*Original Article*

# Anatomical Features of Abdominal Aortic Aneurysm on CT Angiography: A Comparison Study

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***Background***: There is little information about the anatomical characteristics and relationship between ruptured and unruptured abdominal aortic aneurysm (AAA).

***Objective***: The present study was to determine the anatomical differences between the two groups as assessed with multi-detector computed tomographic angiography (CTA).

***Materials and Methods***: A retrospective review of all the patients diagnosed with AAA that underwent CTA before aortic repair were performed with matching between ruptured and unruptured groups for age and gender. Patient characteristics, and morphological data of aneurysmal and non-aneurysmal parts on CTA images were reviewed.

***Results***: Ninety-six patients in each group were matched. The ruptured group had significantly lower systolic blood pressure (p=0.027), and higher blood creatinine (p=0.006). In the aneurysm part, maximal aneurysmal diameter was significantly larger in the ruptured group at 7.8 cm versus 6 cm (p<0.001), as well as the larger lumen diameter (p=0.006), longer aneurysmal length (p=0.005), shorter aneurysmal neck length (p=0.009), and thicker maximal thrombus thickness (p<0.001). In the non-aneurysmal part, the aortic diameter of the ruptured group was significantly larger in every location. Multivariate analysis indicated that maximal aneurysmal diameter, non-aneurysmal part of the infrarenal aortic diameter, aneurysmal neck length, and current smoking status remained significant variables for ruptured AAAs.

***Conclusion***: Ruptured AAAs had shorter aneurysmal neck length and larger diameter of both aneurysmal and non-aneurysmal parts of AAA than unruptured group.

***Keywords***: Abdominal aortic aneurysm; CT angiography

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Abdominal aortic aneurysm (AAA) is an abnormal dilatation of the abdominal aortic wall. This condition is found in about 4% to 10% of men and 0.7% to 2.2% of women who are more than 65 years old(1-4). The most dangerous sequela of an AAA is a rupture, which results in an approximately 90% mortality rate(2). There are two options for treating this disease, conventional open aortic repair and endovascular aortic repair (EVAR). The latter is considered the primary treatment due to its lower morbidity and mortality rates in comparison with conventional open aortic repair(2-5). The current management of AAAs depends on aneurysmal sac diameter and the decision to perform aortic repair must be balanced between AAA rupture risk and operative mortality. Presently, repair of AAAs is recommended when the sac diameter exceeds 5.5 cm or has expanded by more than 1 cm per year(1,3,4). However, there is little information about the anatomical characteristics or the relationship between the ruptured and the unruptured AAA(6,7). The purpose of the present study was to determine the anatomical differences between ruptured and unruptured AAA as assessed with multi-detector computed tomographic angiography (CTA).

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## Materials and Methods

### Patient recruitment

The present study was a retrospective study approved by the Institutional Ethics Committee (AF/17-03/01.1). Patient informed consent was not required. The authors reviewed the CTAs of all the patients diagnosed with AAA that underwent CTA before aortic repair between January 2010 and December 2015. Patients who had saccular aneurysm, suprarenal aortic aneurysm, previous endovascular treatment, or co-existing aortic pathology such as occlusion or dissection were excluded from the study. The evidence of ruptured, impending ruptured, or unruptured AAA was based on CTA findings. The findings of ruptured AAA included retroperitoneal or periaortic hematoma, active contrast extravasation, draped aorta, aortic wall irregularity, aorto-enteric fistula, and aorto-caval fistula(8). The findings of impending ruptured AAA included hyperattenuating crescent sign, decreased thrombus thickness, growing aneurysm of more than 0.5 cm in six months or more than 1 cm in a year, and discontinuity of intimal calcification(8). The ruptured AAAs and impending ruptured AAAs were included in the ruptured group. Patients in ruptured and unruptured groups were matched for age, gender, and the year their CTAs were performed. The initial criterion for age matching was within two years, but it was extended to within six years if the authors could not find a match with age. If more than one unruptured patient could be matched with a ruptured patient, random case selection was done using a random number table.

Patient data, such as age, gender, underlying disease such as heart disease, diabetes mellitus, hypertension, and chronic obstructive pulmonary disease, chief complaint, blood pressure, and serum creatinine, were recorded. If blood pressure or serum creatinine were measured on multiple occasions, the values acquired closest to the day the patients underwent CTA was recorded.

### CTA measurements

CTAs were obtained with a 16-slice or 64-slice multidetector CT scanner from the diaphragmatic dome to the groin with 10- or 40-mm collimation, 2 to 3 mm slice thickness, 1.5:1 or 0.703:1 pitch, 100 to 120 kVp, and automatic exposure control. The dose of contrast media administered was 2 mL/kg but did not exceed 140 mL which was injected using an infusion pump at a rate of 3 to 5 mL per second. The scan included unenhanced, arterial, and venous phases using automatic bolus tracking (region of interest [ROI] at descending aorta with a threshold at 150 HU for arterial phase and post-threshold 60-second delay for venous phase). Multiplanar reconstruction and maximal intensity projection images were acquired in coronal and sagittal views with or without 3-D surface rendering.

Diameter, thickness, and width measurements were measured in the axial view. If the vessel's lumen showed asymmetry, the shorter axis was recorded as the vessel's diameter as it was considered a more accurate representation of AAA diameter(9-11). The transverse width of L3 vertebral body was measured as an index of body habitus(9). Length was measured parallel to the course of the vessel on reconstructed maximum intensity projection (MIP) images. Neck angulation was measured in the coronal or sagittal MIP images that had the largest angle. Intraluminal thrombus circumference was graded from 0 to 4. The absence of intraluminal thrombus was scored=0, thrombi covering less than 90 degrees of aortic circumference were scored=1, between 91 to 180 degrees were scored=2, between 181 to 270 degrees were scored=3, and more than 270 degrees were scored=4.

### Statistical analysis

Statistical analyses were performed using R software version 3.2.2. Data were reported as numbers and percentages for the discrete variables, while the continuous variables were reported as mean ± standard deviation (SD). Comparison of variables between the two groups were done with McNemar chi-square test for discrete variables, paired t-test for continuous variables with normal distribution, and Wilcoxon sign-rank test for continuous variables with non-normal distribution. Association with rupture was evaluated using univariate analysis followed by multivariate analysis with backward logistic regression. Variables yielding a p-value less than 0.05 in the univariable logistic regression analysis were included in the initial model. A p-value of less than 0.05 was considered statistically significant.

## Results

Matching for gender and age was possible for 192 patients with 96 patients in each group. Most patients (88.4%) with ruptured aneurysms complained of abdominal pain. On the other hand, patients with unruptured aneurysms had a more varied chief complaint (Table 1). The prevalence of a history of heart disease, chronic obstructive pulmonary disease, diabetes mellitus, and hypertension were similar between both groups. Smoking status was significantly different. Moreover, the ruptured group had significantly lower systolic blood pressure

**Table 1.** Demographic characteristics and clinical profiles of patients with abdominal aortic aneurysm

| Variable | Ruptured; n (%) | Unruptured; n (%) | p-value (matched) |
|---|---|---|---|
| Age (years); median (IQR) | 73.5 (68, 79) | 74 (69, 79) | |
| Sex | | | |
| Male | 85 (88.5) | 85 (88.5) | |
| Female | 11 (11.5) | 11 (11.5) | |
| Chief complaint | | | |
| Pain | 81 (84.4) | 39 (41.1) | |
| Palpable mass | 5 (5.2) | 21 (22.1) | |
| Others | 6 (6.2) | 1 (1.1) | |
| Asymptomatic | 4 (4.2) | 34 (35.8) | |
| Heart disease | 15 (15.6) | 21 (21.9) | 0.277 |
| COPD | 8 (8.3) | 9 (9.4) | 0.796 |
| Smoking status | | | <0.001 |
| Current | 26 (27.1) | 25 (26.1) | |
| Former | 24 (25.0) | 46 (47.9) | |
| None | 5 (5.2) | 13 (13.5) | |
| No data | 41(42.7) | 12(12.5) | |
| Diabetes mellitus | 7 (7.3) | 9 (9.4) | 0.594 |
| Hypertension | 62 (64.6) | 55 (57.3) | 0.319 |
| Systolic blood pressure (mmHg); median (IQR) | 120 (100, 140.2) | 130 (117, 143.2) | 0.027 |
| Diastolic blood pressure (mmHg); median (IQR) | 73.5 (60, 84) | 76 (69.8, 84) | 0.628 |
| Blood creatinine (mg/dL); median (IQR) | 1.4 (1.1, 2) | 1.1 (0.9, 1.5) | 0.006 |

IQR=interquartile range; COPD=chronic obstructive pulmonary disease

**Table 2.** Morphologic data of aneurysmal part

| | Ruptured (cm); median (IQR) | Unruptured (cm); median (IQR) | p-value (matched) |
|---|---|---|---|
| Maximal aneurysmal diameter | 7.8 (6.7, 8.8) | 6 (5.2, 7.1) | <0.001 |
| Maximal aneurysmal lumen diameter | 5 (4, 6.4) | 4.5 (3.6, 5.6) | 0.006 |
| Aneurysmal length; mean±SD | 10.5±2.6 | 9.5±2.3 | 0.005 |
| Aneurysmal neck length | 2 (1.2, 3.5) | 3 (1.9, 3.9) | 0.009 |
| Aneurysmal neck diameter; mean±SD | 2.7±0.5 | 2.5±0.4 | 0.001 |
| Aneurysmal neck angulation | 52 (36.5, 70) | 51.5 (36, 71.8) | 0.803 |
| Maximal thrombus thickness | 2.8 (2.2, 3.7) | 2 (1.3, 2.9) | <0.001 |
| Intraluminal thrombus circumference (grading); n (%) | | | 0.083 |
| 0 | 2 (2.1) | 8 (8.3) | |
| 1 | 4 (4.2) | 7 (7.3) | |
| 2 | 7 (7.3) | 8 (8.3) | |
| 3 | 24 (25.0) | 29 (30.2) | |
| 4 | 59 (61.4) | 44 (45.9) | |

IQR=interquartile range; SD=standard deviation

(p=0.027), and higher blood creatinine (p=0.006) (Table 1).

Morphologic data of the aneurysms are shown in Table 2. Mean diameter of the ruptured group was 7.8 cm, significantly larger than the 6 cm of the unruptured group (p<0.001). Nine point four percent of ruptured aneurysms had a maximal aneurysmal diameter 5.5 cm or less and most of them (7.3%) had a maximal

**Table 3.** Morphologic data of non-aneurysmal part

| | Ruptured (cm); median (IQR) | Unruptured (cm); median (IQR) | p-value (matched) |
|---|---|---|---|
| Supraceliac aortic diameter; mean±SD | 2.8±0.3 | 2.7±0.3 | 0.026 |
| Suprarenal aortic diameter | 2.5 (2.2, 2.7) | 2.3 (2.2, 2.5) | 0.022 |
| Infrarenal aortic diameter | 2.4 (2.1, 2.7) | 2.2 (2, 2.3) | <0.001 |
| Aortic bifurcation diameter | 4.3 (3.2, 6) | 3.8 (2.8, 5) | <0.001 |
| Renal a.-aortic bifurcation distance; mean±SD | 12.8±2.1 | 12.5±1.8 | 0.290 |
| Right CIA length | 3.8 (3.2, 5) | 4 (3, 4.9) | 0.814 |
| Maximal right CIA diameter | 1.6 (1.4, 2) | 1.7 (1.3, 2.2) | 0.444 |
| Maximal right EIA diameter | 0.9 (0.8, 1) | 0.9 (0.8, 1) | 0.759 |
| Left CIA length; mean±SD | 4.2±1.4 | 4.4±1.7 | 0.419 |
| Maximal left CIA diameter | 1.5 (1.3, 1.8) | 1.7 (1.4, 2.1) | 0.163 |
| Maximal left EIA diameter; mean±SD | 0.877±0.186 | 0.949±0.161 | 0.006 |
| Transverse width of L3; mean±SD | 4.4±0.3 | 4.3±0.3 | 0.152 |

IQR=interquartile range; SD=standard deviation; CIA=common iliac artery; EIA=external iliac artery

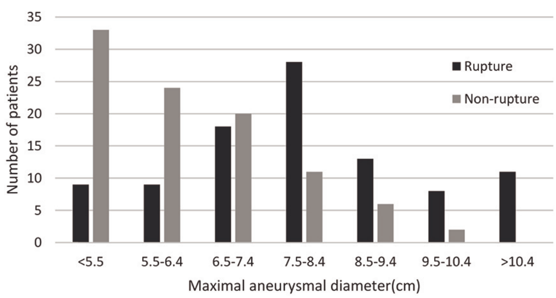


**Figure 1.** Distribution of maximal AAA diameter in ruptured and non-ruptured groups.

aneurysmal diameter between 5.1 to 5.5 cm (Figure 1). Moreover, ruptured AAA had a significantly larger maximal aneurysmal lumen diameter, longer aneurysmal length, shorter aneurysmal neck length, and thicker maximal thrombus thickness.

In the non-aneurysmal part (Table 3), the vessel diameter of the ruptured group was significantly larger than the unruptured group in every location.

After multivariate analysis, four variables including maximal aneurysmal diameter (OR 2.98; 95% CI 1.68 to 5.31; p<0.001), infrarenal aortic diameter (non-aneurysmal part) (OR 7.15; 95% CI 1.81 to 28.31; p=0.001), aneurysmal neck length (OR 0.26; 95% CI 0.08 to 0.91; p=0.021), and current smoking status (OR 13.54; 95% CI 1.39 to 132.3; p=0.025) remained significant (Table 4).

## Discussion

In this retrospective analysis of patients with infrarenal AAA, the authors evaluated the anatomical differences between ruptured and unruptured AAA as assessed with CTA. The present study found that the ruptured group had a larger aorta diameter than the unruptured group in every location, both aneurysmal and non-aneurysmal parts, and longer aneurysmal length. Maximal intraluminal thrombus thickness was also thicker in the ruptured group. Most of the variables that were different between ruptured and unruptured groups were similar to those observed in the previous studies[6,7]. However, only maximal aneurysmal diameter, infrarenal aortic diameter (non-aneurysmal part), and aneurysmal neck length remained significant after multivariate analysis.

Maximal aneurysmal diameter was the most important risk factor for aneurysm rupture and has been used to guide the management of AAA. Many studies have reported the association between the risk of aneurysm rupture and the maximal aneurysmal diameter. At present, maximal aneurysmal diameter of more than 5.5 cm is used as a criterion for aortic repair. The present study also supported the high maximal aneurysmal diameter as one of the risk factors of rupture. However, 9.4% of patients with ruptured aneurysms (n=9) had maximal aneurysmal diameter less than 5.5 cm. A previous study had reported a 0.4% annual rupture rate in AAA that are 5.5 cm or less in size[12]. Recent guidelines have even suggested early aneurysmal repairs in young, healthy patients, particularly women, with an AAA between 5.0 and 5.4 cm in maximal diameter or those with rapid expansion of small fusiform AAAs[13]. This results in smaller aneurysms increasingly being treated, with up to 40% of aneurysms that are 5.5 cm or less in size reported to have received treatment in recent clinical

**Table 4.** Univariate and multivariate analysis of factors associated with ruptured AAAs

| Variables | Univariate | | | Multivariate | | |
|---|---|---|---|---|---|---|
| | Odds ratio | 95% CI | p-value | Odds ratio | 95% CI | p-value |
| Smoking status: compared with non-smoker | | | <0.001 | | | 0.004 |
| Current | 2.23 | 0.62 to 8.06 | 0.221 | 13.54 | 1.39 to 132.3 | 0.025 |
| Former | 1.43 | 0.41 to 4.96 | 0.575 | 5.43 | 0.68 to 43.55 | 0.111 |
| No data | 8.95 | 2.27 to 35.29 | 0.002 | 18.69 | 2.03 to 171.79 | 0.01 |
| Maximal aneurysmal diameter | 2.14 | 1.56 to 2.92 | <0.001 | 2.98 | 1.68 to 5.31 | <0.001 |
| Maximal aneurysmal lumen diameter | 1.37 | 1.11 to 1.69 | 0.001 | | | |
| Aneurysmal length | 1.19 | 1.05 to 1.34 | 0.004 | | | |
| Aneurysmal neck length | 0.75 | 0.61 to 0.92 | 0.004 | 0.26 | 0.08 to 0.91 | 0.021 |
| Aneurysmal neck diameter | 4.06 | 1.78 to 9.28 | <0.001 | | | |
| Maximal thrombus thickness | 1.55 | 1.22 to 1.97 | <0.001 | | | |
| Infrarenal aortic diameter (non-aneurysmal part) | 6 | 2.22 to 16.2 | <0.001 | 7.15 | 1.81 to 28.31 | 0.001 |
| Aortic bifurcation diameter | 1.4 | 1.14 to 1.72 | <0.001 | | | |
| Maximal left EIA diameter | 0.1 | 0.02 to 0.57 | 0.006 | | | |

CI=confidence interval; CIA=common iliac artery; EIA=external iliac artery

trials. In addition, treatment of small AAA with EVAR techniques have also been shown to have a lower risk of operative and 5-year mortality than large AAA[14].

In the non-aneurysmal part, increased infrarenal aortic diameter was also a risk factor of rupture, similarly observed in a study by Fillinger et al[7]. These results may explain the findings made by Renapurkar et al[15] and Kontopodis et al[16], which reported an increased normal aortic diameter was a result of increased aortic volume and, in turn, is associated with the growth rate of the aneurysm and the need for surgical treatment. Furthermore, large infrarenal aortic diameter might reflect systemic vascular system abnormalities, according to the studies by Newman et al[17] and Freiberg et al[18], which reported an association between large infrarenal aortic diameter of more than 2 cm and the incidence of cardiovascular diseases in the future.

Aneurysmal neck length was found to be a protective factor of aneurysm rupture in the present study, similar to the report by Hinchliffe et al[6]. However, the study by Bayle et al[19] found an inverse relationship between aneurysm diameter and neck length in intact AAA, while the study by Fillinger et al[7] demonstrated that there was no significant difference between aneurysmal neck length in the ruptured and unruptured groups after diameter matching. Thus, this variable might be a result of an inverse relationship between aneurysm neck length and maximal aneurysmal diameter rather than an independent protective factor of rupture.

Current smoking status was a significant risk factor for rupture in the present study, which was similarly reported by Fillinger et al[7]. In addition, Brady et al[20] reported an association between current smoking status and the expansion rate of AAA, which was also a risk factor for aneurysm rupture. Therefore, smoking cessation should be recommended to patients to reduce the rate of AAA expansion[21].

The association between intraluminal thrombus thickness and the risk of aneurysm rupture remains controversial. Some studies have demonstrated that greater intraluminal thrombus thickness is associated with reduced risk of rupture, likely due to decreased aortic wall stress with the thrombi acting as a buffer, while others have found that the presence of thrombus is associated with inflammation and therefore, presumed to cause reduced wall elasticity resulting in increased risk of rupture[7,22]. The present study has found that patients with ruptured AAAs had a thicker maximal thrombus thickness. However, this was not statistically significant upon multivariate analysis.

In the present study, the presence of underlying hypertension was not statistically different between the two groups. This differs from the findings in a prior study[7] that demonstrated a higher prevalence of hypertension in patients with ruptured AAAs. This could be attributed to the fact that many of the patients in the present study were diagnosed with ruptured AAA upon their first hospital visit, therefore, a prior history of hypertension may be under-detected.

Lower systemic blood pressure and higher blood creatinine in the ruptured group were also different from those observed in a previous study[7] in which these variables were not significantly different. This may be due to the delay in hospital visit, diagnosis, and referral system, which might cause progressive hypotension and acute kidney injury in the present study patients.

The limitation of the present study is its retrospective nature. Matching between the two groups of patients also created selection bias. Finally, some patients with ruptured AAA were not stable enough to undergo CT angiogram and thus were not included in the study.

### Conclusion

Ruptured AAAs had shorter aneurysmal neck length, larger diameter of aneurysmal, and non-aneurysmal part of AAA than unruptured group.

### What is already known on this topic?

Maximal diameter of abdominal aortic aneurysm is the most important risk factor for rupture.

### What this study adds?

Ruptured AAAs had shorter aneurysmal neck length, larger diameter of aneurysmal, and non-aneurysmal part of AAA than unruptured group.

### Conflicts of interest

The authors declare no conflict of interest.

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