Journal of Radiology in Medicine

Original Article

Doi: 10.51271/JRM-0032

Multidetector computed tomography findings and 3 dimensional volume measurement of intraluminal thrombus in abdominal aort aneurysms

Mihriban Alkan, Nilgün Işıksalan Özbülbül

Department of Radiology, Ankara Bilkent City Hospital, Ankara, Turkiye

Received: 01.05.2025 ◆ **Accepted**: 10.06.2025 ◆ **Published**: 07.07.2025

Cite this article: Alkan M, Işıksalan Özbülbül N. Multidetector computed tomography findings and 3 dimensional volume measurement of intraluminal thrombus in abdominal aort aneurysms. *J Radiol Med.* 2025;2(3):49-52.

Corresponding Author: Mihriban Alkan, mihribanalkan@gmail.com

ABSTRACT

Aims: To output imaging findings of intraluminal thrombus (ILT) and calculate its volume exactly with 3 dimensional (3D) software, in infrarenal abdominal aorta aneurysms (AAA), by multidetector computed tomography (MDCT).

Methods: This was a retrospective study, with patient data included from January 2009 to May 2009 at Turkiye Yüksek İhtisas Hospital Radiology Department. Fifty patients (47 males, 3 females) with a mean age of 67 (47-85) who were referred with a pre-diagnosis of AAA and underwent MDCT were analyzed. Patients with aortic diameter of 30 mm or more at the infrarenal level were included in the study. The patients was divided into 3 groups according to ADmax: ≤5 cm, 5-7 cm and ≥7 cm. The relationship between parameters such as the widest diameter of the aneurysmatic segment, longitudinal length, location of the ILT and aneurysm volume were evaluated with the amount of ILT calculated by semi-automatic method using MDCT images obtained with 16 and 64-detector CT devices.

Results: The study was conducted on a total of 50 patients with an average age of 67 years (47–85), 47 (94%) men and 3 (6%) women. In the aneurysmatic segment, the maximum aortic diameter was measured as mean 5.6 cm (3.7–8.8 cm), and longitudinal length was measured as mean 9.8 cm (4.9–17.1 cm). Aneurysm volume was calculated as 188.8 cm^3 (44.8–670.2 cm^3) on average, and ILT volume as an average of 104.3 cm^3 (11.8–474.7 cm^3). A significant increase in ILT % over 5 cm diameter was found, while ILT % was lower until the maximum aorta diameter reached 5 cm. We found that ILT was concentrated mostly in anterior quadrant in 19 patients (38%).

Conclusion: There is a positive relationship between the thrombus volume (p=0.0001) and the aneurysm volume (p=0.0001) and the maximum diameter of the aneurysm. Since the volume measurements in our study are based on a semi-automatic method that completely separates the structures of interest from the rest by adjusting the threshold values, it's more accurate than 2-dimensional conventional CT measurements based on mathematical calculations in which the thrombus area and the length of the aneurysm in axial sections were used.

Keywords: Abdominal aorta aneurysm, intraluminal thrombus, multidetector computed tomography, MDCT

INTRODUCTION

The most common arterial aneurysm is abdominal aortic aneurysm (AAA).[1] AAA is considered as a degenerative disease of the abdominal aorta, which in etiology atherosclerosis is often thought to play a role.[2] AAA is seen on average 5% more often over the age of 50, with men more affected.[3] Rupture is the most important complication of AAA, which can result in 50-75% mortality.[4]

There are currently no exact criteria for predicting the risk of rupture. Although the general opinion is that the risk of rupture increases as the maximum diameter of the aneurysm increases, with the development of multi-detector computed tomography angiography (MDCTA) and 3-D reconstruction techniques in recent years, studies have focused on the characteristics of intraluminal thrombus (ILT).[5]

In this study, we aimed to expose multidetector computed tomography (MDCT) angiography imaging findings of ILT in patients with intact infrarenal abdominal aortic aneurysms. Also in the current study the volume of ILT measurements were based on a semi-automatic method that completely separates the structures of interest from the rest by adjusting the threshold values resulting more accurate outcomes.

METHODS

This study was prepared by using the data obtained from Medical Master`s Thesis we completed in Ankara Turkiye Yüksek İhtisas Hospital in 2009 (Thesis No: 03.04.2009-221). This was a retrospective study, with the patient data included from January 2009 to May 2009 at Turkiye Yüksek İhtisas Hospital Radiology Department. The patients diagnosed with AAA whom with aorta diameter of 30 mm and wider at the infrarenal level and without any sign of rupture were included.

The data collection adheres to ethical principles. Participants provide informed consent, and data sharing is permitted following anonymization. The study aligns with the Declaration of Helsinki and adheres to the recommendations of the International Committee of Medical Journal Editors (ICMJE).

MDCTA imaging was made by 16-detector (Lightspeed16, General Electric Medical Systems, Milwaukee, Wis., USA) and 64-detector (Aquilion 64, Toshiba Medical Systems, Tokyo, Japan) CT devices. Contrast agent injection was performed using Medrad (Pittsburg, Pa) automatic injector. In all cases, the area of examination from the diaphragm to the level of symphysis pubis was determined on the skenogram (topogram) taken while lying in the supine position. Examinations were carried out by injecting 90-110 ml (1-2 ml /kg) non-ionic contrast agent (Omnipaque 350) at a speed of 4-5 ml/sec with an automatic injector from the vein opened with an 18-gauge intracet from the antecubital vein in the supine position. The examination was initiated after the suprarenal aorta density reached 150-180 HU with a section thickness of 1.25 mm, by using bolus method (Smart-prep, GE Healthcare and Sure Start, Toshiba). Cross-sectional images were obtained with pitch 2, tube rotation speeds of 350 and 500 msn and wide field of view (FOV) parameters with 180-300 mA, 120 kV. All MDCTA examinations took place craniocaudally and in a single breath-holding period.

The resulting images were transferred to the workstation (Advantage Workstation, AW 4.2, GE Medical Systems) for examination. From all cross-sectional images transferred to the working station, reformat images were obtained and recorded again with a cross-sectional thickness of 3 mm and an interval of 3 mm.

Recorded reformat images were evaluated in terms of parameters such as the maximum diameter (AD_{max}) and longitudinal length (LLA) of the aneurysm segment, location of the ILT, aneurysm volume and ILT volume.

Aneurysm and ILT volumes were calculated using the following protocol over reformat images created with 3 mm cross-section thickness and 3 mm interval (**Figure 1**);

1- The initial localization of the aneurysm segment was determined through the axial images of the reformat records.

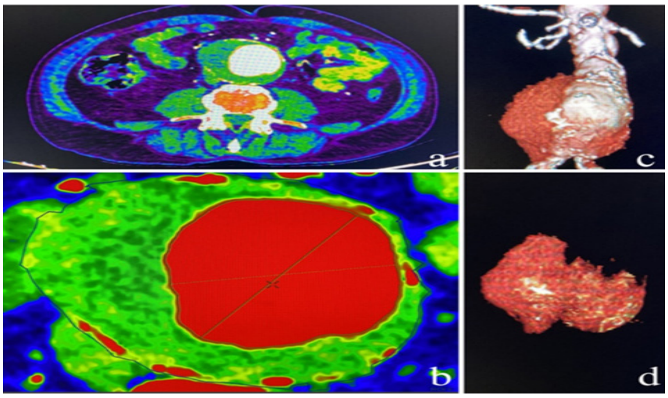

Figure 1. Measurement of infrarenal aortic thrombus (a,b) and 3D reformat images; AAA with ILT(c), only ILT(d)
AAA: Abdominal aortic aneurysm, ILT: Intraluminal thrombus

2- Image was magnified two times

3- The aneurysm of interest was manually drawn so that the circumference of the aorta was not to go outside the aortic wall. This process was repeated by skipping three consecutive images until the aneurysm segment ended. The volume of the resulting aneurysm segment was measured in cm^3.

4- In 10 of the 50 patients in the study, -61/88 HU was determined as the optimal threshold value by experimenting with combinations that would best paint ILT and best suppress the lumen from the threshold values applied in previous study.[6]

In all patients, the volume of ILT was measured by adjusting these threshold values (cm^3).

To evaluate the relationship between the amount of thrombus and other characteristics, we used the ratio we formulated as (ILT volume/ aneurysm volume) X100 (ILT %). The patients was divided into 3 groups according to AD_{max}: ≤5cm, 5-7cm and ≥7cm.[7]

In order to determine the localization in which ILT is the thickest and not to cause confusion in defining the localization of the thrombus, the aneurysm was divided into 4 quadrants with 2 lines perpendicular to each other. It was called anterior quadrant between 10:30 and 01:30 o'clock, left quadrant between 01:30 and 04:30 o'clock, posterior quadrant between 04:30 and 07:30 o'clock, right quadrant between 07:30 and 10:30 o'clock (**Figure 2**).

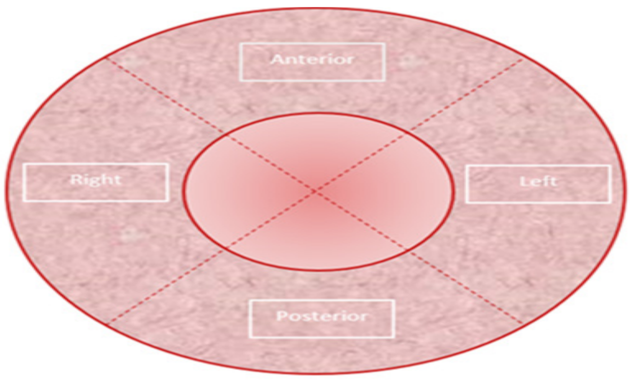

Figure 2. To define the localization of the thrombus, the aneurysm was divided into four quadrants with two lines perpendicular to each other. It was referred to as the anterior quadrant, which was from 10:30 to 01:30 o'clock, the left quadrant, which was from 01:30 to 04:30 o'clock, the posterior quadrant, which was from 04:30 to 07:30 o'clock, and the right quadrant, which was from 07:30 to 10:30 o'clock.

Statistical Analysis

Data analysis was performed using statistical analysis software program SPSS (SPSS 15.0 Inc. Chicago, Illinois). The normality of data was tested by Shapiro-Wilk. Descripitive values such as age, AD_{max}, LLA, volume of the aneurysm, volume of the ILT, and ILT % were given as average±minimum-maximum value and percentage. It was considered statistically significant when the p value was <0.05.

RESULTS

The study was conducted on a total of 50 patients with an average age of 67 years (47–85), 47 (94%) of whom were men and 3 (6%) of whom were women.

Table 1 lists the morphological characteristics of the abdominal aortic aneurysm and ILT. Based on AD_{max}, the participants were split into three groups, and abdominal aortic aneurysm and ILT features of each group were compared in **Table 2**. As the diameter expands, aneurysm volume (p=0.0001) and ILT volume (p=0.0001) significantly increased. A significant increase in ILT % over 5 cm diameter was found, while ILT % was lower until the maximum aorta diameter reached 5 cm.

Table 1. Morphological features of abdominal aortic aneurysm and ILT

AD_{max}, cm	5.6 (3.7-8.8)
LLA, cm	9.8 (4.9-17.1)
Aneurysm volume, cm^3	188.8 (44.8-670.2)
ILT volume, cm^3	104.3 (11.8-474.2)
ILT %	51.7 (11.4-81.3)

The data are shown with mean (min-max). AD_{max}: Maximum aorta diameter, LLA: Longitudinal length of aorta, ILT: Intraluminal thrombus, ILT %: ILT volume/ aneurysm volumeX100

ILT was concentrated in anterior quadrant in 19 patients (38%), left quadrant in 13 patients (26%), posterior quadrant in 8 patients (8%) and right quadrant in 10 patients (20%).

Compared to the distribution of the ILT quadrant with ILT%, the difference between posterior quadrant and anterior, left and right quadrant was statistically significant (p=0.0001, p=0.011 and p=0.0001, respectively). In this case, when the ILT tends to accumulate posteriorly, the ILT% be less. No statistically significant association was found between average ILT volume and age (p=0.35), average ILT % and age (p=0.40).

DISCUSSION

More sophisticated analyses have linked clinical parameters to AAA size and linked aneurysm size to morphological variables.[4] ILT, one of the components of AAA, has therefore become the center of attention of analysis. Measurement of ILT size, especially volume, can be important because ILT volume growth is a predictor of AAA diameter growth.[8] The current study demonstrated a relationship between aneurysm diameter and ILT volume.

When aneurysms were divided into three subgroups according to their diameter, a significant increase in aneurysm volume and ILT volume was observed as the diameter increased. A significant increase in ILT % over 5 cm diameter was found, while ILT % was lower until the maximum aorta diameter reached 5 cm. In addition, ILT tend to be located anteriorly.

The reason of lower ILT % in smaller AAA is probably because protective fibrinolytic mechanism of the body is more active at the early stages of AAA. Because in a study of Piechota-Polanczyk et al.[9] an inhomogeneous multilayered thrombus structure was reported with a stiffer luminal side composed of a dense fibrin network invaded by leukocytes and erythrocytes and by contrast, the medial and abluminal ILT layers with a largely devoid of cellular constituents and to exhibit progressive fibrinolysis and hence decreased thrombus strength and stiffness. Also other multifactorial developmental aspects of AAA and ILT are discussed in their review.

Also Guimarães et al.[10] in their study found that 53% of the cases the mural thrombus was deposited on the anterior wall. As Spanos et al.[11] categorized the thrombus distribution as absent, anterior, posterior and circumferential in their study; anterior location comes after circumferential. Pillari et al.[7] evaluated the relationships between the geometric parameters of the aneurysm and internal parameters such as lumen and ILT in a prospective study; they showed that the ILT volume increased synchronously until the maximum diameter of the aneurysm was 7 cm, the patent pulsatile lumen widened after 7 cm, but no significant increase was detected in the ILT ratio. They suggested that the reason for this was that when the aneurysm exceeded 7 cm, the ILT underwent partial lysis, causing expansion in the patent lumen. Unlike Pillari et al.,[7] in our study, we found that the mean ILT % in aneurysms with a diameter of 5-7 cm was significantly higher than in aneurysms with a diameter of less than 5 cm (p=0.012), and that there was no significant difference in the mean ILT % between aneurysms with a diameter of 5-7 cm and aneurysms with a diameter of more than 7 cm (p=1.000). We thought that the reason why there was no significant difference between aneurysms with a diameter of less than 5 cm and larger than 7 cm in terms of mean ILT % might be due to the small number of patients with aneurysm diameters larger than 7 cm. Larger series are needed for interpretation. Also another

Table 2. Comparison of morphological features of abdominal aortic aneurysm and ILT according to AD_{max}

	≤5 cm (n=18)	5-7 cm (n=24)	≥7 cm (n=8)	p value
Aneurysm volume, cm^3	96.0 (44.8-211.4)	181.1 (84.9-331.7)	420.5 (149.9-670.2)	0.0001*
ILT volume, cm^3	44.0 (11.8-166.3)	103.9 (38.9-223.7)	241.4 (78.5-474.7)	0.0001*
ILT %	41.7 (11.4-81.3)	57.3 (23.5-79.9)	57.2 (29.1-72.8)	0.012** 1.000*** 0.093****

The data are shown with mean (min-max). AD_{max}: Maximum aorta diameter, ILT: Intraluminal thrombus, ILT %: ILT volume/ aneurysm volumeX100, (*) The difference between each group is significant. p value in the comparison of the group ≤5 cm and 5-7 cm (**), 5-7 cm and ≥7 cm (***), ≤5 cm and ≥7 cm (****).

reason can be the measurement technique of ILT amount. They used cross-sectionel area calculation to figure out the amount and ratios instead of 3D volumetric measurements. Since thrombus is consistently an irregular geometric form that may be cause of the differences. Thrombus location was ventral in 28 patients (65%), dorsal in four patients (9.3%), and concentric in 11 patients (25.6%) in their study.

Hans et al.[4] in a study on patients with intact and ruptured AAA they also quantified the ILT volume by 2D methods. They calculated the volume by multiplying the cross-sectionel area of both the aneurysm and the active lumen with the lenght of each segment (at intervals of 10 mm). For segmental ILT volume they substracted the later from the former and for total ILT volume they sum up the volume of all discs. They also found ILT deposited mostly in the anterior compartment. Since in our study we did not evaluate ruptured AAA we could not compare the other result.

In studies aimed at identifying the determinants of aortic thrombosis, techniques such as weighing the weight of the thrombus material removed during the operation, US or CT were applied to determine the amount of thrombus. In CT-based techniques, measurements such as thrombus thickness, area and volume were used.[6] Volume measurements in these studies were mostly determined by 2-dimensional conventional CT, based on the mathematical calculation in which the thrombus area in one or more axial sections and the length of the aneurysm were used. The volume measurements in our study are based on a semi-automatic method that completely separates the structures of interest from the rest by adjusting the threshold values. Since the specified threshold values only paint the thrombus, volume measurement is not affected by factors such as tortiosity of the aneurysm, diameter and thrombus thickness changes at different levels.

Golledge and colleagues[6] also used a similar method for volume measurement in their study, finding a strong relationship between thrombus volume and total aneurysm volume ($r=0.87$, $p<0.0001$) and the maximum aneurysm diameter ($r=0.74$, $p<0.0001$).

Limitations

There were several limitations of our study. First we had small sample size of 50 patients and most of them were male. Since AAA is seen more in males even if the patient population was larger male dominance was an expected situation. Second as mentioned in many studies volumetric and three-dimensional measurements of ILT is more accurate but only disadvantage with this measurement method is that it is time-consuming. Another limitation is that the effect of thrombus volume and density on treatment success and complications could not be investigated due to the lack of patient follow-up.

CONCLUSION

A strong relationship was found between the volume of the thrombus and the volume of the aneurysm and the maximum diameter of the aneurysm. Significant differences were found between small and medium-diameter aneurysms in terms of ILT %, while no significant differences were found between medium-and large-diameter aneurysms. ILT tends to be located anteriorly eccentric, while ILT % is less when located posteriorly eccentric.

ETHICAL DECLARATIONS

Ethics Committee Approval

This study was prepared by using the data obtained from Medical Master`s Thesis we completed in Ankara Turkiye Yüksek İhtisas Hospital in 2009 (Thesis No: 03.04.2009-221).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

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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