Geometric anatomy of the aortic- common iliac bifurcation

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Abstract

The anatomical description of the aortic common iliac region is well known. However, the geometric measurements of this region are not properly established. The research performed on haemodynamic forces and their correlation with atherosclerosis has shown the importance of the geometric anatomy of this region. Only a few studies have been performed in the western world. According to our knowledge, there are no geometric measurements done in Asian population. Therefore, we decided to embark on a preliminary research project on this particular subject using eleven cadavers. This study was designed to seek any apparent asymmetry at the aorto-iliac bifurcation. Measurements were made on 5 female and 6 male cadavers. In majority of female subjects (4/5) there was an asymmetrical right lateral orientation of the abdominal aorta which resulted in a longer left common iliac artery, smaller right common iliac take-off angle and larger right radius of curvature at the aortic-common iliac bifurcation. In male subjects there were more variety in orientation of the abdominal aorta (3 out of 6 had asymmetrical left lateral orientation of the abdominal aorta). Knowledge of both the exact and the average numerical values associated with the local geometry would be essential for a detailed haemodynamic study of the effect of these variations on atherogenesis and it should be further evaluated.

Introduction

The anatomical description of the aortic common iliac region is well known and is available in any standard anatomy textbook [1]. However, the geometric measurements of this region are not properly established. There are only few studies which have been performed in the western world [2]. According to our knowledge there are no geometric measurements done in the Asian population. One can hypothesize that there may be a difference in these measurements between Asian population and western population. Therefore, we decided to embark on a preliminary research project on this subject. The data may be useful in the fields of Medicine, Surgery and Forensic Medicine [3]. Many clinical observations of different degrees of atheromatous involvement of the right and left iliac arteries in patients with symptomatic aorto-iliac occlusive disease have been done by many researchers [3].

Materials and methods

Nine parameters of eleven cadavers were selected for this study. Six of them were geometric parameters related to that particular area. Techniques were also devised to ascertain the geometric parameters (Figures 1, 2). Outside calipers, scales in centimeters, two transparent protractors were used to obtain the measurements. These measurements were performed on cadavers at the anatomy dissecting theater without mobilization of the aortic-common iliac segment. Therefore, the geometric orientation was not altered from its in vivo state. The cadavers have been placed in supine position and the aortic-common iliac segment was dissected.

The following parameters were studied (Figures 1, 2).

1. Age
2. Sex

3. Cause of death
4. The radius of curvature of the right and left aortic-iliac osculating circles at the bifurcation (R_R and R_L). The osculating circle is the circle in the limiting position of the circle tangent, and therefore, having the highest degree of contact, with a three-dimensional space curve. (Figure 1)
5. Take-off angle of the right and left iliac arteries at the bifurcation.(α_R and α_L)
6. Length of both common iliac arteries.(L_R and L_L)
7. Diameter of the aorta just proximal to the bifurcation (D_A)
8. Diameter of both common iliac arteries just distal to the bifurcation (D_R and D_L).
9. The angle between the aortic longitudinal centre line axis and the plane formed by both iliac arteries (θ). (Figure 2)

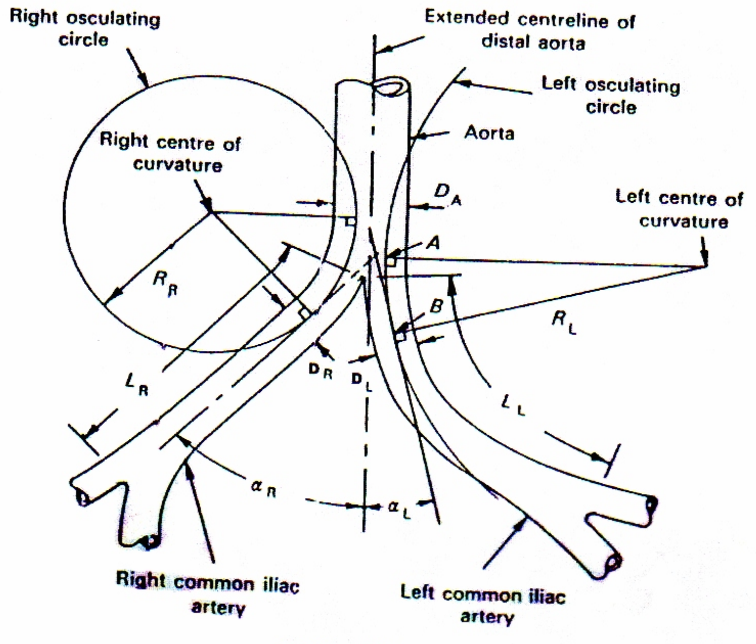

Fig. 1. Anatomical geometry of aortic–common iliac bifurcation.

Geometry of aortic bifurcation

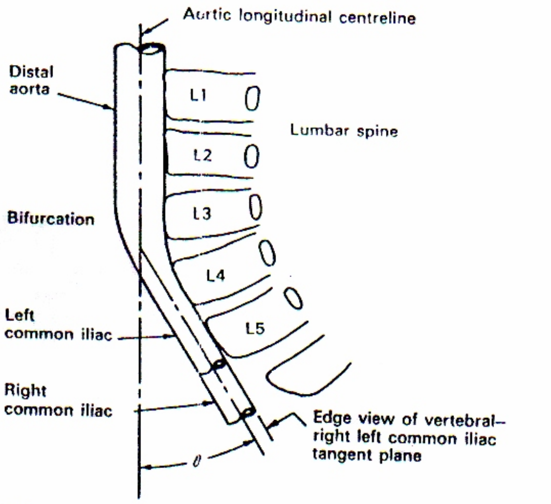

Fig. 2. Section of aortic–common iliac bifurcation through mid-sagittal plane.

For the convenience of measuring above angles, a midline was drawn along the distal aorta and both common iliac arteries. These lines were extended over the aorta to intersect the aortic centerline. The age, sex and cause of death were obtained from the department of anatomy cadaver reports.

Two points (A and B) on each of the imaginary curves at both iliac arteries near the aorto-iliac bifurcation were selected. Then two transparent rulers were placed at the tangent of the circle at points A and B and the radius of curvature was determined as the distance from the tube arc centre line to the intersection of the two rulers. According to that the radius of the curvature of the right and left osculating circles at the bifurcation (R_R and R_L) (Figure 1) was measured.

The angle formed by the intersection of the centerline of the proximal iliac artery B and the extended centerline of the distal aorta is considered as the take off angle. So there are two angles as right and left (α_R and α_L). These were measured directly with a protractor. Either of these angles can become zero when the centerlines of both the aorta and either of the common iliac arteries run parallel to each other.

The (θ) is the angle formed by the aortic longitudinal axis and the plane of both common iliac arteries (Figure 3). It was measured with two transparent rulers. One was aligned parallel to the aortic longitudinal axis and the second was set in the mean plane tangent to both common iliac arteries. These were fixed at the intersection of the two axes and the acute angle (θ) was measured with the protractor.

The length of the common iliac arteries (L_R and L_L) was determined by mobilization and using inside calipers in the segment between the aorta and the common iliac bifurcation.

The diameters of the aorta just before the bifurcation (D_A) and of the iliac arteries (D_R and D_L) immediately after the bifurcation were measured by outside calipers.

All measurements were taken by two independent researchers. Appropriate tests were performed to check for inter-observer differences. In unaffected arteries the thickness of the wall was found to vary between 1 and 2 mm. Possible experimental error was kept to a minimum through the use of precision measuring instruments and is estimated at 5%.

Results

Measurements were obtained in 11 cadavers of which six were male and five were female. The age range was from 64 to 92 years. The average age of males was 77 years and females was 87 years, with the standard deviation being 10 and 6 years, respectively. The above mentioned parameters are tabulated in Tables 1 and 2. In females, the average values of the aorto-iliac take-off angle α_R and α_L were 7.18 degree and 14.58 degree respectively. In males the average values of the aorto-iliac take-off angle α_R and α_L were 16.67 degree and 13.16 degree respectively. In females the average values of curvature (k = 1/R) K_R and K_L were 0.19cm and 0.0958cm, respectively. In males the average values of the curvature (k = 1/R) K_R and K_L were 0.205cm and 0.35cm, respectively. In females the average values of the radius of curvature R_R and R_L were α and 5.7cm. In males the average values of the radius of curvature R_R and R_L were 6.76cm and 4.35cm, respectively. The average values of the angle were calculated. They were 23.2 degree and 22.67 degree respectively. All these were tabulated in Table 3 along with the standard deviation, except for the radius of curvature. As will be mentioned in the discussion, the possible haemodynamic correlation to atherosclerosis may be proportional to the curvature k = 1/R, where R is the radius of curvature. It is not statistically relevant to average the radius of curvature R, as the haemodynamic correlation depends on this quantity in a non-linear way and averaging is a linear process. Also note that some of the radii of curvature are infinite and the average of a set of data containing even one infinite radius of curvature would be infinity, whereas the average of the curvature data is always finite since the reciprocal of infinity is zero. Hence, the average radius of curvature was computed as the reciprocal of the average curvature k. The most significant finding is that the ratio of left to right effective average radius of curvature in males is 0.676 versus 0 for females.

Discussion

Although there is lack of agreement about the role of haemodynamic forces in atherosclerosis, such forces may well influence the constitution of atheroma and its localization. If the biochemical and genetic factors have a uniform effect on the arterial system, then the local variation in haemodynamics between the two iliac arteries may be decisive. Anatomical distinctions between the iliac arteries at the bifurcation are not usually made. However, according to Shah Scarton study the aorta at its bifurcation lies to the left of the sagittal plane midline, with the result that the right iliac artery makes a wider take-off angle, and consequently must be longer, in order to reach the right side. But this present study shows that the previous findings are only compatible with males. In the female subjects the aorta at its bifurcation lies to the right of the sagittal plane midline and the left iliac artery is longer and makes a wider take-off angle. Differences in the angle of bifurcation may directly affect the radius of curvature of imaginary osculating circles.

Table 1 - Aortic-common iliac geometric values (females)

	Length of Common iliac L(cm)		Diameter of iliac at bifurcation D (cm)		Radius of curvature A. I Junction (cm)		Take off angle of common iliac α(deg)		Diameter of Distal aorta	θ		
Case	R	L	R	L	R	L	R	L	D_A(cm)	(deg)	Age	Cause of death
F-1	5.5	4	0.9	1	2	3	15	36	1.4	20	86	Unknown
F-2	3.4	5.6	0.7	0.9	7.7	9	27	0	1.3	53	98	MI
F-3	6.5	7	0.9	0.7	7	3.5	10	26	1.5	12	85	Stroke
F-4	6	6.5	0.78	0.8	α	5.5	14	35	1.37	12	85	Ca Colon
F-5	1.5	3.5	0.79	0.65	5.5	7.5	24	27	1.2	19	82	BA

Ca = carcinoma. MI = myocardial infarction. BA = Bronchial asthma.

Table 2 - Aortic-common iliac geometric values (males)

	Length of Common iliac L(cm)		Diameter of iliac at bifurcation D (cm)		Radius of curvature A. I Junction (cm)		Take off angle of common iliac α(deg)		Diameter of Distal aorta	θ		
Case	R	L	R	L	R	L	R	L	D_A(cm)	(deg)	Age	Cause of death
M-1	7.5	6.5	1.2	1.4	7	9	20	15	2.1	20	74	MI
M-2	3.2	6.5	1.15	0.96	2.1	1.2	35	23	1.21	20	81	Stroke
M-3	8	6	1.1	1.1	8	5	12	11	1.9	25	95	Ca oesophagus
M-4	4.3	5.1	0.9	0.91	4	3.5	15	16	1.7	22	64	BA
M-5	4	4.5	1.2	0.9	6	1.9	9	6	1.8	28	72	Ca stomach
M-6	9.5	8	0.95	1	13.5	5.5	9	8	1.55	21	76	MI

Ca = carcinoma. MI= myocardial infarction. BA = Bronchial asthma.

Table 3 - Average aorto-common iliac geometric values
The standard deviation is shown in parentheses

	α_L (deg)	α_L (deg)	K_R (1/cm)	R_R (cm)	K_L (1/cm)	R_L (cm)	θ (deg)
Female	7.18 (18)	14.58 (24.8)	0.19 (0.18)	α	0.0958 (0.20)	5.7	23.2 (17.07)
Male	16.67 (9.89)	13.16 (6.17)	0.205 (0.146)	6.76	0.35 (0.2725)	4.35	22.67 (3.2)

Our results show differences of angle at the bifurcation and radii of curvature of imaginary osculating circles. If the average velocity of the blood flow is the same in both iliac arteries, then the difference in radii of curvature will result in varying centripetal acceleration in each of them. This in turn will affect the amount of secondary flow and shear stress in the corresponding artery.

The significance of the angle in relation to atherogenesis is not clear and has not been studied haemodynamically. However, it does give the idea of the plane of aortic-iliac bifurcation, and will no doubt alter the plane of symmetry of these and any other flow patterns. Relatively weaker secondary flows may also be produced due to this curvature effect. Our series point out that there are significant geometric differences between the two common iliac arteries at the aortic bifurcation which must alter local haemodynamics and hence the predilection of atherogenesis to certain sites. These are especially severe in males owing to the greater differences in male pelvic geometry as compared to females. Finally, our recommendation is that proper assessment of the haemodynamics requires a much higher precision measurement of the local geometry than that derived from casual observation of the bilateral asymmetry and the sex differences.

References

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