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Original Research Article

ANATOMICAL STUDY OF ABDOMINAL AORTA AND ITS BRANCHES FOR MULTIPLE VARIATIONS

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ABSTRACT

Introduction: Abdominal aorta and its major branches supply oxygenated blood to all the organs in abdominal cavity and lower limbs. Striking variations in the origin and course of the principal branches of abdominal aorta have received the attention of the anatomists and surgeons from long periods. Accurate knowledge of the relationship and course of these arterial conduits and particularly of their variation patterns is of considerable practical importance during laparoscopic and various other surgical procedures.

Aim: This study was conducted to find out normal pattern and variations of abdominal aorta and its different branches.

Materials and Methods: The variations in the branching pattern of abdominal aorta were studied with meticulous dissection and observation, on total 40 adult cadavers (21 males & 19 females), over the period of two years. Variations of various branches of abdominal aorta were noted.

Results: We found absent celiac trunk in 5%, instead of common celiac trunk there were two trunks gastrosplenic and hepatic. Origin of inferior phrenic artery was from celiac trunk in 35% cadavers. Accessory renal arteries were found in 27.5%. Gonadal arteries were originating from renal arteries in 5% cadavers.

Conclusion: These arterial variations should not be ignored during the abdominal operative procedures, because many of the complications would be avoided with the precise knowledge of these anatomical variations.

KEY WORDS: Abdominal aorta, Celiac trunk, Inferior phrenic artery, Accessory renal artery, Gonadal arteries, Superior mesenteric artery, Inferior mesenteric artery, Hepatic artery, Lumbar artery, Aortic Bifurcation.

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INTRODUCTION

Aorta enters the abdomen via the aortic hiatus in the diaphragm at the level of the 12th thoracic vertebra and ends at 4th lumbar vertebra in the transcristal plane. Abdominal aorta and its major branches supply oxygenated blood to all the organs in abdominal cavity and lower limbs. Ventral branches of abdominal aorta supply the gastrointestinal tract. Three lateral paired branches passing to viscera supply suprarenal glands, kidneys and gonads. Paired branches supplying the parieties, are Inferior phrenic & four lumbar arteries. Terminal branches of abdominal aorta are the right and left common iliac arteries [1].

Striking variations in the origin and course of

the principal branches of abdominal aorta have received the attention of the anatomists and surgeons from long periods. Accurate knowledge of the relationship and course of these arterial conduits and particularly of their variation patterns is of considerable practical importance during laparoscopic and various other surgical procedures. The arteries that show frequent variations are the celiac trunk, the renal arteries and the gonadal arteries [2].

Variations of the branches of the celiac trunk were reported by many authors. While vascular anomalies are usually asymptomatic, they may become important in patients undergoing diagnostic angiography for gastrointestinal bleeding, celiac axis compression syndrome, or prior to an operative procedure or transcatheter therapy. Variations of the celiac trunk branches and their relationship to surrounding structures are, therefore of particular importance from a surgical perspective [3].

Knowledge of the variations of renal vascular anatomy has importance in exploration and treatment of renal trauma, renal transplantation, renal artery embolization, surgery for abdominal aortic aneurysm and conservative or radical renal surgery. Familiarity about the possible variations in the renal arterial pattern is especially important for the personnel dealing with various endourologic procedures and innumerable interventional techniques. In most of those situations, it is the comprehensive knowledge of the renal arterial pattern which remains the key issue in determining the technical feasibility of surgical interventions as well as the post operative management.

Awareness of variations of the testicular arteries becomes important during surgical procedures like varicocele and undescended testes. The variations in the origin, number and course of these arteries are of practical significance in clinical practice particularly for surgeons & radiologist. Angiographic images with abnormal vascular patterns may be incorrectly interpreted in the absence of knowledge of variation in pattern of origin of these vessels. Furthermore knowledge of origin and relationship of these vessels is important during abdominopelvic surgeries and renal transplantations [4].

Anatomical knowledge of the abdominal aorta and its branches is important not only to determines flow dynamics but also crucial in understanding pathogenesis of vascular diseases [5]. The knowledge of relationship between anterior visceral and renal arteries is important when undertaking diagnostic arteriography and endovascular interventions.

Hence, the detailed study was undertaken to find out the variations in the branches of abdominal aorta.

MATERIALS AND METHODS

The variations in the branching pattern of abdominal aorta were studied with meticulous dissection and observation, on total 40 adult cadavers (21 males and 19 females), over the period of two years. Embalmed cadavers were procured from department of anatomy, government medical college with prior permission. Cadavers with intra-abdominal pathology that was interfering with the dissection were excluded. Each cadaver was dissected according to guidelines of ¯Cunningham‘s manual of practical anatomy. Anterior abdominal wall was incised and musculocutaneous flaps were reflected laterally. Peritoneal cavity & the lesser sac were opened & branches of celiac trunk were identified. Then as dissection proceeded, different organs of abdomen were removed & simultaneously different branches of abdominal aorta were identified. The following observations were made and noted.

1. Length of the celiac trunk was measured with the help of a thread and measuring scale: between the point of origin of celiac trunk from the anterior surface of the abdominal aorta & the point where it divides into three branches, Common hepatic artery, Left gastric artery and Splenic artery.

2. The branches of celiac trunk were identified & variations were recorded.

3. Total length of abdominal aorta measured between aortic opening of diaphragm & bifurcation of aorta with the help of thread and measuring scale.

4. Number of ventral branches, number of lateral branches, number of dorsal branches &

number of terminal branches of abdominal aorta were recorded.

5. Vertebral level of origin of a) Celiac trunk, b) Superior mesenteric artery, c) Inferior mesenteric artery, d) renal artery, e) Gonadal artery & f) Bifurcation were recorded. At first origin of each artery was identified, then a two-inch nail was hammered into the vertebral column through the centre of the origin of each branch and also at the crotch marking the bifurcation of the abdominal aorta into the common iliac arteries. Care was taken to drive the nail in the transverse plane to avoid the error of an oblique insertion into the vertebral column. Distances between the four nails were measured using sliding callipers, measuring from the centre of one nail-head to the centre of the next nail-head. When the abdominal viscera were removed and the abdominal aorta stripped from the front of the vertebral column, the vertebral level of each nail was determined, and this level was recorded as opposite a specified intervertebral disc or the upper, middle or lower third level of a certain vertebral body.

6. Distances between aortic bifurcation & origins of the branches were measured with the help of thread and measuring scale.

7. Circumference of aorta at: a) aortic opening of diaphragm, b) just above bifurcation, & c) Midway between a & b was measured with the help of thread and measuring scale.

8. Angle of bifurcation of aorta measured with the help of protractor.

Fig. 1: Showing exposure of abdominal aorta for measuring various parameters of study.

Statistical methods used were frequency and percentage for qualitative data & chi-square test as test of significance. Mean, standard deviation, & significance of difference between two means of independent sample were calculated for Quantitative data & data was analyzed by unpaired t test as test of significance. A 'p' value of < 0.05 is considered statistically significant.

RESULTS

Table 1: Variations in the number of various branches of abdominal aorta.

	Ventral branches		Lateral visceral branches				Lumbar arteries	
			Rt		Lt			
	Three	Four	Three	Four	Three	Four	Four pairs	Five pairs
Males (21)	19 (90.48%)	2 (9.52%)	17 (80.9%)	4 (19%)	18 (85.7%)	3 (14.29%)	18 (85.7%)	3 (14.2%)
Females (19)	19 (100%)	0	16 (84.2%)	3 (15.7%)	17 (89.4%)	2 (10.53%)	16 (84.2%)	3 (15.7%)
Total (40)	38 (95%)	2 (5%)	33 (82.5%)	7 (17.5%)	35 (87.5%)	5 (12.50%)	34 (85%)	6 (15%)

Out of all the branches, variations were common with the number of lateral visceral branches especially on right side (17.5%), followed by lumbar arteries (15%). Number of ventral branches showed least variation (5%). Similar observations were seen when the incidence was compared between males and females.

Table 2: Types of variations in the origin of abdominal aortic branches.

S No	Type of variation	Male	Female	Total
1	Absent celiac trunk	2 (9.5%)	0	2 (5%)
2	Inferior phrenic artery from celiac trunk	10 (47.6%)	4 (21 %)	14 (35%)
3	Both Inferior phrenic arteries having a common stem rising from abdominal aorta	2 (9.5%)	0	2 (5%)
4	Accessory right renal artery	5 (23.8%)	1 (5.3%)	6 (15%)
5	Accessory left renal artery	2 (9.5%)	2 (10.5%)	4 (10%)
6	Accessory renal arteries on either side	1 (4.8%)	0	1 (2.5%)
7	Gonadal arteries arising from renal arteries	2 (9.5%)	0	2 (5%)

The most frequent variation observed was inferior phrenic arteries arising from celiac trunk (35%), followed by the occurrence of unilateral accessory renal arteries (10-15%). Least common was occurrence of bilateral accessory renal arteries (2.5%). Occurence of accessory right renal arteries was more frequent in males (23.8%) compared to females (5.3%).

Fig. 2: Origin of accessory hepatic artery from superior mesenteric artery

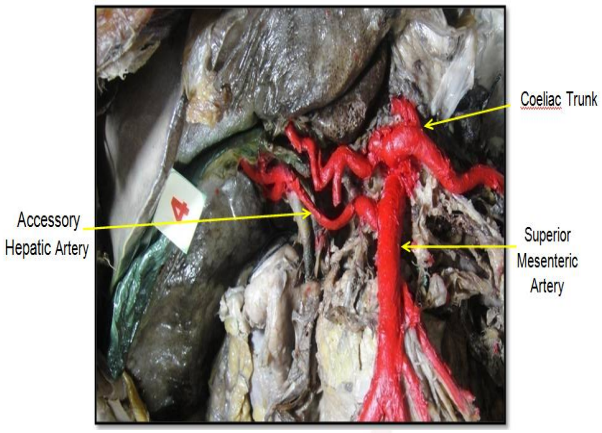


Fig. 3: Origin of accessory hepatic artery from superior mesenteric artery and from Lt. gastric artery.

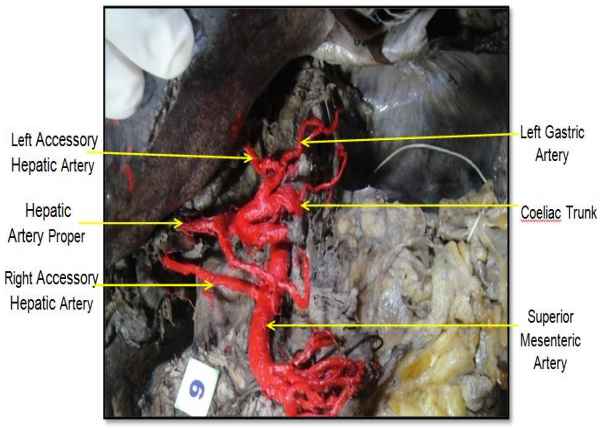


Fig. 4: Gastrosplenic and hepatic trunks.

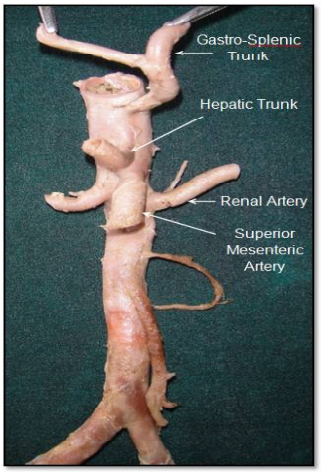


Fig. 5: Duplicate right renal arteries (white arrows).

Fig. 6: Duplicate left renal arteries (white arrows).

Fig. 7: Gonadal arteries arising from renal arteries. On left side one additional gonadal artery.

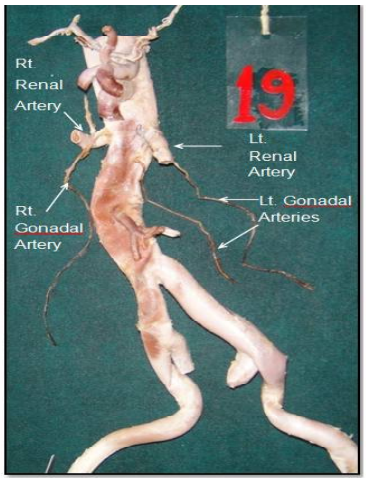


Fig. 8: Gonadal arteries arising from renal arteries.

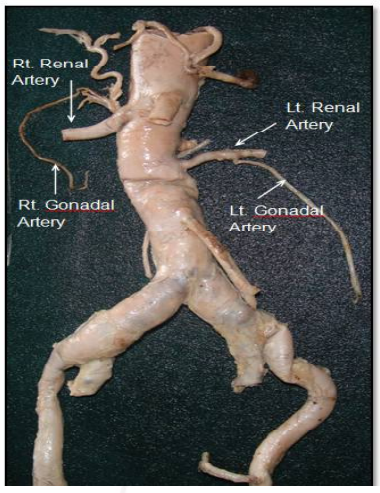
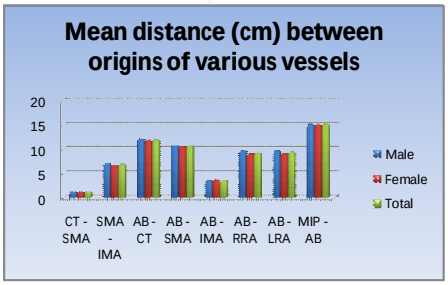


Fig. 9: Origin of both Inferior Phrenic Arteries (IPAs) from abdominal aorta as single root.

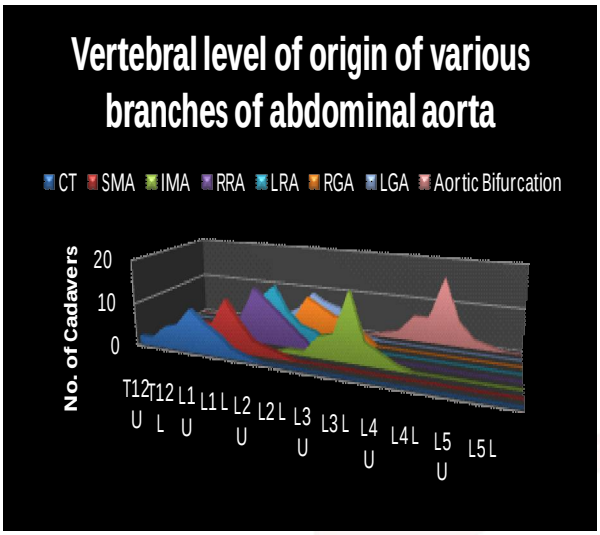
Graph 1: Mean distance (cm) between origins of various vessels.



CT- Celiac Trunk,
SMA- Superior Mesenteric Artery,
IMA-Inferior Mesenteric Artery,
AB-Aortic Bifurcation,
RRA- Right Renal Artery,
LRA- Left Renal Artery,
MIP- Mid Inguinal Point.

The mean distance between the origins of various vessels was constant regardless of the sex, there being no significant difference between males and females.

Graph 2: Vertebral level of origin of various branches of abdominal aorta.



CT- Celiac Trunk, SMA- Superior Mesenteric Artery, IMA- Inferior Mesenteric Artery, RRA- Right Renal Artery, LRA- Left Renal Artery, RGA- Right Gonadal Artery, LGA- Left Gonadal Artery, U- Upper 1/3, M- Middle 1/3, L- Lower 1/3.

The most common level of origin of celiac trunk was opposite the upper border of L1 vertebra. Superior mesenteric artery was seen to be arising most frequently opposite lower border of L1 vertebra. The inferior mesenteric artery commonly given at the level of lower border of L3 vertebra. Renal arteries were seen to be arising at the level of upper border (right renal artery) or middle (left renal artery) of L2 vertebra. Most of the gonadal arteries arose at the level of upper border of L3 vertebra. The most common level of bifurcation of abdominal aorta into common iliac arteries was at the level of upper border of L5 vertebra.

DISCUSSION

Every surgeon and radiologist must have precise knowledge regarding variations of abdominal aorta for diagnostic and/or surgical investigations. Ligation or damage of these arteries without knowing the possible variations during laparotomy, nephrectomy, renal transplantation, arterial reconstruction, laparoscopy and in other surgical applications may cause unpredictable complications, such as segmental or total visceral ischemia and failure[6]. Arterial variations should not be ignored during the abdominal operative procedures, because many of the complications would be avoided with the precise knowledge of the anatomical variations [7].

The mean length of the abdominal aorta was 13.2 cm, with standard deviation of 1.43 (Range being 11-17cm). The mean length of abdominal aorta was slightly less in females (13.2 cm) as compared to males (13.7 cm) the difference being statistically insignificant (p= 0.28). These findings are comparable to the studies by George, Cauldwell & Woodburne [11-13].

Most of the cadavers {38 i.e. (95%)} had three ventral branches & only few {2 i.e. (5%)} cadavers showed presence of four ventral branches. These two male cadavers had gastrosplenic trunk & hepatic trunk instead of a single coeliac trunk, arising directly and separately from aorta. The incidence of gastrosplenic trunk reported by Adachi [14] was 3%, Kimani Mburu [15] 4.9%.

33(82.5%) cadavers had three & 7 (17.5%) cadavers had four lateral visceral branches on right side & 35 (87.5%) cadavers had three & 5 (12.5%) cadavers had four lateral visceral branches on left side. The four lateral visceral branches were one middle suprarenal artery, two renal arteries & one gonadal artery. Out of two renal arteries on either side, one is main artery and other is accessory renal artery, which arose from the abdominal aorta either above or below the main renal artery and followed it to the hilum. It is important to be aware that accessory renal arteries are end arteries; therefore, if an accessory artery is damaged, the part of kidney supplied by it is likely to become ischaemic. No statistically significant difference was found in the incidence of fourth lateral branch (Accessory renal artery) on right/left side between males& females. According to Langman & Sadler [16], these accessory renal arteries with aortic origin represent persistent embryonic vessels during the renal ascent. Gonadal arteries were found to be originating from renal arteries in 2 (5%) cases. Out of these two, one is having duplication of left gonadal artery, one arising from aorta and second arising from left

renal artery. In the second cadaver, right gonadal artery after arising from the right renal artery, arched over right renal vein and then descends downwards. These findings are similar to the findings reported by Rusu [17], Naito [18], Nayak [19], Wadhwa [9] & Salve [20]. Considering that the incidence of a left arching testicular artery is higher than that of a right one, an arching left artery could be an additional cause of left renal vein (LRV) hypertension resulting in varicocele, orthostatic proteinuria and haematuria.

Variations in the origin of inferior phrenic artery were recorded in 16 (40%) cadavers. Origin of Inferior Phrenic Artery from coeliac trunk was recorded in 14 (35%) cadavers. Both Inferior Phrenic Arteries arise from abdominal aorta as single root in 2 (5%) cadavers. Pick and Anson [21] evaluated the largest series regarding the origin of the inferior phrenic artery. They reported the origin of this artery as follows: 47% from aorta, 40% from celiac trunk, 10.5% from right renal artery, 2% from left gastric artery and 0.5% from hepatic artery. The awareness of arterial variations, in relation to the renal, testicular, suprarenal and inferior phrenic arteries could be of paramount importance to the vascular surgeons and urologist and oncologist, during surgery in the retroperitoneal region. The knowledge of variations of vessels in the renal hilar region and retroperitoneal region may have significant contribution to the success of surgical, invasive and radiological procedures of this area.

Only 6 (15%) cadavers had five pairs of lumbar arteries. The incidence of five pairs of lumbar arteries was little less than that was seen in the study by Feller Woodburne [12], who studied 100 cadavers & found five pairs of lumbar arteries in 26% cadavers.

The most frequent vertebral level of origin of Coeliac Trunk was found at the upper third of the first lumbar vertebra similar to the studies by George [13], Cauldwell [11] & Woodburne [12]. However, Neil Pennington [5] reported the most common position being at the level of disc between T12 & L1. The most frequent vertebral level of origin of Superior Mesenteric Artery was at the upper 1/3 of the first lumbar vertebra similar to the studies by George [13] & Cauldwell [11]. However, Neil Pennington [5] reported the most common position being at the level of upper third of L1 while Adachi [14] reported opposite middle third of L1. The most frequent vertebral level of origin of Inferior Mesenteric Artery was found at the lower 1/3 of the third lumbar vertebra similar to the studies by Cauldwell [11], Woodburne [12] & Neil Pennington [5]. However, George [13] and Adachi [14] reported opposite middle third of L3.

Right renal artery was found to take origin between the upper 1/3 of the first lumbar to the disc between second & third lumbar vertebrae, the most frequent vertebral level, similar to Cauldwell [11], being at the disc between first & second lumbar vertebrae. Woodburne [12] found opposite L2 as the most common vertebral level of right renal artery. While the Left renal artery was most frequently found to be arising at the level of upper 1/3 of second lumbar vertebra similar to Cauldwell & Woodburne.

Gonadal arteries were seen most frequently arising opposite lower 1/3 of 2nd lumbar vertebra on either side.

Abdominal aorta was found to bifurcate opposite the disc between third & fourth lumbar vertebrae to the lower 1/3 of fifth lumbar vertebra, the most frequent being at the disc between fourth & fifth lumbar vertebrae, comparable to finding by Cauldwell [11]. However, George [13], Woodburne [12] & Neil Pennington [5] reported lower 1/3 of L4 as the most frequent level of bifurcation of the abdominal aorta.

The commonly found positional variations of the branches of aorta and aortic bifurcation can disturb the surgical exploration of lumbar vertebra of these areas and cause complications to the vessels. Therefore, a spinal surgeon should to be aware of these variations before the surgery. One must identify the variations before the operation in order to prevent the difficulty of surgery and the complications that may occur.

We also studied the distance between various major branches of the aorta. The celiac trunk (CT) and the superior mesenteric arteries (SMA) were, on an average, 1.29 cm apart. While the average distance between superior mesenteric artery (SMA) & Inferior mesenteric artery (IMA)

was 6.95 cm. These findings correlate with George [13] & Woodburne [12].

The average distance of origin of the major branches from aortic bifurcation was Celiac Trunk 12.01 cm, Superior Mesenteric Artery 10.72 cm, Inferior Mesenteric Artery 3.7 cm & renal arteries 9.3 cm. These findings correlate with the studies by George [13], Cauldwell-Anson [11] and Feller-Woodburne [12].

The average distance of aortic bifurcation from the Mid Inguinal Point was 15.2 cm.

The average Diameters of aorta at aortic opening of diaphragm was 2.19 cm, Midway between aortic opening of diaphragm & bifurcation was 1.67 cm, just above bifurcation was 1.65 cm. The aorta provides elastic recoil proximally and essentially acts as a conduit distally. As observed in previous studies the diameter of the abdominal aorta in present study also decreased progressively from proximal to distal along its length. This decrease being attributed to the decrease in flow volume as blood is supplied to the viscera.

The average angle of bifurcation of abdominal aorta was 47.2, with no statistically significant difference amongst males and females. These findings correlate with the studies by Feller-Woodburne [12] & Kajorn Lakchayapakorn [10].

Right deviation of the aorta was observed in 19 (47.5%) and left deviation in 12 (30%). 5 (12.5) cadavers showed both right & left deviation, while deviation was absent in 35% (14) cadavers.

Although the number of specimens examined in this study is relatively small, the observations with respect to the origin of all the branches are comparable to previous reports. The issue of whether the embalming process results in changes in vessel characteristics (length, diameter) has not been addressed; however, the assumption has been made that any changes that might have occurred will be consistent across all vessels, and as such the vessels of interest in this study will have been affected in proportion to their size.

CONCLUSION

From this study we conclude that the mean length of the abdominal aorta was 13.2 cm. Two male cadavers had gastrosplenic trunk & hepatic trunk instead of a single coeliac trunk, arising directly and separately from aorta. 17.5% cadavers had assessory renal arteries. Gonadal arteries were found to be originating from renal arteries in 2 (5%) cases. Variations in the origin of inferior phrenic artery were recorded in 16 (40%) cadavers. The most frequent vertebral level of origin of Coeliac Trunk was found at the upper third of the first lumbar vertebra. Right renal artery was found to take origin between the upper 1/3 of the first lumbar to the disc between second & third lumbar vertebrae. Left renal artery was most frequently found to be arising at the level of upper 1/3 of second lumbar vertebra.

Gonadal arteries were seen most frequently arising opposite lower 1/3 of 2nd lumbar vertebra on either side. Abdominal aorta was found to bifurcate opposite the disc between third & fourth lumbar vertebrae to the lower 1/3 of fifth lumbar vertebra, the most frequent being at the disc between fourth & fifth lumbar vertebrae. The celiac trunk (CT) and the superior mesenteric arteries (SMA) were, on an average, 1.29 cm apart. While the average distance between superior mesenteric artery SMA & inferior mesenteric artery (IMA) was 6.95 cm. The average distance of origin of the major branches from aortic bifurcation was Celiac Trunk 12.01 cm, Superior Mesenteric Artery 10.72 cm, Inferior Mesenteric Artery 3.7 cm & renal arteries 9.3 cm. The average distance of aortic bifurcation from the Mid Inguinal Point was 15.2 cm. 47.2 ^{0} was the average angle of bifurcation of abdominal aorta. The average Diameters of aorta at aortic opening of diaphragm was 2.19 cm, Midway between aortic opening of diaphragm & bifurcation was 1.67 cm, just above bifurcation was 1.65 cm.

Conflicts of Interests: **None**

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