008).

An interesting finding in our study was that the endoluminal measurement of both coronary arteries varies parallelly. To our knowledge, this observation is being reported for the first time. Further studies are necessary to elucidate the relevance of these findings. Also, ostium caliber for the right and left coronary arteries, end-trunks´ caliber in both coronary arteries, and the anterior interventricular branch were significantly higher in males. This lends support to the studies by Vaccarino *et al*. (1995) and Shukri *et al*. that report significantly smaller dimensions in women compared to men.

In their study Özdimer & Sökmen (2020) contradict the general belief that women have narrower coronary arteries than men. Though this may be the result of ungrouped data from various ethnic populations, and the evidence presented involving scarce number of studies that compare white and Asian-Indian subjects. It is worthwhile mentioning the limitation between the various ethnic population comparison studies, since they use different measurement points in each arterial branch.

With respect to coronary dominance 88.0 % displayed right dominance, 11 % left dominance 11.0 % and 1.0 % co-dominance similarly to Vasheghani-Farahani *et al*. who found values of 84.2 %, 10.9 % and 4.8 %, respectively. Interestingly, subjects with right dominance showed an average caliber at end-trunk greater than those with left dominance. It has also been reported that the ending lumen of the left coronary trunk and the anterior interventricular branch are not affected by dominance (Dodge *et al*.; Vasheghani-Farahani *et al*.).

Right trunk length was significantly longer (3.6 mm) in younger subjects, suggesting that the length of the trunk of the RCA decreases with age. Nevertheless, the length of the left arterial trunk did not change in relation to sex, age or dominance. Since it was present in 3.0 % of subjects in the sample, we consider that tortuosity should be analyzed during future evaluations. Furthermore, 42 subjects were excluded from this study because they presented tortuosity that interfered with the measurement.

As noted by Zhu *et al*., coronary heart disease, has become a primary health concern for the world population in recent decades. Thorough knowledge of the dimensions of the coronary arteries in patients is critical, especially during coronary interventions such as stent placement, sizing of endoprosthesis or decisions regarding these procedures (Manjappa *et al*., 2016). The endoluminal diameter is an important predictor of the results, following coronary artery bypass graft surgery (CABG) and for percutaneous coronary intervention (PCI). Undoubtedly, dominance is an important factor for surgeons and radiologists, and should be considered prior to any such interventions. It is noteworthy that a dominant left coronary artery is associated with worse outcome and prognosis following extensive myocardial infarction (STEMI) when compared to right dominance or a balanced system (He *et al*.; Veltman *et al*., 2014).

As in Davutoglu *et al*., it has been proposed that recording coronary tortuosity for follow-up studies is an important variable to consider. Coronary tortuosity has been shown to be associated with subclinical atherosclerosis even in normal coronary angiography, and could also be an indicator of systemic tortuosity of the retinal artery. Moreover, it is a factor that makes measurements difficult for this type of biometric study. Coronary tortuosity is generally not recorded during coronary angiography procedures.

Since variations exist in populations between different countries, this study is an important means to accurately determine population measurements. This research presents several working lines that may be applied in clinical studies of systemic tortuosity. These may include comorbidities, study of the circumflex branch or other branches, incorporating additional angiographic projections to choose different points of the coronary arteries and population comparisons among others.

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RESUMEN: Un factor clave durante los procedimientos quirúrgicos cardiacos tal como el bypass coronario, es el conocimiento exhaustivo de las arterias coronarias y su anatomía. La angiografía coronaria es un método mínimamente invasivo que se utiliza para evaluar la anatomía y obtener diferentes medidas. El presente estudio fue diseñado para evaluar el diámetro endoluminal, la longitud del tronco y la distribución anatómica de las arterias coronarias en sujetos chilenos sin lesiones angiográficas significativas. Las mediciones fueron realizadas en 238 sujetos chilenos de ambos sexos con un rango etario entre 45 a 78 años. Tres examinadores preparados llevaron a cabo las mediciones utilizando el software Leonardo®. Se midieron los ostios y los diámetros luminales distales de los troncos coronarios derecho e izquierdo, como también las longitudes del tronco de las arterias coronarias derecha e izquierda. Además, se identificaron los ostios de la arteria interventricular anterior, dominancia y tortuosidad. En la arteria coronaria derecha, los diámetros (3,8 ± 1,2 mm y 3,6 ± 1,0 mm) se observaron variaciones según el sexo y la dominancia, y la longitud (35,2 ± 12,5 mm) difirió según la edad. En la arteria coronaria izquierda, los diámetros (4,9 ± 1,1 mm y 4,7 ± 1,0 mm) fueron mayores en los hombres que en las mujeres. La arteria coronaria izquierda mostró mayor diámetro y longitud que la arteria coronaria derecha. La prevalencia de dominancia arterial derecha fue del 88,0 %. Los pacientes con dominancia arterial derecha presentaron mayor calibre distal en la arteria coronaria derecha que aquellos con dominancia arterial izquierda (p <0,05), especialmente en pacientes mayores. En siete sujetos se observó una tortuosidad arterial significativa.

PALABRAS CLAVE Arterias Coronarias, Angiografía; Biometría; Población chilena.

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