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A CROSS-SECTIONAL STUDY OF ABDOMINAL AORTIC BIFURCATION & ITS GEOMETRIC ANATOMY

Anatomy

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ABSTRACT

Background: A detailed knowledge of the topography of abdominal aortic bifurcation is necessary for surgeons to minimize vascular injury. In addition, the geometric anatomy & associated haemodynamic forces affect the atherogenicity & development of aortoiliac occlusive disease. The abdominal aortic bifurcation & its geometric anatomy was studied in 12 cadavers in South Indian population in the current study as information in Asian population about these parameters is limited. **Methodology:** Abdominal aortae & their bifurcations were carefully exposed to note various parameters which were measured using a protractor, rulers & digital vernier callipers. **Results:** Abdominal aorta bifurcated at body of L4 in 33.33% cases, mean bifurcation angle was 55.8 ± 10.5°. The mean values of angle of aortoiliac planarity & laterality were 23.25 ± 8.96° & 11.88 ± 4.24° respectively. **Conclusion:** Knowing the anatomy of aortic bifurcation & common iliac arteries is extremely important for various procedures like interbody fusion surgery, laparoscopic lumbar dissectomy & abdominal aortic aneurysm. This knowledge is also useful for kissing stent reconstruction, an intervention for aortoiliac disease. It will also benefit the conduct of haemodynamic studies to study the etiology of atherogenesis.

KEYWORDS

Abdominal aorta; Bifurcation; Planarity; Laterality

Introduction

It is difficult to determine the exact prevalence of aortoiliac occlusive and peripheral artery disease because many patients are asymptomatic. For the general population, these estimates have been found out to range between 3.56 – 14%, slightly higher for people aged >70 years (14 – 20%) & about 23% for those >80 years (Kimyaghalam et al., 2024). Geometry of the arteries at or near its bifurcation is an important factor for developing or affecting atherogenesis as it can influence the blood flow fields. So, everyone's unique arterial geometry might influence that person's risk of developing arterial diseases (Fisher & Fieman, 1990). Tissue response to changes in mechanical environment can be mediated by changes in geometry (radius, thickness). Thus, mechanobiological interaction could be a key factor for atherosclerosis development (Humphrey & Schwartz, 2021). In addition, anatomy of aortic bifurcation (AB) & common iliac arteries (CIAs) is useful for surgeries related to spinal problems like segmental lordosis, spondylolisthesis, foraminal stenosis & invasive procedures like lumbosacral total disc arthroplasty. Its knowledge is very useful for cardiovascular diseases like aortic stenosis and calcified atherosclerosis of bifurcation region & external beam radiotherapy preferred for treatment of carcinoma cervix (Ekingen and Çetinçakmak, 2022). There are limited studies pertaining to the geometric anatomy of aortic bifurcation among the Asian population. Hence, the current study's objevtives were to determine the vertebral level & geometric anatomy of abdominal aortic bifurcation in South Indian population.

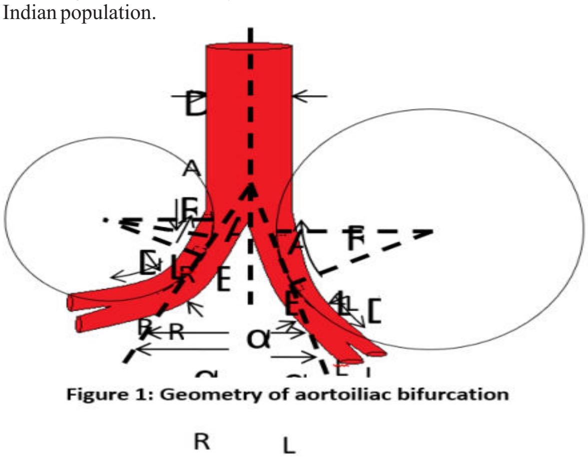

Figure 1: Geometry Of Aortoiliac Bifurcation

MATERIALS & METHODS

A cross-sectional study was done over a period of 2 months (July to August 2023) on 12 cadavers in Department of Anatomy by convenient sampling method. Cadavers with undissected posterior abdominal wall were included for the study. Cases of lumbarisation or sacralisation of vertebrae, grossly visible aneurysms of abdominal aorta were excluded from the study. After meticulous dissection of the abdomen & removal of abdominal viscera, peritoneum & fibrofatty tissue, terminal part of abdominal aorta & its bifurcation was properly exposed in the posterior abdominal wall. Vertebrae were counted from the sacrum & 4 planes of vertebra were considered for determining the level of bifurcation: lower border of body, middle of body, upper border of body & intervertebral disc level. For assessing the geometric parameters, certain techniques were used. A digital vernier calliper, two transparent rulers in centimetres, a transparent protractor along with guide wires were used to measure the following parameters (shown in Figure 1): angle of abdominal aortic bifurcation (α), take-off angle of right & left iliac arteries at the bifurcation (α_R & α_L), angle between abdominal aorta and common iliac arteries (β_R & β_L), bifurcation asymmetry (BA), radius of curvature of right & left aortoiliac osculating circles at bifurcation (R_R & R_L), diameter of abdominal aorta (D_A), diameter of both common iliac arteries (D_R & D_L), length of both common iliac arteries (L_R & L_L), angle of aorto-iliac planarity (θ), angle of aortic laterality (Ψ). For measuring the above angles, a midline was drawn using guide wires along the distal aorta and the common iliac arteries till they met the aortic centreline. Abdominal aortic bifurcation angle & take-off angles were directly measured using a protractor [Figure 2(a)]. For calculating the bifurcation asymmetry, two more angles were considered. The angles between one iliac artery & aorta were designated as β_1 & β_2 for right & left sides respectively. Bifurcation asymmetry was determined using the formula: $[\beta_1 - \beta_2]/\beta_1 + \beta_2$. Interpretation of the formula is that if the angle asymmetry is zero, the right & left aortoiliac angles are equal. Radius of curvature was determined by selecting two imaginary points A & B on each of the imaginary curves at both iliac arteries near the bifurcation. Two transparent rulers were then placed at tangents of the circle at points A & B. Radius of curvature was measured as the distance from the tube arc centre line to the intersection of the two rulers [Figure 2(b)]. The length of both common iliac arteries was measured using inside callipers in the segment between the aorta & the common iliac bifurcation. All the lengths were taken at 3 different levels & their average was considered as the final value. The diameters of the aorta (D_A) & both common iliac arteries (D_R & D_L) were measured using outside callipers. The angle formed by terminal aortic axis and plane of proximal iliac arteries is known as aortoiliac planarity

(θ). For measuring this, two rulers were used. One was aligned parallel to aortic longitudinal axis, other was kept in the median plane tangent to both common iliac arteries & the angle between them was measured by a protractor [Figure 2(c)]. The angle of laterality (Ψ) was measured by calculating the difference between 2 axes – one midline vertebral axis & the long axis of abdominal aorta using a protractor [Figure 2(d)]. Readings were taken by 2 different investigators & their average was considered as the final reading to minimize error.

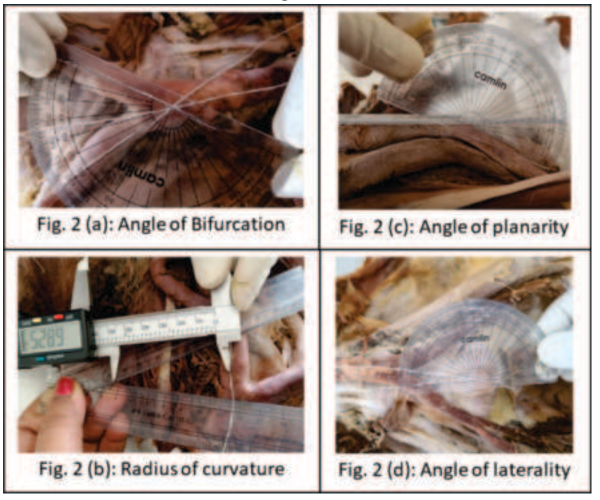

Fig. 2 (a): Angle of Bifurcation

Fig. 2 (c): Angle of planarity

Fig. 2 (b): Radius of curvature

Fig. 2 (d): Angle of laterality

Figure 2: Measurements Of Various Parameters

RESULTS

Measurements were obtained in 12 cadavers (9 male & 3 female). AB was seen at the level of body of L4 (33.33%, most common) & upper border of L4 (25%, 2nd most common). The details of other parameters are given in Table 1.

Table 1: Mean Values Of Different Parameters

Sr. No.	Parameter	Mean value	
1.	Angle of aortic bifurcation (α)	55.83 ± 10.59°	
2.	Bifurcation asymmetry (BA)	0.03 ± 0.01 cm	
3.	Diameter of abdominal aorta (D_A)	1.74 ± 1.23 cm	
4.	Angle of aortoiliac planarity (θ)	23.25 ± 8.96°	
5.	Angle of aortic laterality (Ψ)	11.88 ± 4.24°	
		Right side	Left side
6.	Take of angle (α_R & α_L)	29.5 ± 7.51°	26.29 ± 4.96°
7.	Radius of curvature (R_R & R_L)	5.96±1.36cm	6.20±1.43 cm
8.	Diameter of CIA (D_R & D_L)	14.78±1.23cm	14.05±1.17cm
9.	Length of CIA (L_R & L_L)	4.70±1.28cm	5.16±0.94cm

DISCUSSION

The most studied parameters of abdominal aortic bifurcation are its level & angle of bifurcation. Knowledge of the level of its bifurcation & the prevertebral vascular anatomy is important for any surgical procedures done in this region (Deswal et al., 2014). In a study done by Lalitha (2022), in 37.73% cases, AA bifurcated at lower border of L4 & 35.84% at its upper border. Lee et al. (2004) performed an MRI study to evaluate the anatomic significance of abdominal aortic bifurcation with majority (45%) of patients showing bifurcation at upper half of L4. The level of bifurcation is said to vary with age & gender. Abdominal aortic bifurcation slightly shifts caudally with age Kiran et al., 2024. Comparison of various parameters of our study with other studies is given in Table 2.

Table 2: Comparison Of Various Parameters Of Current Study With Other Studies

Sr. No.	Study	Population	Level of bifurcation	α	α_R	α_L	BA (in cm)
1.	(Ogeng'o et al., 2010)	Kenyan	Lower border of L4 (38.7%)	55.2°	-	-	4.4
2.	(Shakeri et al., 2007)	American	-	44.30 ± 14.77°	-	-	3.78 ± 3.51
3.	(Deswal et al., 2014)	Sikkim	L4 (64%)	50.16 ± 8.64°	27.24 ± 7.65°	22.92 ± 7.01°	-
4.	(Bargeron et al., 1985)	-	-	35.0 ± 11.1°	18.6 ± 11.0°	16.4 ± 11.7°	2.2 ± 19.8
5.	Current study	South Indian	Body of L4 (33.33 %)	55.83 ± 10.59°	29.5 ± 7.51°	26.29 ± 4.96°	0.03 ± 0.01

The aortoiliac bifurcation angle serves as an independent risk factor for the development of atherosclerosis (Shakeri et al., 2007). The mean bifurcation angle also varies with age & gender (Lalitha, 2022). Higher angles are more susceptible for development of atherosclerotic diseases. A smaller bifurcation angle & lower planarity angle is seen in older population. Whites are reported to have a lower bifurcation angle than Asians at a given age (Sun et al., 1994).

The minimalistic value of BA in the present study can be because of less sample size. Shah et al. (1978) performed a study on geometry of aortic bifurcation and found the mean value of R_R to be 2.9 cm in both males & females, R_L as 3.9 cm in females & 6.3 cm in males. They stated that radius of curvature plays an important role in regulating the amount of secondary flow & shear stress in the artery. This is because if the blood flow average velocity is same in both iliac arteries, then the difference in radius of curvature results in varying centripetal acceleration in each of the artery thereby affecting flow & shear stress. In the study done by Deswal et al. (2014), the diameters of AA, right & left CIAs were 16.06 ± 2.4mm; 9.91 ± 1.86mm & 9.22 ± 2.44mm respectively. Kronek and Žitný (2015) in their study found the average D_A to be 13.88 ± 4.5mm, and mean diameter of CIAs to be 8.7 ± 3.8cm. In the study by Shah et al. (1978), mean values of D_A, D_R & D_L were 2.02 cm, 2.3 cm, & 0.7 cm. (Friedman and Ding, 1998) studied the variability of planarity of human aortic bifurcation & found the mean angle of planarity to be 0.899 ± 0.062°. The angle of planarity probably alters the plane of symmetry & flow patterns but needs to be evaluated haemodynamically Shah et al. (1978). They found out the mean angle of laterality to be 10 ± 10° & 8 ± 6° in males & females respectively, & that the radius of curvature for iliac arteries is directly affected by the angle of laterality. The variability in vascular anatomy & the relationship between AA & CIAs with lumbosacral spine according to age may be contributed by spondylosis, loss of disc height, lengthening & winding of abdominal aorta (Pirró et al., 2005).

CONCLUSION

The aortic bifurcation level & iliocaval junction presents a major limitation to extensive exposure in this region as transperitoneal laparoscopic approach in surgeries related to lumbosacral spinal region & pelvic floor diseases has become extremely common (Pirró et al., 2005). Geometry induced haemodynamic alterations may lead to abnormal vascular remodelling which can further predispose to aneurysms (Tanweer et al., 2014). In addition, further detailed assessment of haemodynamic studies related to abdominal aortic bifurcation & its geometry is required which will clarify a person's risk of developing arterial disease.

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