The validity of arterial measurements in a South African embalmed body population

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Abstract

Knowledge of the normal arterial diameter at a given anatomical point is the first step toward quantifying the severity of cardiovascular diseases. According to several studies, parameters such as weight, height, age and sex can explain morphometric variations in arterial anatomy that are observed in a population. Before the development of a reference database against which to compare the diameters of arteries in a variety of pathological conditions, the compatibility between cadaver measurements and computed tomography (CT) measurements must first be established. **Purpose:** The aim of this study was to compare cadaver measurements and CT measurements at 19 different arterial sites in order to establish whether cadaver measurements are a true reflection of a living population. **Methods:** A total of 154 embalmed cadavers were randomly selected from the Department of Anatomy at the University of Pretoria, 36 embalmed cadavers were randomly selected from the Department of Human Anatomy at the University of Limpopo, Medunsa Campus. Dissections were performed on the cadaver sample and the arterial dimensions were measured with a mechanical dial-sliding caliper (accuracy of 0.01 mm). Approximately 30 CT images for each of the 19 arterial sites were retrospectively selected from the database of radiographic images at the Department of Radiology, Steve Biko Academic Hospital. Radiant, a Digital Imaging and Communications in Medicine (DICOM) viewer was used to analyze the CT images. **Results:** The only statistically significant differences between the cadaver measurements and CT measurements were found in the left common carotid- and the left subclavian arteries. The null hypothesis of no statistically significant difference between the cadaver and CT measurements was accepted since the *P*-value indicated no significant difference for 87% of the measurements, the exception being the left common carotid- and the left subclavian arteries. **Conclusions:** With the exception of two measurements, measurements in cadavers and living people are interchangeable and concerns regarding the effect of distortion and shrinkage are unfounded. Even small changes in arterial diameter greatly influence blood flow and blood pressure, which contribute to undesirable clinical outcomes such as aortic aneurysms and aortic dissections. This study completes the first step towards the development of a reference database against which to compare the diameters of arteries in a variety of pathological conditions in a South African population.

Keywords: cadaver arterial measurements, computed tomography arterial measurements; arterial dimensions; morphometric variation

1. Introduction

Knowledge of the normal arterial diameter at a given anatomical point contributes to quantifying the severity of a cardiovascular disease. Studies on the association between changes in arterial diameter and cardiovascular risk factors have been done in the coronary arteries [1], different aortic segments [2-7] and iliac arteries [4,7].

Physiological responses related to cardiovascular diseases lead to an increase in arterial diameters. These physiological responses may cause a widespread increase in arterial dimensions that is not limited to the narrowing of only a specific arterial segment. It is therefore difficult to establish whether the arterial segments that appear normal are truly normal [8]. This difficulty causes a problem with regard to the conventional radiographic estimation of the severity of a cardiovascular disease. The *percentage of stenosis* is based on a ratio of the diameters of a narrowed arterial segment to a normal arterial segment of a specific arterial site [8]. Unfortunately, because the normal arterial diameter cannot be accurately assessed in humans, the clinical efficacy of this estimate is diminished.

The solution to this problem is to find methods such as reference databases according to which we may predict normal arterial diameter at a given anatomical point and to use this diameter as normal reference to calculate the *percentage of stenosis*. At present, data on the normal diameter of human arteries in a South African population are not available in such a methodical format [8].

Although image diagnostic methods such as ultrasound and computed tomography (CT) become more accurate every day, cadaver studies are still an important source for medical knowledge, particularly those studies intending to clarify anatomical-morphological features.

Concerns regarding cadaver studies embrace the possibility that the use of cadaveric tissue to measure arterial diameter may yield measurements that do not accurately reflect a living population. Arteries contain a high percentage of elastic tissue and smooth muscle in the tunica media; for this reason, arteries are not prone to collapse and should accurately reflect their true diameter [9,10].

A component regarding a living population is often added to cadaver studies in order to compare the samples, analyse the comparisons and differences and ultimately conclude whether the use of cadaveric tissue is an accurate reflection of the living population.

The aim of this study was to compare cadaver measurements and CT measurements at different arterial sites in order to establish whether South African cadaver measurements are a true reflection of a living South African population.

2. Materials and methods

2.1 Cadaver sample

All cadavers used for this study were legally obtained and stored in the Department of Anatomy, University of Pretoria (UP), South Africa, for research and teaching purposes, according to the rules and regulations stated in the South African National Health Act, 61 of 2003. Ethical clearance to perform this study was obtained from the Faculty of Health Sciences Research Ethics Committee at the University of Pretoria (83/2014).

A total of 154 embalmed cadavers were randomly selected from the Department of Anatomy at the University of Pretoria, 36 embalmed cadavers were randomly selected from the Department of Anatomy at the University of Limpopo, Medunsa Campus – making up a total sample of 190 cadavers that were examined. Dissections were performed on the cadaver sample and the arterial dimensions were measured with a mechanical dial-sliding caliper (accuracy of 0.01 mm).

The demographic information related to each cadaver in the Department of Anatomy was obtained from the hospital records. The weight and height were measured post-mortem, pre-embalmment and should therefore be an accurate reflection of the weight and height of the individual.

The 190 cadavers were divided into two subgroups, 125 males and 65 females. Cadavers were not excluded due to height, weight or age. The age of the cadavers ranged from 20 to 99 years. Cadavers with known or visible aneurysms, arterial dissections or those who have undergone previous vascular surgery or suffered from any known vascular pathology were excluded from the study.

The relevant arteries were exposed during the dissection of the cadavers in the Department of Anatomy. Where necessary, the arteries were further cleaned prior to the arterial measurements being taken. Without compressing the artery, measurements were taken for the outer diameter at the 19 arterial sites (Table 1).

Table 1: Measured arterial sites

#	Arterial site	Abbreviation
1	Ascending aorta proximal to fibrous pericardium	AA
2	Abdominal aorta at level of celiac trunk	AC
3	Abdominal aorta before terminal bifurcation	AB
4	Left internal carotid artery distal to carotid body	LIC
5	Right internal carotid artery distal to carotid body	RIC
6	Left common carotid artery at origin	LCC
7	Right common carotid artery at origin	RCC
8	Left brachial artery before bifurcation	LBA
9	Right brachial artery before bifurcation	RBA
10	Left subclavian artery at origin	LSC
11	Right subclavian artery at origin	RSC
12	Left popliteal artery in popliteal fossa	LPA
13	Right popliteal artery in popliteal fossa	RPA
14	Left femoral artery inferior to inguinal ligament	LFA
15	Right femoral artery inferior to inguinal ligament	RFA
16	Left common iliac artery at origin	LCI
17	Right common iliac artery at origin	RCI
18	Left coronary artery at origin	LC
19	Right coronary artery at origin	RC

A sample of the measurements was re-taken by the primary investigator in order to minimize intra-observer error. A sample of measurements was also re-taken by a separate, independent individual, in order to minimize inter-observer error.

2.2 CT sample

Approximately 30 CT images for each of the 19 arterial sites were retrospectively selected from the database of radiographic images at the Department of Radiology, Steve Biko Academic Hospital. The demographic information, related to each patient, was obtained from this database and included age and sex.

In order to allow for comparisons to be made, CT scans of patients between the ages of 15 and 65 years, of both sexes were included.

The patient scans were screened and selected by a consultant radiologist and the CT images of patients with known or visible arterial aneurysms, arterial dissections or those who have undergone previous vascular surgery or suffered from any known vascular pathology were excluded from this study.

Radiant, a Digital Imaging and Communications in Medicine (DICOM) viewer was used to analyze the CT images. Using the on-screen measuring function, calibrated for each image, the outer diameter of each of the 19 arterial sites was recorded.

The 19 arterial sites were identified as a representation of the arteries of the human body. Elastic arteries, which are close to the heart and defined as low-resistance pathways were included, as well as muscular arteries, which are more distal, active in vasoconstriction and less distensible [10].

3. Results

To establish whether there is a statistical significant difference between the measurements of the cadaver sample and the CT sample, representing a living South African sample, *t*-tests were performed. Cadavers and CT patients were matched for age and sex and 22 matching pairs were found (Table 2). Cadavers and CT patients were also matched to age alone and 29 matching pairs were found (Table 3).

Table 2 shows the *P*-values found when comparing the cadaver measurements to the CT measurements for the specific age and sex matched pairs. A *P*-value smaller than 0.05 (shaded), indicates a statistically significant difference.

Table 2: Cadaver sample *vs.* CT sample (age and sex)

Measurement	***P*-value**
Ascending aorta proximal to fibrous pericardium	0.0665
Abdominal aorta at level of celiac trunk	0.6250
Abdominal aorta before terminal bifurcation	0.5000
Left internal carotid artery distal to carotid body	0.0547
Right internal carotid artery distal to carotid body	0.1914
Left common carotid artery at origin	0.0156
Right common carotid artery at origin	0.0742
Left brachial artery before bifurcation	*
Right brachial artery before bifurcation	*
Left subclavian artery at origin	0.0273
Right subclavian artery at origin	0.2188
Left popliteal artery in popliteal fossa	0.6250
Right popliteal artery in popliteal fossa	0.3500
Left femoral artery inferior to inguinal ligament	0.8125
Right femoral artery inferior to inguinal ligament	0.4375
Left common iliac artery at origin	0.7500
Right common iliac artery at origin	0.5000
Left coronary artery at origin	*
Right coronary artery at origin	*

* see limitations (section 5)

Table 3 shows the *P*-values found when comparing the cadaver measurements to the CT measurements for the specific age matched pairs. A *P*-value smaller than 0.05 (shaded), indicates a statistical significant difference.

Table 3: Cadaver sample *vs.* CT sample (age)

Measurement	*P*-value
Ascending aorta proximal to fibrous pericardium	0.0051
Abdominal aorta at level of celiac trunk	0.2500
Abdominal aorta before terminal bifurcation	0.4375
Left internal carotid artery distal to carotid body	0.1094
Right internal carotid artery distal to carotid body	0.2891
Left common carotid artery at origin	0.0156
Right common carotid artery at origin	0.0756
Left brachial artery before bifurcation	*
Right brachial artery before bifurcation	*
Left subclavian artery at origin	0.0156
Right subclavian artery at origin	0.2188
Left popliteal artery in popliteal fossa	1.0000
Right popliteal artery in popliteal fossa	0.1250
Left femoral artery inferior to inguinal ligament	0.8125
Right femoral artery inferior to inguinal ligament	0.4688
Left common iliac artery at origin	0.8125
Right common iliac artery at origin	0.8135
Left coronary artery at origin	*
Right coronary artery at origin	*

* see limitations (section 5)

4. Discussion

The null hypothesis of no statistically significant difference between the cadaver and CT measurements was accepted since the *P*-value indicated no significant difference for 87% of the measurements, the exception being the left common carotid- and the left subclavian arteries.

These arteries are found on the left side of the neck, branching off the brachiocephalic trunk from the arch of the aorta. (Fig. 1) Since the origin of these two arteries differ from the origin of the same arteries of the right side of the neck, and it is the only two arteries showing a statistical significant difference between cadaver and CT measurements (taken at origin), the notion that the embalming process might have affected the structure of the brachiocephalic trunk (and its branches) as the first branch of the arch of the aorta was considered. This is probably unlikely as the pressure or speed of the embalming process would have resulted in more differences between the two samples. It is possible that when comparing the cadaver measurements with a larger CT sample, the differences might not be significant. This theory will be tested in future studies.

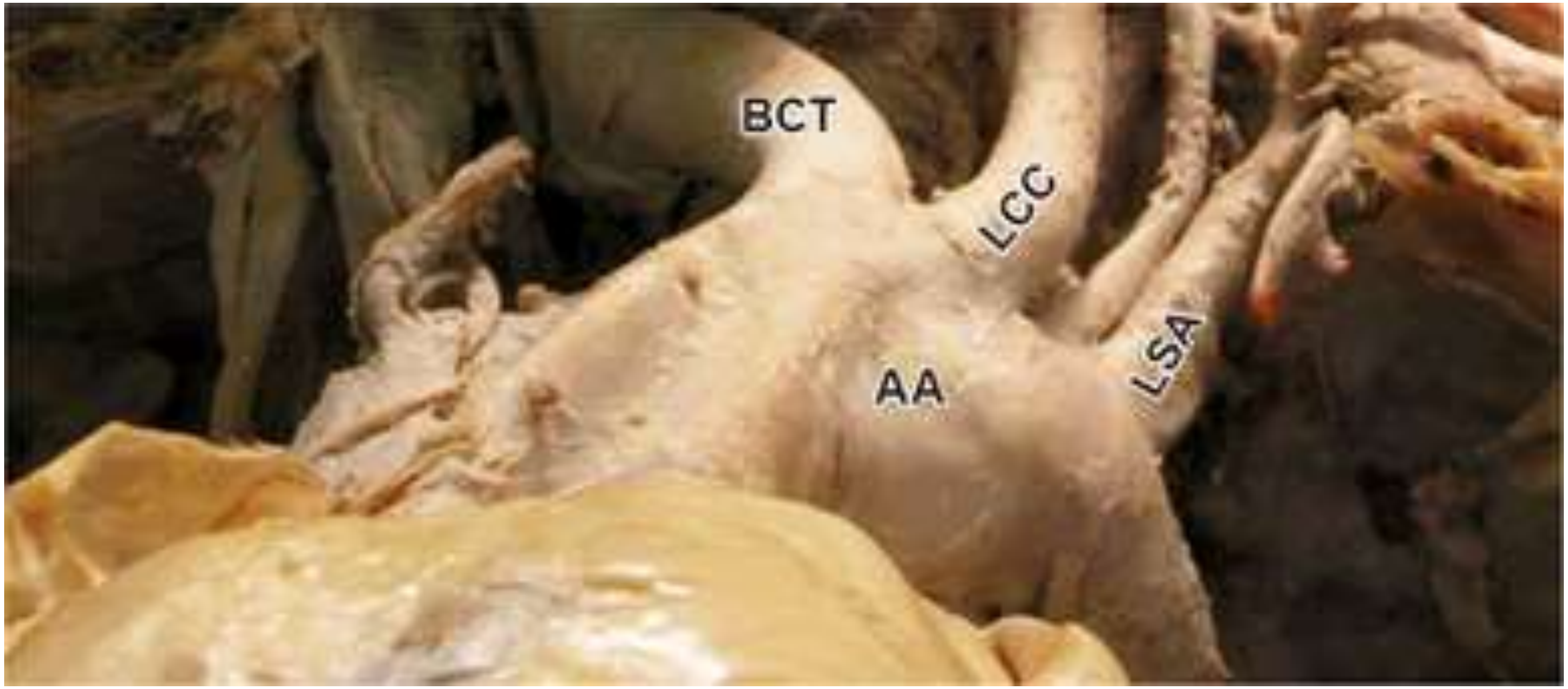

Fig. 1. Aortic arch in embalmed body. *AA* aortic arch, *BCT* Brachiocephalic trunk, *LCC* left common carotid artery, *LSA* left subclavian artery

The collected arterial dimensions with no statistical significant difference observed between the cadaver sample and CT sample, will form the basis of an arterial reference data set that will be extended during future research. This will allow the prediction of the normal arterial diameter at a given anatomical point and for it to be used as normal reference to calculate the *percentage of stenosis.*

An extensive arterial dimension database for a South African population might provide better insight into the normal and abnormal diameters of the different arteries affected. This knowledge could contribute to early diagnosis of various cardiovascular diseases and arterial abnormalities.

5. Limitations

If not indicated in the records, it is impossible to determine whether the cadavers or CT patients suffered from conditions such as elevated blood pressure, atherosclerosis, diabetes mellitus or high cholesterol during life. It is also unclear whether they were smokers or suffered from other risk factors that could have accelerated age-related changes in the structure and function of arterial anatomy. The use of a large cadaver sample should minimize the influence of such factors.

Full body CT images are scarce and therefore the 30 CT images for 15 of the 19 arterial sites were collected from 65 patients. The lefts and right brachial arteries and the left and right coronary arteries were not measured on CT because these areas are only visible on a CT image when specifically scanned, searching for pathology – pathology that could possibly influence the dimensions of these arteries. For future studies, the CT sample will be enlarges, eliminating possible discrepancies leading to the differences found between cadaver- and CT samples.

6. Conclusion

This study completed the first step towards the development of a cadaver-based arterial reference data set that will provide us with a quantitative estimate of the severity of cardiovascular diseases in a South African population. Such a database would aid in the assessment of arterial changes with the advancement of age as well as the assessment of arterial dimensions within groups with different demographic data.

The non-collapsing nature of arteries of the cadaver sample was validated by the results of this study, making cadaveric research possible and valid. Arterial measurements in cadavers and living people are interchangeable and concerns regarding the effect of distortion and shrinkage are unfounded.

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