

Normal aortic diameters within the Mexican population and the impact of gender and ethnicity

Diámetros aórticos normales en la población mexicana y el impacto del género y la etnia

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Abstract

Background: There is a lack of studies describing the normal size of the aorta in Mexican population. **Objective:** To analyze aortic measurements in Mexican patients and to compare them with patients from five different countries. **Methods:** Measurements of the aorta were divided in Mexicans and controls. Comparisons between ethnicities and groups were performed using Mann Whitney rank sum test. **Results:** The registry included 166 patients, 106 (63.8%) were enrolled in Mexico and 60 (36.1%) in the control group. Mexican patients had smaller aortic diameters compared to the control group, at the level of the right renal artery ostium, inferior mesenteric artery, and aortic bifurcation. The Hispanic population had significantly smaller aortic diameters from the level of the celiac artery to the aortic bifurcation. **Conclusion:** The normal aortic diameters in the Mexican population are smaller compared to other countries.

Keywords: Aortic anatomy. Aorta. Aortic dimensions. Aortic size.

Resumen

Antecedentes: Faltan estudios que describan el tamaño normal de la aorta en población mexicana. **Objetivos:** Analizar las medidas aórticas en pacientes mexicanos y compararlas con pacientes de cinco países diferentes. **Métodos:** Las medidas de la aorta se dividieron en mexicanos y controles. Se realizó una comparación entre etnias y grupos mediante la prueba de suma de rangos de Mann Whitney. **Resultados:** El registro incluyó a 166 pacientes, 106 (63.8%) eran de México y 60 (36.1%) en el grupo control. Los pacientes mexicanos tenían diámetros aórticos más pequeños en comparación con el grupo control, a nivel del ostium de la arteria renal derecha, la arteria mesentérica inferior y la bifurcación aórtica. La población hispana tenía diámetros aórticos significativamente más pequeños desde el nivel de la arteria celíaca hasta la bifurcación aórtica. **Conclusión:** Los diámetros aórticos normales en la población mexicana son menores en comparación con otros países.

Palabras clave: Anatomía aórtica. Aorta. Dimensiones aórticas. Tamaño aórtico.

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Introduction

An arterial aneurysm is defined as a permanent localized dilatation of an artery, having at least a 50% increase in diameter when compared to its expected normal diameter¹. The normal diameter of the infrarenal aorta is traditionally based on the findings of Horejs et al.² who retrospectively reviewed 260 computed tomography (CT) scans. Although ethnicity was not mentioned in that publication, it could be assumed that most patients were Americans, as the study was performed in Chicago. Since then, the American³ and European⁴ guidelines define an abdominal aortic aneurysm when the aortic diameter is greater than 30 mm.

Ultrasound (US), magnetic resonance imaging (MRI), and CT play a central role in the evaluation of aortic diseases, with CT being the most accurate modality to determine outer vessel wall diameter². There is frequently a poor agreement between US and CT diameters, particularly when close to the treatment threshold. Guidelines recommend to use the former for surveillance of small AAA and the latter for pre-operative imaging⁵.

An AAA is a common, potentially fatal, but treatable disease, particularly if detected before rupture with a clear indication threshold based on its diameters. Therefore, it is important to accurately determine the normal size of the abdominal aorta, so clinicians can determine when an aorta becomes aneurysmal, for guiding therapeutic decisions⁶. This is also of relevance regarding secondary risk prevention as the guidelines advice to start with platelet inhibitors and statins in all patients diagnoses with an AAA to reduce cardiovascular morbidity and mortality.

There are no studies that describe the normal size of the aorta in Mexican people, which led us to implement this study. Given the specific ethnic variation in Mexico, with many Native Americans, the normal diameters could differ from those of Horejs et al.² The purpose of the present study is to assess the paired differences in aortic diameter measurements, obtained by CT scans, in patients without aortic pathology from Mexico and to compare them with patients from other countries.

Methods

A transversal study was conducted among five countries by six experienced vascular specialists. Data were obtained anonymously and retrospectively reviewed. The study was approved by ethics committee, and Institutional Review Board from all the centers involved

and has, therefore, been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

The inclusion criteria were contrast-enhanced CT scans obtained for non-vascular disorders, slice thickness of ≤ 0.5 mm, and age ≥ 18 years. Patients with aortic aneurysm were excluded from the analysis.

The collected data included country, gender, age, length, weight, and body mass index (BMI). The patients were divided into two groups: Mexicans and control group, of non-Mexican patients. Furthermore, a division by ethnicities was made into three groups, Hispanic (Latin America), European, and North America.

The aortic diameter was measured including the wall (outer-to-outer diameter) and perpendicular to the centerline of the vessel in multiplanar reconstructions using dedicated software packages. OsiriX (Pixmeo, Geneva, Swiss), Horos (Nimble Co LLC Purview, Annapolis, MD, USA), or Carestream Vue (Onex Corporation, Rochester, USA) software were used, based on preferences or availability of each center. Two other researchers, one vascular surgeon (MAF) and one radiologist (MAC), randomly audited the 30% of the measurements obtained and reported by local investigators.

The aortic diameter was measured at the level of celiac axis (CA), superior mesenteric artery (SMA), right renal artery (RRA), inferior mesenteric artery (IMA), aortic bifurcation, right common iliac artery (RIA), and left common iliac artery (LIA).

Statistical analysis

Comparison between both groups was done using Mann–Whitney rank sum test and $p < 0.05$ was considered statistically significant. The 95% confidence intervals are also described.

Results

The study included 166 patients, 106 (63.8%) were enrolled in México and 60 (36.1%) in the control group, enrolled in four countries including 21 (12.6%) patients from Argentina, 12 (7.2%) patients from Costa Rica, 16 (9.6%) patients from Spain, and 11 (6.6%) patients from the United States. Seventy-seven (46.3%) patients were male and the mean age was 51.3 ± 17 years. There was no difference in age, sex, and BMI between the two groups, although the BMI was not reported in patients from Argentina and the USA (Table 1).

Table 1. Comparison between Mexicans and non-Mexicans

| | Overall Mexican (n = 106) | CI 95% | Overall non-Mexican (n = 60) | CI 95% | p value |
|----------------------------------|------------------------------|-------------|---------------------------------|-------------|--------------|
| Age mean (years) | 49.9 ± 18.1 | 46.4-53.4 | 53.5 ± 16.9 | 46.4-58.0 | 0.21 |
| Length (cm) | 165.0 (189.0-136.0) | 163.5-167.1 | 165.0 (146.0-181.0) | 161.8-167.8 | 0.826 |
| Weight (kg) | 71.5 (130.0-45.0) | 69.9-76.2 | 65.0 (45.0-115.0) | 63.0-73.0 | 0.255 |
| BMI | 25.9 (18.0-44.0) | 25.6-27.6 | 24.8 (16.5-39.3) | 23.4-26.5 | 0.154 |
| Aortic diameter at | | | | | |
| Celiac axis (mm) | 21.4 ± 3.6 | 20.6-22.0 | 21.6 ± 3.5 | 20.1-23.2 | 0.342 |
| Superior mesenteric artery (mm) | 19.3 ± 3.3 | 19.0-20.1 | 20.6 ± 4.0 | 19.2-22.7 | 0.052 |
| Right renal artery (mm) | 17.1 ± 3.3 | 16.7-17.8 | 19.9 ± 4.2 | 18.4-22.0 | 0.001 |
| Inferior mesenteric artery (mm) | 15.7 ± 2.5 | 15.4-16 | 18.2 ± 4.9 | 16.9-21.2 | 0.006 |
| Aortic bifurcation (mm) | 15.2 ± 2.3 | 14.9-15.7 | 17.6 ± 4.5 | 16.9-20.8 | 0.004 |
| Left iliac artery (mm) | 10.1 ± 1.7 | 10.1-10.8 | 10.5 ± 1.8 | 10.1-11.5 | 0.062 |
| Right iliac artery diameter (mm) | 10.5 ± 1.8 | 9.7-10.3 | 10.7 ± 1.8 | 10.1-11.4 | 0.34 |

Bold values mean it was statistically significant.

Aortic diameters of the Mexican population compared to controls

At the CA and SMA level, there were no significant differences between groups. At the level of the right renal artery, the mean aortic diameter was 2.8 mm smaller in the Mexican group compared to the control group ($p = 0.001$). Furthermore, at the level of the IMA and the aortic bifurcation, the diameter was significantly lower in the Mexican group; 2.5 mm and 2.4 mm, respectively ($p = 0.006$ and 0.004). There were no significant differences at the level of the iliac arteries. The aortic and iliac diameters are depicted in [Table 1](#).

Gender differences

Overall, when comparing between Mexican males and Mexican females, females have smaller aortic diameters than Mexican males. When comparing between Mexican patients and control group, Mexican male patients had a smaller aortic diameter at the level of SMA compared to the control group, with a mean size difference of 4.4 mm ($p = 0.05$). However, this was not true on the female counterpart. The aortic diameter at the level of the right renal artery was smaller in both genders in Mexican patients compared with the control group, by difference in mean size of 3.8 mm in males ($p = 0.001$), and 0.6 mm in females ($p = 0.009$). The aortic diameter at the level of the IMA was smaller in Mexican male patients compared with the control group, with a mean difference size of 5.1 mm ($p = 0.001$). There was no statistical difference observed between female patients on this location. At the aortic bifurcation,

Mexican patients both males and females had smaller diameters compared with the control groups, with a mean difference in the male group of 3.4 mm and 1.5 mm in female group, respectively ($p = 0.001$, $p = 0.043$). Measures between genders are displayed in [Table 2](#) and [3](#).

Ethnic differences

The Hispanic population consisted of 139 (83.7%) patients, whereas North American and European and North American population consisted of 16 (9.6%) and 11 (6.6%) patients, respectively. When comparing aortic diameters at the level of the CA, SMA, right renal artery, IMS, the aortic bifurcation, and right iliac artery, Hispanic population had smaller diameters at these levels, following by North American and European patients, with statistical significance. However, this was not true regarding the left iliac artery size. The differences of aortic diameters between ethnicities are displayed in [Table 4](#).

Discussion

Ever since the “suggested standards for reporting on arterial aneurysms” were published in 1991, an aneurysm was defined in size as 50% increase in diameter compared to the expected normal diameter of the artery¹. Consequently, it became mandatory to determine which is the normal diameter of the aorta to define an aortic aneurysm. This normal aortic diameter was mostly based on studies that were performed on an occidental population, and their results were assumed as a the ground truth². In France, Brivady et al.⁷

Table 2. Comparison between males patients

| | Males | | | | |
|----------------------------------|---------------------|-------------|----------------------|-------------|--------------|
| | Mexican (n = 51) | CI 95% | Non-Mexican (n = 26) | CI 95% | p value |
| Age mean (years) | 49.6 ± 16.4 | 45.0-54.2 | 54.8 ± 15.1 | 49.2-63.7 | 0.187 |
| Length (cm) | 172.0 (145.0-189.0) | 128.2-172.8 | 170.0 (163.0-181.0) | 167.2-173.1 | 0.527 |
| Weight (kg) | 75.0 (55.0-130.0) | 72.9-81.8 | 78.5 (62.0-82.0) | 69.7-78.7 | 0.771 |
| BMI | 25.9 (18.0-37.9) | 25.2-27.7 | 25.7 (22.0-28.6) | 24.3-26.8 | 0.702 |
| Aortic diameter at | | | | | |
| Celiac axis (mm) | 22.4 ± 3.6 | 21.4-23.5 | 23.4 ± 3.6 | 21.3-25.5 | 0.268 |
| Superior mesenteric artery (mm) | 20.7 ± 2.7 | 20.0-21.5 | 22.8 ± 3.5 | 20.8-25.4 | 0.005 |
| Right renal artery (mm) | 18.4 ± 2.9 | 17.5-19.2 | 22.1 ± 4.0 | 19.7-25.1 | 0.001 |
| Inferior mesenteric artery (mm) | 16.6 ± 2.2 | 16.0-17.2 | 21.7 ± 8.2 | 18.9-24.6 | 0.001 |
| Aortic bifurcation (mm) | 16.0 ± 2.1 | 15.5-16.6 | 19.5 ± 4.7 | 18.4-23.8 | 0.001 |
| Left iliac artery (mm) | 11.2 ± 1.8 | 10.7-11.7 | 11.6 ± 1.9 | 10.5-12.8 | 0.334 |
| Right iliac artery diameter (mm) | 10.7 ± 1.7 | 10.2-11.2 | 11.4 ± 1.8 | 10.7-12.7 | 0.135 |

Bold values mean it was statistically significant.

Table 3. Comparison between females patients

| | Females | | | | |
|----------------------------------|---------------------|-------------|----------------------|-------------|--------------|
| | Mexican (n = 55) | CI 95% | Non-Mexican (n = 34) | CI 95% | p value |
| Age mean (years) | 50.2 ± 19.7 | 44.9-55.6 | 52.6 ± 18.3 | 38.9-57.6 | 0.573 |
| Length (cm) | 162.0 (136.0-175.0) | 158.5-162.4 | 161.0 (146.0-171.0) | 156.8-163.6 | 0.774 |
| Weight (kg) | 65.0 (45.0-115.0) | 64.8-73.4 | 60.0 (45.0-115.0) | 53.7-71.9 | 0.113 |
| BMI | 26.0 (19.0-44.0) | 25.2-28.3 | 24.3 (16.5-39.3) | 21.5-27.4 | 0.138 |
| Aortic diameter at | | | | | |
| Celiac axis (mm) | 20.3 ± 3.1 | 19.5-21.2 | 20.1 ± 3.7 | 17.9-22.2 | 0.778 |
| Superior mesenteric artery (mm) | 18.5 ± 2.8 | 17.7-19.3 | 18.9 ± 3.6 | 16.5-21.2 | 0.589 |
| Right renal artery (mm) | 16.2 ± 2.7 | 15.5-17.0 | 18.2 ± 3.6 | 16.0-20.5 | 0.009 |
| Inferior mesenteric artery (mm) | 15.1 ± 2.1 | 14.5-15.7 | 16.6 ± 4.5 | 13.7-19.3 | 0.089 |
| Aortic bifurcation (mm) | 14.6 ± 1.9 | 14.1-15.2 | 16.1 ± 3.9 | 14.1-19.3 | 0.043 |
| Left iliac artery (mm) | 9.8 ± 1.5 | 9.4-10.2 | 10.1 ± 1.5 | 9.1-10.8 | 0.314 |
| Right iliac artery diameter (mm) | 9.3 ± 1.3 | 9.0-9.7 | 9.9 ± 1.5 | 9.2-10.6 | 0.058 |

Bold values mean it was statistically significant.

assessed the diameter of infrarenal abdominal aorta using ultrasonography in 1413 patients with atherosclerosis of the lower limbs. They reported a mean diameter of 15.9 mm in women and 20.4 mm in men. In a similar study performed by Ouriel et al.⁸ on American individuals, the diameter was 19 mm in females and 23 mm in males.

The first published study that evaluated ethnical differences in the normal aortic diameters was performed on a Saudi population using ultrasonography. No significant differences with occidental population were observed, with a mean aortic diameter of 18.7 mm in females and 19.3 mm in males⁹. More recently, there were a few studies that observed differences between

the aortic diameters in their populations compared to literature. In a Korean study that included 1218 people, the mean diameter of the infrarenal aorta was 19.0 mm in males and 17.9 mm in females¹⁰. Furthermore, Sari-osmanoglu et al.¹¹ reported a mean aortic diameter of 16 mm in males and 15 mm in females in the Turkish population. Both studies used ultrasound as imaging modality. A similar study performed on 142 Indian subjects, using contrast-enhanced CT showed a median aortic diameter of 12.0 mm and 13.8 mm in women and men, respectively¹². Finally in a Thai population, studied with CT scan, a mean diameter of 13.3 mm in women and 14.9 mm in men was reported¹³. In our study, we find mean aortic diameter of Mexican patients at the

Table 4. Comparison between ethnicities

| | Europeans (n = 16) | CI 95% | Hispanics (n = 139) | CI 95% | North Americans (n = 11) | CI 95% | p value |
|---------------------------------|------------------------|-----------|------------------------|-------------|--------------------------------|-----------|-----------------|
| Age mean | 53.5 ± 9.2 | 48.6-58.4 | 50.5 ± 18.4 | 47.5-53.6 | 56.6 ± 18.6 | 44.0-69.1 | 0.486 |
| Length | 167.0 (156.0-181.0) | 165-171.7 | 165.0 (136.0-189.0) | 163.8-166.5 | NA | | 0.109 |
| Weight | 76.0 (45.0-82.0) | 62.5-76.9 | 70.0 (45.0-130.0) | 69.4-75.3 | NA | | 0.96 |
| BMI | 25.1 (16.5-28.6) | 22.2-26.4 | 25.0 (18.0-44.0) | 25.5-27.4 | NA | | 0.257 |
| Aortic diameter at | | | | | | | |
| Celiac axis (mm) | 24.2 ± 2.7 | 22.6-25.7 | 21.0 ± 3.7 | 20.4-21.7 | 22.1 ± 2.3 | 20.6-23.7 | *0.005 |
| Superior mesenteric artery (mm) | 24.9 ± 3.1 | 22.6-25.9 | 19.3 ± 2.1 | 18.8-19.9 | 21.3 ± 2.2 | 18.8-22.8 | **0.001 |
| Right renal artery (mm) | 23.7 ± 3.5 | 21.8-25.6 | 17.4 ± 3.2 | 16.9-18.0 | 20.1 ± 2.4 | 18.4-21.7 | ***0.001 |
| Inferior mesenteric artery (mm) | 23.5 ± 4.1 | 21.3-25.7 | 15.9 ± 2.8 | 15.4-16.4 | 19.7 ± 11.8 | 11.8-27.7 | ***0.001 |
| Aortic bifurcation (mm) | 22.6 ± 4.0 | 20.5-24.8 | 15.4 ± 2.4 | 15.0-15.8 | 15.5 ± 2.2 | 14.0-17.0 | **0.001 |
| Left iliac artery (mm) | 11.3 ± 1.8 | 10.3-12.3 | 10.5 ± 1.8 | 10.2-10.8 | 10 ± 1.3 | 9.1-10.9 | 0.143 |
| Right iliac artery (mm) | 11.2 ± 1.6 | 10.3-12.0 | 10.1 ± 1.7 | 9.8-10.4 | 9.7 ± 1.2 | 8.9-10.5 | 0.056 |

Behind de P value: *Hispanic different from European; **European different from Hispanic and North America; ***all different between each other. NA = Not available. Bold values mean it was statistically significant.

level of the IMA of 16.63 mm and 15.14 mm in males and females, respectively.

As to our knowledge, there is only one other study evaluating aortic diameter differences between races. In this multi-ethnic study of atherosclerosis, aortic diameter in people of Chinese, African, and Hispanic descendant was smaller than the aortic diameter of Caucasians, even after adjusting for differences in body size and other factors. Measurement was done with CT but all 6814 patients were recruited from six American field centers¹⁴. Our results show that the normal aortic diameter is smaller in Mexican population compared with three other countries from America and Spain, but only at the level where aortic abdominal aneurysms mostly occur.

Our study also collected information on the family origin with various options, such as European, Hispanic, or North Americans. Most patients included were classified as being Hispanic. This generic division, however, made is impossible to determine the true ethnicity of our study groups. Moreover, it is very complex to define ethnicity in the American population, since actual population is the result of a complex admixture between Native Americans and immigrants from diverse origin. Furthermore, their distribution is heterogeneous even between Hispanic countries. Genomic composition of argentine population is composed by 67% of European, 27% of Native American, 0.3% of West African, and 0.1% of East Asian¹⁵. In Costa Rica, genomic ancestry

proportions are composed by 54% European, 32% Native American, and 13% West African¹⁶. In Mexico, the Native American, European, and West African account for 56%, 37%, and 5% of the population, respectively¹⁷.

The results from the present study are hypothesis generating. We clearly observed a smaller diameter in the overall Mexican population and the question remain whether is influences by the relatively high number of Native Americans in this group. Moreover, it is unclear whether this observation would have repercussions for the threshold for preventive treatment of an AAA. Commonly elective treatment is indicated when the aortic diameter is > 55 mm, assuming 20 mm normal aortic diameter. In the Mexican study population, a similar relative increase would reflect an aortic diameter of 43.5 mm^{3,4}. These observations encouraged us to design a new study in larger subset of healthy volunteers from different ethnicities based on genomic data and determine the anatomical differences between them. This could further support the need of redefined the size of abdominal aortic aneurysm in the specific subgroups of the population.

The present study has limitations, such as vascular specialists based on their own experience and availability chose the measurement software tool. Although, there is some evidence on difference of aortic diameter related to its measurement during systole or diastole, it is not yet accurately assessed, and ECG-gated scans

are not widespread; therefore, no direction was done on this topic¹⁸. Another weakness of our study is the sample bias. The sample was gathered by a retrospective fashion rather than a calculated one. Furthermore, there was a lack on the report of length and weight in patients from Argentina and the USA, making not possible to compare these variables with the aortic diameter. In the same way, the relation between male-female genders is not the same between the two groups, and it could be a cause of bias. Furthermore, Mexican patients were collected in a single center, so it may not be representative of the varying ethnic and racial groups in our country. A larger population-based multicenter study with an adequate representative sample, ideally in normal subjects would be beneficial in obtaining more representative values.

Conclusion

We have shown that the normal aortic diameters in the Mexican population, both males and females, are smaller, compared to other countries, particularly at the infrarenal level. A Hispanic background and female gender are also related to smaller diameters. However, these conclusions required subsequent validation by a study with a larger population and a representative sample. The clinical consequences of these observations remain to be shown.

Disclaimer

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical disclosures

Protection of human and animal subjects. The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code

of Ethics of the World Medical Association (Declaration of Helsinki).

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

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