Original Research Article

A Study of Abdominal Aorta and its Unpaired Branches in Cadavers

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ABSTRACT:

Introduction - Abdominal aorta structurally is a large elastic artery which conducts blood from the heart to the medium-sized arteries distributing blood to abdominal organs and lower limbs. Abdominal aorta is prone to atherosclerosis and aneurismal dilatation. It is also prone to developing dissecting aneurysm. Many of these conditions are treated by interventional radiologists and vascular surgeons who need to have a thorough knowledge of anatomy of abdominal aorta and its variations. Hence this study was undertaken to provide some metric data pertaining to abdominal aorta and also to highlight variant anatomy.

Materials and Methods - Abdominal aortae of 60 cadavers which were embalmed using 10% formalin were used for this study. The study technique consisted of meticulous dissection, observation and measurement of various parameters.

Observation and Results - The variations in the origin, course, branching pattern, vertebral level, internal diameter and measurement of the distance between the branches of abdominal aorta and its termination were studied and recorded.

Conclusion - Abdominal aorta is an important arterial conduit during aortography, selective arterial catheterization, cardiac catheterization, coronary angiography, angiocardiography and interpositional vascular graft; so it is of paramount importance to know the accurate topographical anatomy of abdominal aorta and its branches. Knowledge of the vascular variations is a must and it contributes largely in the prevention of misdiagnosis and procedure-related complications.

Keywords: abdominal aorta, aortic opening of diaphragm, coeliac trunk, superior mesenteric artery, inferior mesenteric artery, bifurcation of aorta, right and left common iliac artery.

Introduction:

Abdominal aorta is an important conduit supplying blood to the lower half of the body i.e. the walls of the abdomen, all the abdominal organs including the kidneys and the gonads and the lower limbs.[1] Occlusion of abdominal aorta or its branches may occur acutely due to dissection or thrombo-embolism or may occur chronically due to fibromuscular dysplasia or atherosclerosis or external compression by mass lesions. Aneurysms are abnormal dilatations of the artery where the diameter of the artery increases by ≥ 50% compared to normal segments. Aneurysms occur when there is a localized weakening of the arterial wall which may be due to atherosclerosis, hypertension, hereditary or acquired connective tissue disorders.[2] Abdominal aortic aneurysm is one of the commonest arterial aneurysms though aneurysmal dilatation of its splanchnic branches is not that common. Aortic dissection occurs due to a tear in the intima of the aorta through which blood under

high pressure passes separating the intima from the media.[3] Many of these conditions are diagnosed and treated by interventional radiologists and absolute knowledge of anatomy of aorta and its branches is mandatory for them.

The abdominal aorta is the final section of the aorta, the largest artery in the body. This median vessel begins as a continuation of descending thoracic aorta at the aortic opening in the diaphragm, opposite the lower border of the twelfth thoracic vertebra and thoracolumbar intervertebral disc. It then passes downwards in front of the vertebral column to end at the lower border of fourth lumbar vertebra, a little to the left of the midline, by dividing into two common iliac arteries.[4] Branches of the abdominal aorta may be grouped into: A. Unpaired visceral branches like Coeliac trunk, Superior mesenteric artery and Inferior mesenteric artery. B. Paired visceral branches like Middle suprarenal arteries, Renal arteries and Gonadal arteries. C. Parietal branches like Inferior phrenic arteries, Lumbar arteries and D. Terminal branches like Median sacral artery and Common iliac arteries.[5] Knowledge about abdominal aorta is indispensable to the anatomists, interventional radiologists, cardiologists, general surgeons and vascular surgeons; yet there is not enough literature pertaining to the anatomy of abdominal aorta in Indian subjects.

Hence, this study was undertaken with the following aims and objectives**:**

Aims and Objectives:

a) To know the variations in the vertebral level and internal diameter of aortic opening of diaphragm, coeliac trunk, superior mesenteric artery, inferior mesenteric artery, bifurcation of abdominal aorta and right and left common iliac arteries at their origin b) to measure the distance between sites of origin of ventral splanchnic branches of abdominal aorta. c) to measure the total length of abdominal aorta and the length of the stem of the inferior mesenteric artery d) to correlate these findings with the different clinical conditions pertaining to the abdominal aorta in the diagnosis and treatment.

Materials and Methods

Abdominal aortae of 60 cadavers which were embalmed using 10 % formalin were used for this study. Of these 60 cadavers 53 were males and 7 were females. Cadavers were dissected meticulously to expose the abdominal aorta from the aortic opening of diaphragm to its bifurcation.

Internal diameter of abdominal aorta at the aortic opening of diaphragm was measured in two axes, transverse and vertical. Coeliac trunk, superior mesenteric artery, interior mesenteric artery were cut flush at their origin and their internal diameters were measured in two axes. A ‘V’ cut was made at the bifurcation of the aorta and the internal diameters of the right and the left common iliac arteries at their origin were measured in two axes with the help of divider and measuring scale. Then the aorta was cut transversely at the bifurcation and the internal diameter of the aorta at the bifurcation was measured in two axes.

Pins were inserted through the apex of aortic opening of diaphragm, through the centre of origin of coeliac trunk, superior mesenteric, interior mesenteric arteries and at the site of bifurcation of aorta. Then the distance between all the pins were measured and recorded with the help of divider and measuring scale. The total length of the abdominal aorta from the aortic opening to its bifurcation was measured with the help of a thread and a scale.

The vertebral levels of the aortic opening of diaphragm, aortic bifurcation, origin of coeliac trunk, superior mesenteric artery, and inferior mesenteric artery were recorded as opposite the upper, middle or lower third of certain vertebral body or intervertebral disc. For the purpose of mathematical measurement, length of one

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intervertebral disc was considered as equal to 1/3rd of the length of the vertebral body. Thus the class intervals were all considered to be of equal size.

Observation and Results

The mean vertebral level of aortic opening of diaphragm was found at lower third of the eleventh thoracic vertebra (Class interval = 4.5), origin of coeliac trunk at lower third of twelfth thoracic vertebra (Class interval = 8.5), origin of superior mesenteric artery at upper third of the first lumbar vertebra (Class interval =10.5), origin of inferior mesenteric artery at middle third of the third lumbar vertebra (Class interval =19.5) and bifurcation of abdominal aorta at middle third of the fourth lumbar vertebra (Class interval =22.5). **(TABLE - 1) (Fig.1)**

The mean internal diameter of abdominal aorta at the level of the aortic opening of diaphragm was found to be 1.32 cm, of coeliac trunk at its origin 0.5 cm, of superior mesenteric artery at its origin 0.65 cm, of inferior mesenteric artery at its origin 0.22 cm, of abdominal aorta just before its bifurcation 1.02 cm, right common iliac artery at its origin 0.75 cm and of left common iliac artery at its origin 0.7 cm. **(TABLE - 2) (Fig. 2)**

The mean distance between the apex of aortic opening of diaphragm and site of origin of coeliac trunk was found to be 2.91 cm, between site of origin of coeliac trunk and site of origin of superior mesenteric artery 1.37 cm, between site of origin of superior mesenteric artery and site of origin of inferior mesenteric artery 5.42 cm, between site of origin of inferior mesenteric artery and site of bifurcation of aorta 3.12 cm.

(TABLE – 3) (Fig. 3)

The mean length of abdominal aorta was found to be 12.8 cm and the mean length of the stem of inferior mesenteric artery was 3.31 cm.

Discussion

The word “aorta” is a Greek word describing the large artery from which heart hangs.[2] Aristotle distinguished the thick, firm tendinous structure of the aorta from the thin membranous structure of the vein.[6] Arteries are important conducting channels and distribution of these is like a highly ramified tree, aorta being the central trunk which branches and re-branches and becomes progressively smaller in its peripheral course.[7,8]

Awareness regarding anomalous vascular patterns at the site of interventional procedures is always of clinical significance.[9] Atherosclerosis is more severe in abdominal aorta and iliac arteries due to the wave reflection and this heightened blood pressure enhances the onset of fatigue in vessel wall. While the exact etiology of abdominal aortic aneurysm is unknown, clinical features imply a systemic connective tissue disorder with familial tendencies. The lack of vasa vasorum has also been attributed to the formation of atherosclerotic changes in the abdominal aorta more commonly than in the thoracic aorta.[2] Dissecting aneurysm is formed by a split in the coat of the aorta where vasa vasorum fail in their function due to hypoxia.[3] Aortography should always precede selective arterial catheterization.[10]

The distance between the coeliac trunk and the superior mesenteric artery is very minimal and sometimes both of them arise from the common trunk, hence during the selective arterial catheterization of superior mesenteric artery, using the antegrade approach, one may pass the catheter into the orifice of the coeliac trunk which lies just cranial to it. To overcome such difficulties interventional radiologist should be aware of the exact vertebral level of origin of the vessel, the distance between the branches and variation if any in these parameters. George R (1934) in its study of 120 cadavers found the mean vertebral level of the origin of coeliac artery was at the upper edge of the first lumbar vertebra (Class interval = 5.5 with SD (σ) = 1.59), superior mesenteric artery at the junction of the middle and the lower third of the first lumbar vertebra (Class interval = 7.6 with SD (σ) = 1.39), inferior mesenteric artery opposite the middle of the third lumbar vertebra

(Class interval = 15.1 with SD (σ) = 1.53), bifurcation of aorta opposite the lower third of the fourth lumbar vertebra (Class interval = 19.8 with SD (σ) = 1.64) .[11] Anson and Mcvay (1936) in their study of 100 consecutive cadavers had recorded the position of the abdominal aortic branches and of the aortic bifurcation in relation to the upper, middle and lower thirds of the vertebrae.[12] Cavdar, Sehirli and Pekin (1997) during the dissection of a 54 year male cadaver had found the aortic opening of diaphragm to be located at the level of L_1.[13] Pennington and Soames (2005) in their study of 15 embalmed cadavers found the mean level of bifurcation of aorta was at the lower third of the body of L_4 with the coeliac, superior mesenteric and inferior mesenteric arteries arising at the level of the T_{12}/L_1 intervertebral disc, upper third of the body of L_1 and lower third of the body of L_3, respectively.[14] In our study recorded vertebral levels of origin of various ventral branches of abdominal aorta are shown in **Table 1.**

The diameter of abdominal aorta and its branches is the single most important determinant in the decision to repair an abdominal aortic aneurysm.[15] Dotter and Steinberg (1949) had visualized the human normal aortas angiocardiographically.[16] Steinberg I, Archer M, Steinberg CR (1965) had measured the abdominal aortic diameters at 4 sites: 1) at 11th rib because at this region thoracic aorta pierces the diaphragm to enter the abdomen 2) above the renal arteries, an area which is almost ½ of the length of the abdominal aorta 3) below the renal arteries, chosen because occlusive and aneurysmal atherosclerotic disease frequently originates at this site and 4) at the bifurcation of aorta, a predominant site of atherosclerosis.[17] Pennington and Soames (2005) measured the external and internal diameter of the branches of aorta in a plane perpendicular to the longitudinal axis of the vessel as close to its origin as possible using Mitutoyo calipers.[14] According to Songür A et al. diameters of celiac trunk (CT), superior mesenteric artery (SMA) and inferior mesenteric artery (IMA) were 6.43±1.59 mm, 7.38±1.67 mm and 3.61±0.72 mm respectively.[18] In a paper by JH Joh et al, the reference diameter of infrarenal segment of abdominal aorta in Korean population is 1.9 cms for males and 1.79 cm for females. The same authors have also mentioned that the diameter of aorta increases with age.[21] The internal diameter of abdominal aorta in our study is shown in **TABLE 2.**

George R (1934) found the mean distance between coeliac artery and superior mesenteric artery 1.6 cm with SD(σ) = 0.50, between superior mesenteric and inferior mesenteric artery 7.1 cm with SD (σ) = 1.21, between inferior mesenteric artery and the bifurcation of aorta 4.6 cm with SD (σ) = 1.02.[11] Anson and Mcvay (1936) had found out the distance between the site of origin of abdominal aortic branches from the site of bifurcation and also measured the distance between the sites of origin of adjacent visceral branches.[12] Feller, Woodburn (1961)[19] and Yahel, Arensburg (1998)[20] had measured the distance between the origin of the aortic branches from the aortic bifurcation. Pennington and Soames (2005) had measured the distance of the aortic branches from the midpoint of T_{12}.[14] The distance between adjacent aortic branches in our study is shown in **TABLE 3.**

George R (1934) had measured the length of the stem of inferior mesenteric artery and found it to be ranging from 1.5 to 9.0 cm, with the mean length of 3.8 cm.[12] In our study, the mean length of the stem of inferior mesenteric artery was 3.3 cm with a range of 1.5 to 5.2 cm. George R (1934) had measured the total length of the abdominal aorta as the sum of the distance between the four selected points from the origin of the coeliac artery to the aortic bifurcation.[12] Pennington and Soames (2005) measured it from the midpoint of the 12th thoracic vertebra to the aortic bifurcation.[15] Mean total length of the abdominal aorta in our study was 12.8 cm with a range of 8.4 cm to 17.2 cm.

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Conclusion

While approaching the abdominal aorta, clinicians ought to know the accurate topographical anatomy of abdominal aorta and its branches and the variations. It is necessary for the clinicians to continue the investigation in the pathogenesis of obstructive and aneurysmal aortic lesions and to review the anatomy, physiology and physical factors of vascular tree with a new perspective.

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Table 1 - Frequency Distribution of Vertebral Levels of Aortic Opening of Diaphragm, Origin of Splanchnic Branches of Aorta and Bifurcation of Aorta

Class Interval showing vertebral level	Aortic opening of the diaphragm (No.of specimens)	Origin of Coeliac Trunk (No.of specimens)	Origin of Superior Mesenteric Artery (No. of specimens)	Origin of Inferior Mesenteric Artery (No. of specimens)	Bifurcation of Aorta (No.of specimens)
Intervertebral disc between T10 and T11	03				
Upper 1/3rd of T11	08				
Middle 1/3rd of T11	06				
Lower 1/3rd of T11	16				
Intervertebral disc between T11 and T12	05	01			
Upper 1/3rd of T12	12	03			
Middle 1/3rd of T12	06	07			
Lower 1/3rd of T12	04	18	01		
Intervertebral disc between T12and L1		14	06		
Upper 1/3rd of L1		12	22		
Middle 1/3rd of L1		02	14		
Lower 1/3rd of L1		03	11		
Intervertebral disc between L1 and L2			06		
Upper 1/3rd of L2					
Middle 1/3rd of L2					
Lower 1/3rd of L2					
Intervertebral disc between L2 and L3				05	
Upper 1/3rd of L3				11	
Middle 1/3rd of L3				26	
Lower 1/3rd of L3				11	

Intervertebral disc between L3 and L4				05	03
Upper 1/3rd of L4				02	15
Middle 1/3rd of L4					27
Lower 1/3rd of L4					12
Intervertebral disc between L4 and L5					03

TABLE-2: Internal diameter of Aorta and its Splanchnic Branches

Sr. no	Parameters	Mean (cm)	SD (σ)	Range (cm)
1.	Abdominal aorta at the level of aortic opening of diaphragm	1.32	0.24	0.9 – 1.85
2.	Coeliac trunk at its origin	0.5	0.09	0.4 – 0.75
3	Superior mesenteric artery at its origin	0.65	0.1	0.4 – 0.85
4.	Inferior mesenteric artery at its origin	0.22	0.06	0.1 – 0.35
5.	Abdominal aorta just before its bifurcation.	1.02	0.16	0.75 –1.45
6.	Right common iliac artery at its origin	0.75	0.06	0.65 –0.85
7.	Left common iliac artery at its origin.	0.7	0.05	0.65 –0.85

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TABLE-3: Distance between the Origins of Ventral Branches of Abdominal Aorta

Sr no	Parameters	Mean (cm)	SD (σ)	Range (cm)
1.	Apex of aortic opening of diaphragm & site of origin of coeliac trunk.	2.91	0.66	1.5 – 4.4
2.	Site of origin of coeliac trunk & site of origin of superior mesenteric artery.	1.37	0.37	0.8 – 3.0
3.	Site of origin of superior mesenteric& site of origin of inferior mesenteric artery	5.42	1.24	2.6 – 8.5
4.	Site of origin of inferior mesenteric artery & site of bifurcation of abdominal aorta	3.12	0.83	1.6 – 4.7

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Fig.1: Illustration showing the vertebral level of the bifurcation of abdominal aorta (Red arrow)

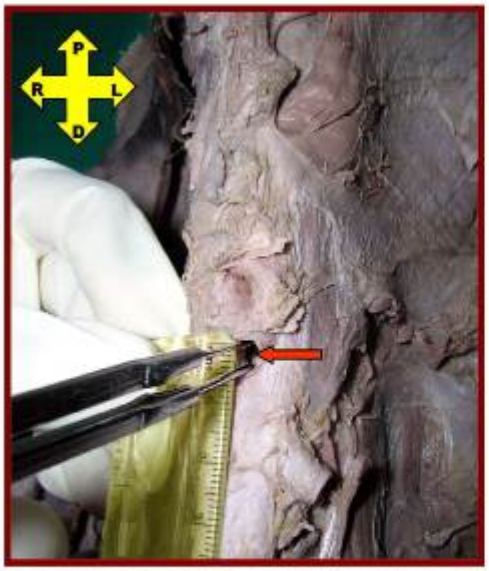

Fig.2: Illustration showing the measurement of diameter of superior mesenteric artery at its origin (Red arrow)

Fig.3 Illustration showing the measurement internal of distance between the site of origin of superior mesenteric artery (Red arrow) and the site of origin of inferior mesenteric artery (White arrow)

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