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Assessment of the abdominal aorta regarding its morphology, morphometry, and concomitant pathologies associated with abdominal aorta aneurysm

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ABSTRACT

Aims: The abdominal aorta (AA) plays a crucial role in both invasive and non-invasive radiological procedures, particularly in hepatorenal and colorectal surgeries. In this study, the abdominal aorta was examined morphologically, and the presence of aneurysms and accompanying pathologies was discussed. Anatomical structures that can guide surgeons and radiologists were defined as landmarks, and a morphometric approach was made.

Methods: This study examined the AA of 20 formalin-embalmed American cadavers (ages 50-96) donated to Albert Einstein College of Medicine's C&DA Department. From supine cadavers, aortic bifurcation (BA) levels were examined for the vertebral column. Linear, longitudinal, and transverse distances were measured between the Left renal artery (LtRA) and branching points of BA, diameters of AA, tortuosity, and morphology were examined.

Results: Four of the 20 cadavers included in the study had AA aneurysm (AAA). Cadaveric examinations showed aortic dilatation, abdominal aorta wall thickness, atherosclerosis, thrombus formation at the Superior Mesenteric Artery (SMA), an abdominal tortuous aorta, L3 vertebrae deviation, multiple AAA, hemivertebrae, L3 compression fractures, and osteodegenerative changes. The average AA transverse diameter is 22.93±2.69 mm. Upon assessment of the correlation between advancing age and the incidence of AAA in the male population, no statistically significant relationship was found (p=0.167).

Conclusion: Although the exact role of atherosclerosis in the development of AAA remains unclear, it may contribute to their occurrence; studies with larger cohorts are needed to better understand their prevalence and associated anatomical changes.

Keywords: Abdominal aorta aneurysm, atherosclerosis, abdominal aorta tortuosity, abdominal aorta, lumbar deviation, hemivertebrae

INTRODUCTION

The abdominal aorta (AA) is situated anterior to the inferior border of the 12th thoracic vertebra and descends anterior to the vertebral column, terminating at the level of the 4th lumbar vertebra (LV), typically to the left of the midline by bifurcating into the two common iliac arteries. Aneurysms typically exhibit localized dilation accompanied by wall thinning of the vessel. Normally, the abdominal aorta measures approximately 2-3 cm in diameter, but these dimensions may vary in the presence of vascular pathologies. Conditions such as abdominal aortic aneurysm (AAA) are characterized by progressive enlargement and structural weakening of the vessel wall. AAA is characterized by abnormal dilation of the abdominal aorta and may displace adjacent anatomical structures such as the inferior vena cava and the third part of the duodenum.

Globally, aortic aneurysms (including both thoracic and abdominal) resulted in approximately 167,249 deaths in 2017-equivalent to an age-standardized death rate of 2.19 per 100,000 persons-placing them among the leading 15 causes of cardiovascular mortality worldwide.[1] The lifetime prevalence of abdominal aortic aneurysm varies according to ethnicity, age, and other factors. The projected incidence ranges from 1.0% to 2.2% in females and from 1.3% to 8.9% in males.[2]

The aorta gradually tapers from the thoracic region toward the aortic bifurcation. With advancing age, the diameter of the abdominal aorta tends to increase, particularly in males. Lederle et al.[3] demonstrated that infrarenal aortic diameter increases with age, is larger in males, and correlates with body size. These factors should be considered when assessing AAA. AAA is strongly associated with advanced age, male

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sex, and especially smoking-current smokers face nearly a fivefold higher risk of AAA compared to never-smokers, while former smokers have approximately a twofold increased risk. Furthermore, each additional year smoking increases AAA risk by around 4%.[4,5]

Metabolic disorders, such as diabetes and dyslipidemia, are known to affect vascular structure and function, contributing to atherosclerosis and arterial wall remodeling. Although diabetes is a well-known cardiovascular risk factor, evidence indicates an inverse relationship between diabetes and the occurrence and progression of AAA.[6] Although both AAA and arterial tortuosity syndrome (ATS) affect the arterial wall, their underlying histopathological features differ significantly. In ATS, histology typically reveals defects in connective tissue architecture due to mutations in extracellular matrix-related genes, leading to arterial elongation and tortuosity. In contrast, AAA is primarily characterized by chronic inflammation, degradation of elastin and collagen, and protease-mediated destruction of the medial layer.[7] These distinct mechanisms underscore the differing pathogenesis of these two vascular conditions. Peripheral vascular disease and coronary heart disease (CHD), two atherosclerosis-linked diseases, are strong AAA predisposing variables, according to population-based research.[8] Solberg et al.[9] mentioned that numerous epidemiological studies have linked CVRF to AAA. However, few studies have examined the interaction between subclinical ATS and CVRF and the abdominal aortic diameter (AAD) and enlarged AAD (EAAD) 25 mm, which are connected to AAA risk.

A tortuous abdominal aorta (ATA) can also cause inferior vena cava suppression. This abnormality may cause necrosis, centrilobular congestion, liver cirrhosis and fibrosis.[10] ATA can potentially inhibit the inferior vena cava. The AA plays a key role in various procedures. It may predict complications in transfemoral transcatheter aortic valve replacement (TAVR) and serves as a critical marker for AAA repair. Additionally, aortic tortuosity should be considered, as it can impact procedural success in both settings.[11]

Focal stenosis of aortic and/or pulmonary arteries with extensive elongation and tortuosity of the aorta and mid-sized arteries are signs of arterial tortuosity syndrome (ATS).[12] Soft or doughy hyperextensible skin, joint hypermobility, inguinal hernia, and diaphragmatic hernia may indicate a widespread connective tissue problem. Skeletal anomalies include pectus excavatum or carinatum, arachnodactyly, scoliosis, knee/elbow contractures, and camptodactyly.[13]

The cardiovascular system remains a leading contributor to morbidity and mortality across all age groups. Aneurysm formation and dissection, particularly at the aortic root and along the arterial tree, are major concerns. Additionally, ischemic events involving the cerebrovascular and abdominal arterial circulation, such as non-hemorrhagic strokes, further highlight the systemic impact of vascular pathology.

Invasive and noninvasive radiological procedures both rely on the abdominal aorta and abdominal surgeries, especially those involving the hepatorenal and colorectal areas. Aneurysms and related diseases were reviewed after morphological examinations of the abdominal aorta and adjacent structures were performed in this study. A morphometric technique was used to define landmarks to guide radiologists and surgeons during abdominal procedures.

METHODS

A unique combination of two reliable landmarks was tested in this cadaveric study to accurately identify the BA (aortic bifurcation) in three-dimensional coordinates. These landmarks were listed: Vertebral body, Left renal artery (LtRA). This study included anatomical analysis of 20 formalin-embalmed cadavers provided to the Department of Anatomy at Albert Einstein College of Medicine (AECOM), focusing on 20 cases (12 males, 8 females, aged 50-96). All donors authorized for donation and use in clinical trials were accepted in compliance with New York's Anatomical Gift Law. This project is exempt from ethical approval as it employs course cadavers from the Albert Einstein College of Medicine C&DA Department, consistent with the exemption categories specified in Einstein-IRB-citation104(d). A 52-year-old female participant was excluded from the experiment due to metastatic stomach cancer in the para-aortic area. The others have no history of previous abdominal injuries, pathological diseases, or surgical procedures. The AA of the supine cadavers was accessible anteriorly, focusing on the aortic branches.

We used a Mitutoyo Digital Caliper (approved by Mitutoyo America Corp. Calibration Lab.-control number 887014, range 0.000 inch-0006 inch), goniometer, dissection instruments, and an Olympus digital camera for our research. We first analyzed the trajectory of the abdominal aorta, the vertebral column branching levels for BA, morphological changes, tortuosity, aneurysms, wall thickness, variations, osteodegenerative changes, and compression fractures. We grouped vertebral bodies by height: upper, medium, and bottom. However, some AA branches developed from the intervertebral disc.

Coeliac trunk (CT), Superior mesenteric artery (SMA), Inferior mesenteric artery (IMA), LtRA, BA, and their transverse, longitudinal, and linear distances, abdominal aorta diameter were evaluated (**Figure 1**). Statistical analysis was also performed on artery sources and branching angles. We removed the abdominal aorta from the cadaver and vertically dissected it along its major axis from the right and left common iliac arteries to split it into ventral and dorsal segments. Digital photos of the resected ventral surfaces of the AA were taken from the intravascular lumen. The study examined BA morphology, tortuosity, and BA branching locations. Linear(e1), longitudinal(e2), and transverse distances between LtRA and the BA were measured. The BA's transverse diameter at the LtRA level (a1) was also measured. Compare the findings with prior research in the literature.

Statistical Analysis

Data analysis of the data was performed in the SPSS 26.0 program (SPSS, 26.0, Chicago, IL.). The Kolmogorov-Smirnov test validated that the data had a normal distribution ($p<0.05$), while the Levene test results indicated that the

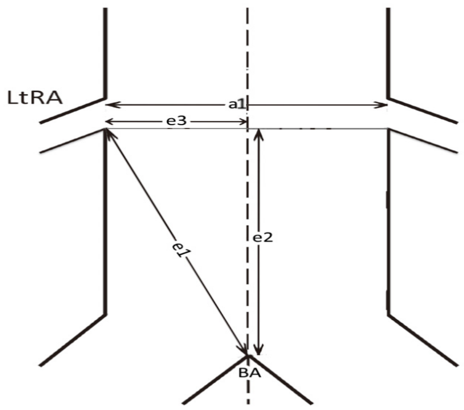

Figure 1. Schematic diagram of measured items of the abdominal aorta at the Lt. RA level; e1 (LtRA to BA linear); e2 (Lt. RA to BA longitudinal); e3 (LtRA to BA transverse distance); a1 (BA's transverse diameter at the LtRA level)

LtRA: Left renal artery, BA: Aortic bifurcation, IVD: Intervertebral disc

variances among groups were equal (p<0.05). Given that both assumptions presented in the study were satisfied, the t-test for independent samples was employed for group comparisons, while Pearson correlation analysis was utilized to assess the linear relationship between variables.

RESULTS

The AAin the 19 cadavers examined was divided into the right and left common iliac arteries, facilitating the assessment of BA development levels in relation to the vertebral column, particularly specific vertebral levels. In summary, as depicted in Figure 2, 32% of the BA is located at' the intervertebral disc (IVD) level between the 4th and 5th lumbar vertebrae, 21% from the upper third of the 4th lumbar vertebra, 21% from the middle third of the 4th lumbar vertebra, 16% from the lower third of the 4th lumbar vertebra, 5% from the IVD level between the 3rd and 4th lumbar vertebrae, and 5% from the middle third of the 5th lumbar vertebra. These percentages take into account the age and gender distribution of the cadavers.

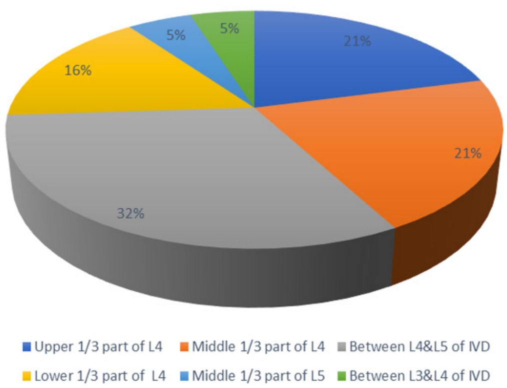

Figure 2. Branching point of the aortic bifurcation from the vertebral column

The transverse diameters of the abdominal aorta within the lumen were evaluated at the bifurcation of the left renal artery from the abdominal aorta. The mean transverse diameter of the abdominal aorta, derived from 19 measurements, is 22.93±2.69 mm.

The measurements of linear, longitudinal, and transverse distances between LtRA and BA were performed accordingly. (e1, e2, e3). The mean linear distance(e1) is 92.67±25.45 mm. The mean longitudinal distance(e2) is 96.24±15.80 mm. The mean transverse distance(e3) between LtRA and BA is 9.08±3.06 mm (Table 1).

Table 1. Descriptive statistics results for males and females

Variable	Males (n=12) M (SD)	Females (n=7) M (SD)	Total (n=19) M (SD)
Age	80.92±10.69	74.71±12.41	78.63±11.43
a1	23.40±2.74	22.10±2.59	22.93±2.69
e1	91.80±28.41	94.18±21.4	92.67±25.45
e2	98.06±12.45	93.11±21.13	96.24±15.80
e3	8.29±3.06	10.43±2.77	9.08±3.06

e1 (Lt. RA to BA linear); e2 (Lt. RA to BA longitudinal); e3 (Lt. RA to BA transverse distance); a1 (BA's transverse diameter of the abdominal aorta at the LtRA level), LtRA: Left renal artery, BA: Aortic bifurcation

91-year-old male (Case 1) had cadaveric examination, which revealed aortic dilatation and aneurysm wall thickness. At the level of the left renal artery, the transverse diameter of the abdominal aorta was 29.04 mm. The aortic bifurcation was located at the middle third of the fifth lumbar vertebra (Table 2).

79-year-old female (Case 2) had an AA aneurysm, atherosclerosis, and SMA thrombus. Aortic bifurcation occurred around the middle third of the fourth lumbar vertebra, with an 18.54 mm transverse abdominal aorta diameter at the left renal artery level (Table 2).

A double right renal artery was found in an 80-year-old man (Case 3). Figure 3, and 4 show AA aneurysm, ATA, and L3 vertebrae deviation in addition to this anatomic variance. The transverse abdominal aorta at the left renal artery level was 24.08 mm wide and bifurcated at the lower third of the fourth lumbar vertebra (Table 2).

Male, 88 years old (Case 4), the cadaveric examination revealed several abdominal aortic aneurysms, hemivertebrae, an L3 compression fracture, increased intervertebral body height at L2-L3, and osteodegenerative alterations (Figure 5, and 6). The aortic bifurcation was situated in the upper third of the fourth lumbar vertebra, with the diameter of the transverse abdominal aorta at the left renal artery level, measuring 26.83 mm (Table 2).

Table 2. Descriptive measures related abdominal aorta in four cases

Cases	Age/gender	a1	e1	e2	e3	Branching point of BA
Case I	91, M	29.04 mm	115.95 mm	114.0 mm	8.7 mm	L5M1/3
Case II	79, F	18.54 mm	61.46 mm	60.77 mm	8.63 mm	L4 M1/3
Case III	80, M	24.08 mm	105.79 mm	102.91mm	93 mm	L4 L1/3
Case IV	88, M	26.83 mm	10.63 mm	101.59 mm	11.61mm	L4 U1/3

e1 (Lt. RA to BA linear); e2 (Lt. RA to BA longitudinal); e3 (Lt. RA to BA transverse distance); a1 (BA's transverse diameter of the abdominal aorta at the LtRA level), LtRA: Left renal artery, BA: Aortic bifurcation, U1/3: Upper third, M1/3: Middle third, L1/3: Lower 1/3

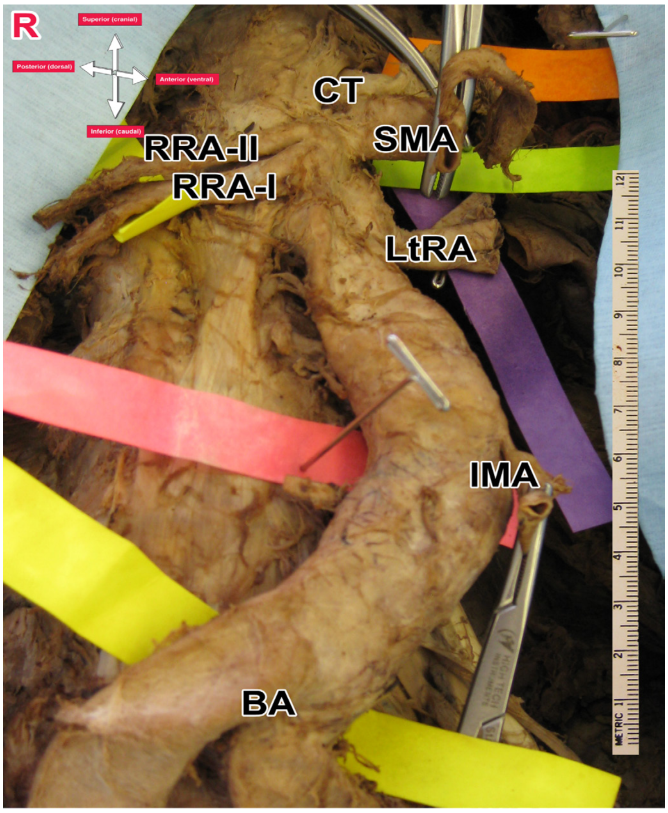

Figure 3. The aspect of the superior side of the supine-positioned cadaver. In addition to double renal arteries, AA aneurysm (*), ATA, and L3 vertebrae deviation were also found.

AA: Abdominal aorta, ATA: Tortuous abdominal aorta, LtRA: Left renal artery, BA: Aortic bifurcation, CT: Coeliac trunk, SMA: Superior mesenteric artery, IMA: Inferior mesenteric artery

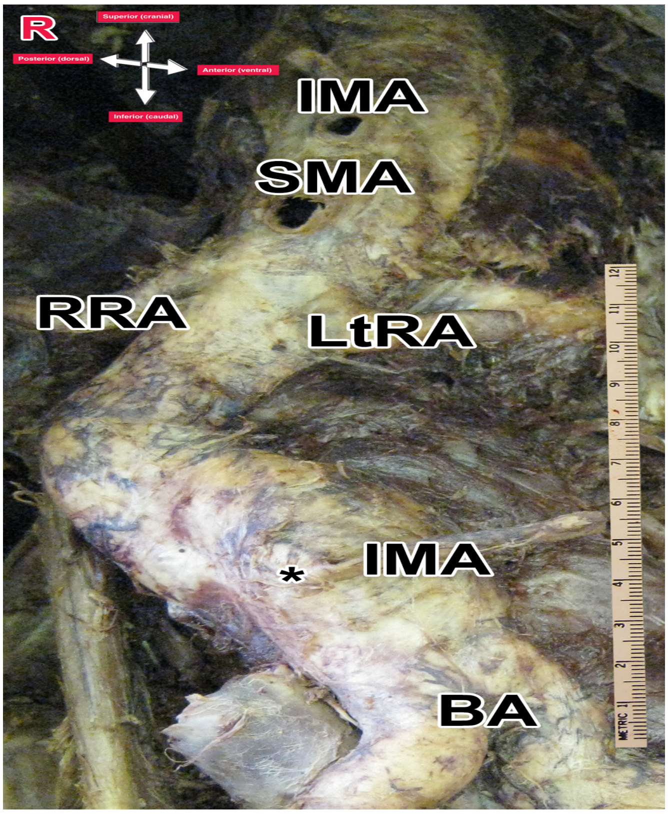

Figure 5. AA with branches related to this study, removed from the cadaver to take measurements. As a result of this cadaveric examination, multiple AA aneurysms, hemivertebrae, ATA, L3 compressor fracture, increased intervertebral body height (L2-L3), and osteodegenerative changes were described

AA: Abdominal aorta, LtRA: Left renal artery, ATA: Tortuous abdominal aorta, BA: Aortic bifurcation, CT: Coeliac trunk, SMA: Superior mesenteric artery, IMA: Inferior mesenteric artery, RRA: Right renal artery

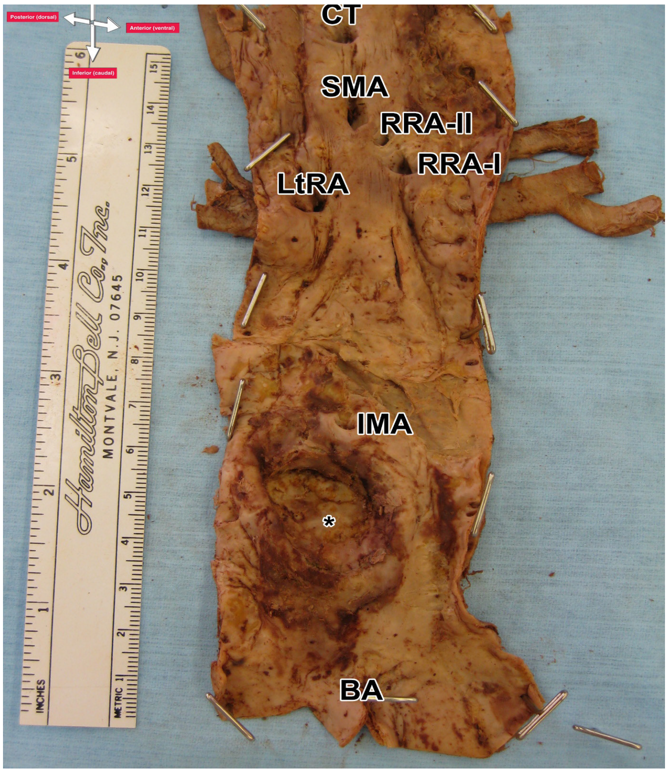

Figure 4. The lumen of the abdominal aorta with branches related to this study was dissected ventrally from the line that crosses the BA. Two openings of renal arteries (RRA-I, RRA-II) and the abdominal aorta aneurysm (*) are clearly

LtRA: Left renal artery, BA: Aortic bifurcation, CT: Coeliac trunk, SMA: Superior mesenteric artery, IMA: Inferior mesenteric artery, RRA: Right renal artery

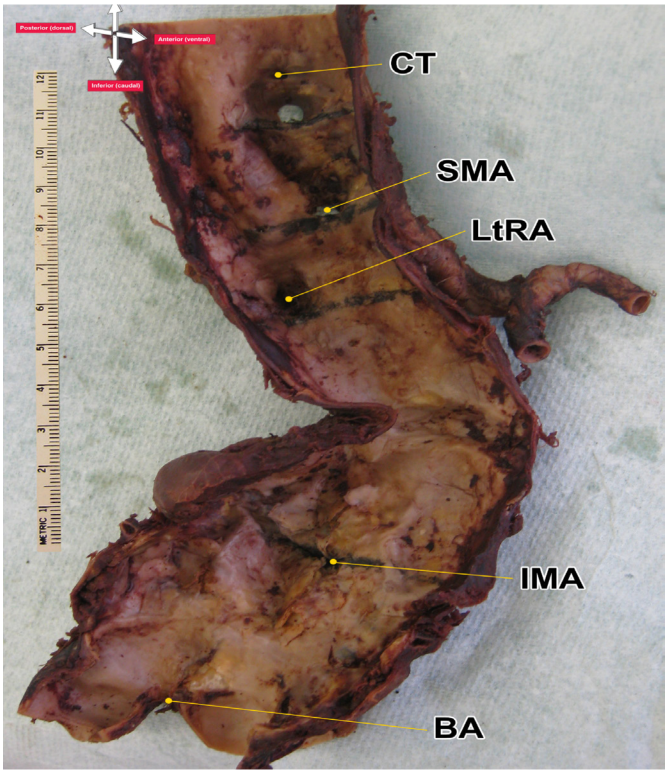

Figure 6. The lumen of the AA with branches related to this study, was dissected ventrally from the line that crosses the Aortic bifurcation. In addition findings from this case, ATA, Multiple AA aneurysms, and atherosclerotic changes were described

AA: Abdominal aorta, LtRA: Left renal artery, ATA: Tortuous abdominal aorta, BA: Aortic bifurcation, CT: Coeliac trunk, SMA: Superior mesenteric artery, IMA: Inferior mesenteric artery, RRA: Right renal artery

In a statistical analysis of the male population, no significant link was identified between the incidence of AAA and advancing age (p=0.167>0.05).

There is no statistically significant correlation between advancing age and aortic diameter in males (p=0.138>0.05).

DISCUSSION

The primary finding of this study is that in 32% of the cadavers, the aortic bifurcation was located at the intervertebral disc (IVD) level between the 4th and 5th lumbar vertebrae, indicating this level as the most common site of bifurcation. In the 19 cadavers examined, the abdominal aorta was observed to divide into the right and left common iliac arteries at variable levels along the lower lumbar spine. Specifically, 21% bifurcated at the upper third of L4, 21% at the middle third of L4, 16% at the lower third of L4, 5% at the IVD between L3 and L4, and 5% at the middle third of L5 (**Figure 2**). These findings provide updated anatomical reference data on aortic bifurcation levels and support prior studies reporting L4 as the most common site, while also highlighting inter-individual variability potentially influenced by age, sex, and degenerative changes. These results align closely with large cadaveric and imaging studies in the literature, which consistently report L4 as the most common bifurcation level-such as the systematic review by Greek investigators identifying L4 body in 42.2% of 3537 specimens,[14] and a Thai cadaver study finding L4 body bifurcation in 70.1% of 187 specimens.[15] MRI studies similarly report L4 in about two-thirds of cases (e.g., 67% in a 441-patient series).[16] Compared to these benchmarks, our 32% at the L4-L5 disc reflects the variability evident across populations and supports the broad range-from upper L3 to upper S1-reported in anatomo-radiological studies.[14] Finally, we acknowledged potential contributors to variability in bifurcation level in our sample-including age-related vascular dilation, aneurysms, degenerative spinal pathology, and lumbosacral transitional vertebrae-and noted the limitations related to sample size and heterogeneity.

Powell et al.[17] claim that hereditary defects in proteolytic enzymes cause AAA, implying that atherosclerosis may be coincidental. Our goal was to understand the association between atherosclerosis and aortic enlargement, particularly in the abdominal region; thus, we eliminated aortas with visible aneurysms. The examination supports that atherosclerotic arterial wall degradation causes aneurysms, notably in the. Atherosclerosis may not cause AAA, but it is undoubtedly a major component.

The Society for Vascular Surgery and the International Society for Cardiovascular Surgery defined abdominal AAA as an infrarenal segment, with a reported mean diameter of 16.6-21.6 mmfor females and 19.9-23.9 mm for males, as determined by computed tomography and intravenous arteriography.[18] Conversely, certain researchers have defined AAA as an infrarenal aortic diameter of 30 mm.[19] There is still no consensus on the standard length of aortic diameter or other mathematical methods to characterize a AAA; however, Hirsch et al.[19] recommended 30.0 mm. More importantly, postmortem investigations show that AAAs with lower diameters rupture, whereas bigger AAAs do not.[12] This suggests that even smaller aorta diameters and expansion rates may be therapeutically relevant.

Our findings indicate a possible association between medial degeneration, aortic size, and atherosclerosis, although this relationship was not statistically significant. The strongest correlation was observed between AA plaque production and wall erosion and significant media microarchitecture degeneration. These data revealed that AA alterations may predispose to aneurysm formation. Plaque composition and progression affect aortic size.[12] Due to their larger necrotic cores, abdominal aortic plaques rupture or ulcerate. Plaque-induced artery wall weakening and atrophy define atherosclerosis. This thinning and the basic bulging beneath the plaques may produce atherosclerosis-related enlargement. Thus, this method can maintain a wide lumen for long periods. This compensatory expansion may avoid or delay AA stenosis or produce aneurysms. Much more research is needed on how risk variables affect aortic plaque progression.[20]

Although not statistically significant, the observed trends may support the hypothesis that atherosclerotic wall changes play a role in abdominal aortic aneurysm development. Atherosclerosis may not cause all AAA, but it is likely to play a key role. Few articles have described the abdominal tortuous aorta.[21-23] There is no literature on the safety of complications and abdominal surgery in this condition. An ATA predicted problems in transfemoral transcatheter aortic valve replacement patients. Kinnel et al.[11] found that non-ruptured AAA patients had more aortic tortuosity than ruptured AAA patients of equal aneurysm size, suggesting that it may lessen rupture risk, and the abdominal aorta's lateral displacement can be misconstrued as an aneurysm when palpated through the abdominal wall as a pulsatile mass, according to Feller and Woodburne.[24]

The breadth and degree of abdominal aorta tortuosity can cause aortic lumen obstruction, hypertension, discomfort, and insufficiency.

A complete preoperative radiological assessment and skills are needed for surgical and endovascular interventions to be successful and safe.

Multiple renal arteries are associated with abdominal aorta tortuosity and aneurysm, according to Cetinok.[25]

Since the LtRA was the reference point in prior studies on the AA and its branches, the catheter often lodges there first. Catheter implantation is easier when LtRA and vascular distances are estimated.[26,27] Considering LtRA changes, we estimated BA's position on the AA relative to the columna vertebralis in this study.

Takahashi et al.[27] found that the lateral diameter of the aorta at the inferior border of the left renal artery was 20.1±2.9 (14.7-25.1) mm, as ascertained from intravascular observations. Sonesson et al.[28] indicated that the internal diameter of the aorta at the LtRA level, as assessed by ultrasonography, was 20.4±2.4 mm in a 70-year-old male and 17.3±2.0 mm in a female. Cauldwell and Anson[29] measured a distance of 100.0±13.6 mm from the outer surface of the blood vessels to the middle of the LtRA. Many articles solely provided quantifiable values. The dimensions and caliber of blood arteries might differ across individuals due to anatomical and physiological traits, especially height, as well as the existence of vascular pathologies. In our research, we examined the transverse diameters of the AA within the lumen at the site where the LtRA bifurcates from the AA. The diameters mean for male gender was 23.40±2.74 mm; for females22.10±2.59 mm, among each gender was 22.93±2.69 mm.

Pirró et al.[30] revealed the following findings from cadaver examinations for the vertebral body level of the AB: L3 2%, L4 50%, L4/5 intervertebral disk 7%, L5 39%, and S1 2%. The results presented by Prakash et al.[31] were as follows: L3 20%, L4 54%, and L5 26%. Chithriki et al.[16] conducted MRI studies that segmented the vertebral body into three sections, yielding the following results: L3 upper 0.9%, L3 middle 1.4%, L3 lower 7.0%, L3/4 intervertebral disk 13.4%, L4 upper 19.1%, L4 middle 24.0%, L4 lower 23.8%, L4/5 intervertebral disk 7.7%, L5 upper 1.6%, L5 middle 0.9%, and L5/S1. intervertebral disk 0.9%. Our study reveals that 32% of aortic bifurcations arise at the intervertebral disc level between the 4^{th} and 5^{th} lumbar vertebrae, 21% from the upper third of the 4^{th} lumbar vertebra, 21% from the middle third of the 4th lumbar vertebra, 16% from the lower third of the 4^{th} lumbar vertebra, 5% from the intervertebral disc level between the 3^{rd} and 4^{th} lumbar vertebrae, and 5% from the middle third of the 5th lumbar vertebra, considering the ages and genders of the cadavers analyzed (Table 1, Graphic 1).

Our investigation delineated various findings, including aortic dilatation, concomitant aortic aneurysm wall thickness, atherosclerosis, and thrombus at the superior mesenteric artery (SMA). A double right renal artery was noted, accompanied by multiple aortic aneurysms, hemivertebrae, aortic deviation at the L3 vertebra, a compression fracture at L3, increased intervertebral body height between L2 and L3, and osteodegenerative alterations.

It is common for the LtRA to be the initial location of catheter entrapment during abdominal angiography, which involves passing the catheter upward from the femoral artery to the AA in a real clinical environment. In order to place catheters more easily, it is necessary to determine the distance between the LtRA and other blood vessels.[28]

We expressed the relative positional relationships of LtRA in an indexed format, referencing the longitudinal, linear, and transverse distances of the aorta to mitigate the impact of variations in individual concurrent pathologies associated with AA Aneurysm.

No statistically significant relationship was found between age and the transverse diameter of the abdominal aorta at the level of the left renal artery. While a weak positive trend was observed, it does not permit any definitive interpretation due to the absence of statistical significance in the current dataset. Future studies with larger and more homogeneous samples are required to further investigate this potential relationship.

Limitations

One limitation of this study is the relatively small sample size, which may have reduced the statistical power of some analyses and limited the ability to detect significant associations. Consequently, results with p-values above 0.05 should be interpreted with caution. Larger, multicenter studies are needed to confirm these findings and provide more robust conclusions regarding the morphometric characteristics and related vascular pathologies.

CONCLUSION

This cadaveric study demonstrated variability in aortic bifurcation levels, most commonly at the L4-L5 intervertebral disc. Although no statistically significant correlation was found between age and aortic diameter at the level of the left renal artery, a weak positive trend was observed. AAA cases frequently presented with additional anatomical variations such as vertebral deformities, aortic tortuosity, and accessory renal arteries. These rare combinations may have implications for surgical and endovascular planning. The main limitation of the study is the small sample size, which may have limited statistical power. Further research with larger cohorts and radiological or histological correlation is needed to clarify the relationship between aortic morphology, atherosclerosis, and aneurysm development. A better understanding of these variations could enhance the safety of vascular procedures.

ETHICAL DECLARATIONS

Ethics Committee Approval

This project is exempt from ethical approval as it employs course cadavers from the Albert Einstein College of Medicine C&DA Department, consistent with the exemption categories specified in Einstein-IRB-citation104(d).

Informed Consent

Since the study was conducted without the participation of any living being, no written consent form was obtained.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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REFERENCES

1. Wei L, Bu X, Wang X, Liu J, Ma A, Wang T. Global burden of aortic aneurysm and attributable risk factors from 1990 to 2017. *Glob Heart.* 2021;16(1):35. doi:10.5334/gh.920

2. Lederle FA. Aneurysm diameter. *Eur J Vasc Endovasc Surg.* 2000;20(3): 316. doi:10.1053/ejvs.1999.1124
3. Lederle FA, Johnson GR, Wilson SE, et al. Relationship of age, gender, race, and body size to infrarenal aortic diameter. The aneurysm detection and management (ADAM) veterans affairs cooperative study investigators. *J Vasc Surg.* 1997;26(4):595-601. doi:10.1016/s0741-5214(97)70057-0
4. Wilmink TB, Quick CR, Day NE. The association between cigarette smoking and abdominal aortic aneurysms. *J Vasc Surg.* 1999;30(6):1099-1105. doi:10.1016/s0741-5214(99)70049-2
5. Aune D, Schlesinger S, Norat T, Riboli E. Tobacco smoking and the risk of abdominal aortic aneurysm: a systematic review and meta-analysis of prospective studies. *Sci Rep.* 2018;8(1):14786. doi:10.1038/s41598-018-32100-2
6. Golledge J, Clancy P, Jamrozik K, Norman PE. Obesity, adipokines, and abdominal aortic aneurysm: health in men study. *Circulation.* 2007; 116(20):2275-2279. doi:10.1161/CIRCULATIONAHA.107.717926
7. Hobbs SD, Claridge MW, Quick CR, Day NE, Bradbury AW, Wilmink AB. LDL cholesterol is associated with small abdominal aortic aneurysms. *Eur J Vasc Endovasc Surg.* 2003;26(6):618-622. doi:10.1016/s1078-5884(03)00412-x
8. MacSweeney ST, O'Meara M, Alexander C, O'Malley MK, Powell JT, Greenhalgh RM. High prevalence of unsuspected abdominal aortic aneurysm in patients with confirmed symptomatic peripheral or cerebral arterial disease. *Br J Surg.* 1993;80(5):582-584. doi:10.1002/bjs.1800800510
9. Solberg S, Forsdahl SH, Singh K, Jacobsen BK. Diameter of the infrarenal aorta as a risk factor for abdominal aortic aneurysm: the Tromsø study, 1994-2001. *Eur J Vasc Endovasc Surg.* 2010;39(3):280-284. doi: 10.1016/j.ejvs.2009.10.017
10. Wadhwa A, Soni S. An accessory renal artery from a tortuous abdominal aorta: a case report. *J Clin Diagn Res.* 2012;6:1292-1293.
11. Kinnel M, Faroux L, Villecourt A, et al. Abdominal aorta tortuosity on computed tomography identifies patients at risk of complications during transfemoral transcatheter aortic valve replacement. *Arch Cardiovasc Dis.* 2020;113(3):159-167. doi:10.1016/j.acvd.2019.10.006
12. Darling RC, Messina CR, Brewster DC, Ottinger LW. Autopsy study of unoperated abdominal aortic aneurysms. The case for early resection. *Circulation.* 1977;56(3 suppl):II161-II164.
13. Callewaert B, De Paepe A, Coucke P. Arterial Tortuosity Syndrome. In: Adam MP, Feldman J, Mirzaa GM, Pagon RA, Wallace SE, Amemiya A, eds. GeneReviews®. Seattle (WA): University of Washington, Seattle; November 13, 2014.
14. Panagouli E, Antonopoulos I, Tsoucalas G, et al. Case series and a systematic review concerning the level of the aortic bifurcation. *Folia Morphol (Warsz).* 2021;80(2):302-309. doi:10.5603/FM.a2020.0064
15. Khamanarong K, Sae-Jung S, Supa-Adirek C, Teerakul S, Prachaney P. Aortic bifurcation: a cadaveric study of its relationship to the spine. *J Med Assoc Thai.* 2009;92(1):47-49.
16. Chithriki M, Jaibaji M, Steele RD. The anatomical relationship of the aortic bifurcation to the lumbar vertebrae: a MRI study. *Surg Radiol Anat.* 2002;24(5):308-312. doi:10.1007/s00276-002-0036-3
17. Powell J, Greenhalgh RM. Cellular, enzymatic, and genetic factors in the pathogenesis of abdominal aortic aneurysms. *J Vasc Surg.* 1989;9(2):297-304. doi:10.1067/mva. 1989.vs0090297
18. Johnston KW, Rutherford RB, Tilson MD, Shah DM, Hollier L, Stanley JC. Suggested standards for reporting on arterial aneurysms. Subcommittee on Reporting Standards for Arterial Aneurysms, Ad Hoc Committee on Reporting Standards, Society for Vascular Surgery and North American Chapter, International Society for Cardiovascular Surgery. *J Vasc Surg.* 1991;13(3):452-458. doi:10.1067/mva.1991.26737
19. Hirsch AT, Haskal ZJ, Hertzer NR, et al. ACC/AHA guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Associations for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (writing committee to develop guidelines for the management of patients with peripheral arterial disease)-summary of recommendations. *J Vasc Interv Radiol.* 2006;17(9):1383-1398. doi:10.1097/01.RVI.0000240426.53079.46
20. Zarins CK, Xu CP, Glagov S. Aneurysmal enlargement of the aorta during regression of experimental atherosclerosis. *J Vasc Surg.* 1992; 15(1):90-101. doi:10.1067/mva.1992.34045
21. Xu H, Huang J, Zeng Y, et al. Network pharmacology and molecular analysis of mechanisms underlying the therapeutic effects of Rhubarb in treating atherosclerosis and abdominal aortic aneurysm. *Heliyon.* 2025;11(4):e41906. doi:10.1016/j.heliyon.2025.e41906
22. Jahangir E, Lipworth L, Edwards TL, et al. Smoking, sex, risk factors and abdominal aortic aneurysms: a prospective study of 18 782 persons aged above 65 years in the Southern Community Cohort Study. *J Epidemiol Community Health.* 2015;69(5):481-488. doi:10.1136/jech-2014-204920
23. Van de Luijtgaarden KM, Rouwet EV, Hoeks SE, Stolker RJ, Verhagen HJ, Majoor-Krakauer D. Risk of abdominal aortic aneurysm (AAA) among male and female relatives of AAA patients. *Vasc Med.* 2017;22(2):112-118. doi:10.1177/1358863X16686409
24. Feller I, Woodburne RT. Surgical anatomy of the abdominal aorta. *Ann Surg.* 1961;154(Suppl 6):239-252. doi:10.1097/00000658-196112000-00033
25. Çetinok EH. Renal artery variations with clinical significance: multiple renal arteries and their coexistent anatomical abnormalities: a cadaveric study. *Maltepe Tıp Derg.* 2024;16(2):46-54. doi: 10.35514/mtd.2024.111
26. Pennington N, Soames RW. The anterior visceral branches of the abdominal aorta and their relationship to the renal arteries. *Surg Radiol Anat.* 2005;27(5):395-403. doi:10.1007/s00276-005-0026-3
27. Takahashi T, Takeuchi K, Ito T, Hayashi S, Qu N, Itoh M. Positional relationships of abdominal aorta landmarks for angiography: observations from the intravascular space. *Surg Radiol Anat.* 2014;36(7): 681-688. doi:10.1007/s00276-013-1249-3
28. Sonesson B, Länne T, Hansen F, Sandgren T. Infrarenal aortic diameter in the healthy person. *Eur J Vasc Surg.* 1994;8(1):89-95. doi:10.1016/s0950-821x(05)80127-6
29. Cauldwell EW, Anson BJ. The visceral branches of the abdominal aorta: topographical relationships. *Am J Anat.* 1943;73(1):27-57. doi:10.1002/aja.1000730103
30. Pirró N, Ciampi D, Champsaur P, Di Marino V. The anatomical relationship of the iliocava junction to the lumbosacral spine and the aortic bifurcation. *Surg Radiol Anat.* 2005;27(2):137-141. doi:10.1007/s00276-004-0301-8
31. Prakash, Mokhasi V, Rajini T, Shashirekha M. The abdominal aorta and its branches: anatomical variations and clinical implications. *Folia Morphol (Warsz).* 2011;70(4):282-286.