

# Predictive CT Features in Ruptured Abdominal Aortic Aneurysm

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**Objective:** To evaluate the CT findings including size of aneurysm, hyperattenuation crescent sign and focal discontinuity of mural calcification to predict the risk of ruptured aneurysm.

**Material and Method:** Records of 27 patients, who underwent Multislices Computed Tomography (MDCT) and required operative repair of abdominal aortic aneurysm from July 2000 to July 2003 were retrospectively reviewed. Two radiologists evaluated the images by consensus, analyzing the aneurysm size, hyperattenuation crescent sign, and focal discontinuity of mural calcification.

**Results:** The authors found that the mean maximum AP diameters of the aneurysm in the ruptured and non-ruptured group were 6.95 cm and 5.50 cm, respectively. All patients in the ruptured group had an aneurysm size of more than 5.0 cm. The hyperattenuation crescent sign and focal discontinuity of mural calcification had a high specificity for predicting ruptured aneurysm, 95% and 100%, respectively. There was statistical significant difference between the ruptured aneurysm and non-ruptured groups in the patients who had maximum aneurysm size more than 5 cm with positive hyperattenuation crescent sign ( $p < 0.041$ ).

**Conclusion:** A maximum size of aneurysm greater than 5 cm with positive hyperattenuation crescent sign is a suggestive sign to predict ruptured aneurysm.

**Keywords:** Abdominal aortic aneurysm, Diagnostic, CT

**J Med Assoc Thai 2006; 89 (4): 434-40**

**Full text. e-Journal:** <http://www.medassocthai.org/journal>

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Rupture of abdominal aortic aneurysm (AAA) is a life threatening complication. The overall mortality rate of AAA ruptures ranges from 70% to 94%. More than half of the patients die before they reach the hospital. Even among patients who reach the hospital and undergo operative repair, the average mortality rate is approximately 50%. The average operative mortality rate of 4% for non-ruptured AAA<sup>(1-5)</sup>. The classic symptoms of ruptured AAA are hypotension, abdominal pain or flank pain, and pulsatile abdominal mass. However, this classic triad presented in less than 50% of the patients in one series<sup>(6)</sup>. CT is usually requested in hemodynamically stable patients to confirm the diagnosis and to exclude other causes of abdominal pain, such as intraabdominal abscess, mass, renal colic, or enlarged lymph nodes.

There is no problem in diagnosing frank AAA rupture, which shows massive periaortic hemorrhage involving the perirenal or pararenal spaces or both, anterior displacement of the kidney, indistinct aortic wall at the site of the rupture, and extravasations of intravenous contrast material in acute bleeding<sup>(7-14)</sup> is easily done. Nonetheless, some patients have abdominal pain, and their CT scans fail to reveal massive retroperitoneal hemorrhage or extravasations of contrast material. These patients may have impending or contained ruptured AAA. Many authors have studied the internal architecture of AAA which may be helpful in predicting the risk of a rupture<sup>(15-18)</sup>.

A high-attenuation crescent sign was first described in 1988 by Pillari et al<sup>(15)</sup>. This was the crescentic hyperattenuation area within the aortic wall or mural thrombus of AAA, which suggested penetration of blood into the mural thrombus. As the rupture progressed, the hemorrhage extended to the outer margin of the thrombus and was limited by the aortic

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wall<sup>(16)</sup>. The sensitivity and specificity of high attenuation crescent sign as an indicator of complicated aneurysm was 77% and 93%, respectively<sup>(17)</sup>. This sign showed a statistically significant correlation with large aneurysm size ( $p < 0.001$ ).

Siegel et al<sup>(18)</sup> studied the internal architecture of AAA from CT images for diagnosis of ruptured AAA. They concluded that detection of a high-attenuation crescent sign or focal gap of circumferential wall calcification was associated with ruptured AAA.

Depending only on the size of AAA, the risk of rupture varies. For a 4 cm aneurysm, the risk was approximately 2%; but for aneurysms larger than 5-cm, the risk increased to 25%-41% over 5 years<sup>(6)</sup>. Because the risk of rupture increased substantially with larger aneurysms, most vascular surgeons would electively repair AAA larger than 5 cm in diameter unless there was a strong contraindication for surgery<sup>(19)</sup>.

The purpose of the present study was to evaluate the interesting CT findings, which had been reported from the previous studies included: The maximum diameter of AAA, the presence of high-attenuation crescent sign, and focal gap of circumferential calcification, whether those can predict or associate with ruptured AAA.

#### Material and Method

Between July 2000 and July 2003, the records of the patients, whose diagnosis was abdominal aortic aneurysm (AAA), admitted to Srinagarind Hospital, Khon-Kaen University were reviewed retrospectively.

There were 27 patients who had a complete clinical history, multislices CT images, operative findings, clinical outcome and/or follow up data. There were 23 male, and 4 female patients, age ranged from 27 to 85 years. All of them underwent abdominal CT scan to determine the type and complication of AAA prior to any surgical intervention.

All CT examinations were performed with multislices CT scanner (SIEMENS SOMATOM Plus 4). Pre-and postcontrast scans were obtained. The technique was 120 KV, 100 mAs, 300 mAs and 5 mm collimation. The postcontrast enhanced scans were done when the attenuation of contrast material in abdominal aorta was about 80-100 HU. The contrast medium (100 ml, 300 mgI/ml, nonionic contrast medium) was administered intravenously by mechanical injector at the rate of 3 ml/sec.

All CT images were reviewed by two radiologists for the types of aneurysm and the interesting findings with blinded operative findings. The dis-

agreement was resolved by consensus. Because the presence of retroperitoneal hemorrhage is easily identified in some patients with aortic rupture, the studies could not be interpreted in a blinded fashion.

#### Definition of the CT findings<sup>(18)</sup>:

1) The maximum AP diameter of AAA is measured on axial image.

2) The high-attenuation crescent sign is the curvilinear area paralleling the aortic wall, which the attenuation higher than intraluminal aortic blood on non-contrast enhanced CT, or high attenuation compare to adjacent psoas muscle on contrast enhanced CT (Fig. 1, 2).

3) Focal gap in circumferential calcification is an abrupt broken in thin or thick continuous pattern of mural calcification (Fig. 2).

#### Statistical analysis

The sensitivity, specificity, positive and negative predictive values were calculated for hyperattenuation crescent sign and focal discontinuity of mural calcification as the indicators of ruptured abdominal aortic aneurysms.

The two-tailed Fisher exact test was used to determine the statistical significance of the presence or absence of hyperattenuation sign versus the insult of ruptured aneurysm. A p-value of less than 0.05 was considered statistical significant.



**Fig. 1** Unenhanced CT scan shows abdominal aortic aneurysm with positive hyperattenuation crescent sign (arrow). Note the small amount of periarotic hematoma. The surgical finding of this patient was concealed rupture AAA

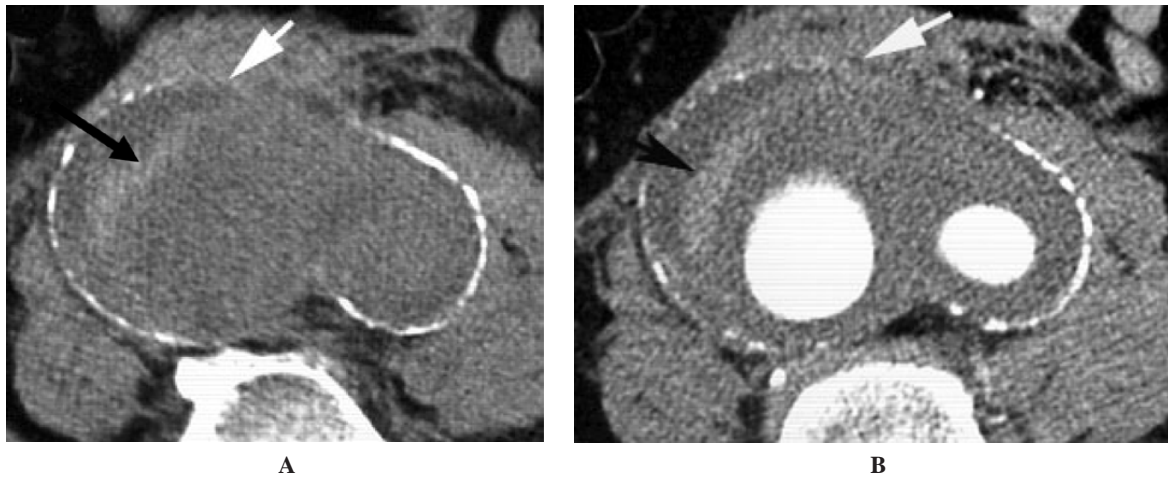
## Results

The authors found suprarenal type [n = 1 (3.7%)], juxtarenal type [n = 1 (3.7%)], and infrarenal type [n = 25 (92.6%)] AAA. In 8 (29.6%) of the 27 patients, the aneurysm complications encountered at surgery were frank rupture (3 cases, 11.1%), and contained rupture (5 cases, 18.5%).

At CT, all patients with ruptured aneurysm had maximum AP diameter of more than 5 cm (Table 1). The mean maximum AP diameters of aneurysm were

6.95 cm (range 5.5-8.5 cm) and 5.50 cm (range 4.0-9.0) in ruptured and non-ruptured group, respectively.

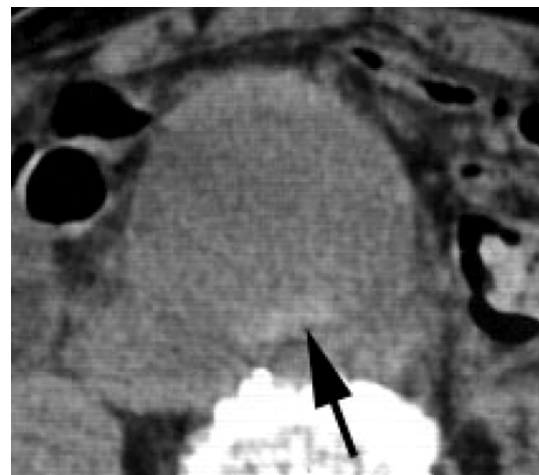
The hyperattenuation crescent sign was identified in 6 (22%) patients (Fig. 1, 3, 4). Five of them had ruptured aneurysm at surgery (concealed rupture in 3 patients and frank rupture in 2 patients). The remaining 1 patient did not have AAA ruptured at operation (Fig. 5). The overall sensitivity of hyperattenuation crescent sign as an indicator of complication of aneurysm (ie, concealed rupture, or frank rupture) was 62.5%



**Fig. 2** Focal discontinuity of continuous mural calcification. (A) Unenhanced CT scan reveals focal break of calcification at the anterior wall of the aneurysm (white arrow) and positive hyperattenuation crescent sign (black arrow). (B) A contrast enhanced CT scan in the same patient reveals a high crescentic area which has a higher density than the adjacent psoas muscle (black arrow)



**Fig. 3** Unenhanced CT scan, there is positive hyperattenuation crescent sign at the anterior wall of the aneurysm (arrow). This patient had frank rupture of aneurysm at surgery



**Fig. 4** Unenhanced CT scan, the CT image shows small high attenuation crescent area at the posterior wall of the aneurysm (arrow). Concealed rupture of the aneurysm was found at surgery

**Table 1.** The result of AP diameter in ruptured aneurysm versus non-ruptured abdominal aortic aneurysm

Size	Results		Total
	Ruptured	Non-ruptured	
Grade I (<5 cm)	0	8	8
Grade II (5-7 cm)	4	8	12
Grade III (>7 cm)	4	3	7
Total	8	19	27

**Table 2.** The results of hyperattenuation crescent sign in abdominal aortic aneurysm

Crescent sign	Results		Total
	Ruptured	Non-ruptured	
Positive	5	1	6
Negative	3	18	21
Total	8	19	27

Sensitivity =  $5/8 \times 100 = 62.5\%$

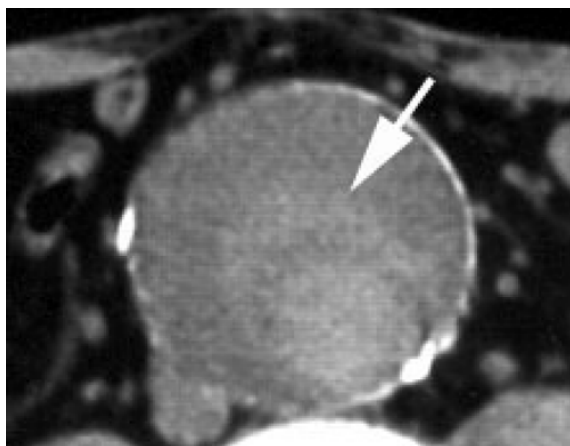
Positive predictive value =  $5/6 \times 100 = 83.3\%$

Specificity =  $18/19 \times 100 = 94.7\%$

Negative predictive value =  $18/21 \times 100 = 85.7\%$

and the specificity was 94.7%. The positive and negative predictive values of the sign were 83.3% and 85.7%, respectively (Table 2).

All patients with ruptured aneurysm had the maximum aneurysm size of more than 5 cm (Table 1).



**Fig. 5** False positive hyperattenuation crescent sign. Non-enhanced CT image shows high density crescent area at the most inner aspect of mural thrombus (arrow). Note the relatively low density of this area compared to the intraluminal blood. No evidence of ruptured aneurysm was found at surgery

They all had positive hyperattenuation crescent sign. However, in the non-ruptured group, 11 of 19 patients had an aneurysm size > 5 cm, only 1 from those 11 patients had positive hyperattenuation crescent sign. There was statistical significant difference between the ruptured and non-ruptured groups in the patients who had maximum aneurysm size more than 5 cm with positive and negative hyperattenuation crescent sign ( $p < 0.041$ ) (Table 3).

At CT, only one patient in the present study revealed focal discontinuity of mural calcification ( $n = 1$  [3.7%]) (Fig. 2), and concealed rupture was found at surgery (Table 4). When correlating this CT image to the surgical findings, the site of discontinuity of mural calcification was the ruptured site. The sensitivity of

**Table 3.** The correlation between aneurysm size (> 5 cm) and hyperattenuation crescent sign

Crescent sign	Results	
	Ruptured	Non-ruptured
Positive	5	1
Negative	3	10

\*  $p = 0.041$  by Fisher's Exact test

**Table 4.** The results of focal discontinuity of continuous mural calcification and ruptured aneurysm

Discontinuity of calcification	Results		Total
	Ruptured	Non-ruptured	
Positive	1 (12.5%)	0 (0%)	1
Negative	7 (87.5%)	19 (100%)	26
Total	8 (100.0%)	19 (100%)	27

focal discontinuity of mural calcification as an indicator for ruptured aneurysm was 12.5% (1/8 x 100) and specificity of 100% (19/19 x 100). Positive and negative predictive values were 100% (1/1 x 100) and 73% (19/26 x 100), respectively.

### Discussion

The CT diagnosis of ruptured abdominal aortic aneurysm is based exclusively on the ability of the interpreter to detect extraluminal hemorrhage (usually retroperitoneum) in patients with abdominal pain and a large abdominal aortic aneurysm (10, 20). A patient presenting with abdominal pain, a large abdominal aortic aneurysm, and no frank rupture in retroperitoneal space on CT scan poses a diagnostic dilemma. Symptoms may have resulted from a small contained leakage or an impending rupture. In that case, an emergent or semiemergent surgery is indicated<sup>(18)</sup>. It would be helpful if additional CT findings could identify patients whose aneurysms are unstable, especially when the CT diagnosis of rupture is difficult or impossible to make.

Hyperattenuation crescent sign was first described by Pillari et al in 1988<sup>(15)</sup>. This sign suggests penetration of blood into the mural thrombus and may extend to the outer margin of the thrombus while ruptured process is in progress. This sign shows a statistical significant correlation with a large aneurysm size<sup>(17)</sup>. Peripheral hyperattenuation crescent sign has been hypothesized to represent an early sign of aneurysm rupture by Mehard et al<sup>(17)</sup>. The sensitivity and specificity of this sign to predict the risk of a ruptured aneurysm are about 77% and 93%, respectively<sup>(17)</sup>.

Johnson et al<sup>(21)</sup> listed many helpful features of abdominal aortic aneurysm seen on CT scan that suggest instability of the aneurysm, including focal discontinuity of calcified rim and contrast material insinuating into the thrombus itself. Conversely, some authors have suggested that some features of aneurysms seen on CT scan may indicate that an aneurysm

is stable and unlikely to rupture<sup>(16)</sup>. Specifically, identification of a large amount of thrombus or mural calcification may be protective<sup>(15)</sup>.

The present study showed the sensitivity of hyperattenuation crescent sign in a ruptured aneurysm is 62.5%. This sign had high specificity (95%) and high positive predictive value (83%) in predicting a ruptured aneurysm. There was a false positive in only one case in the present study.

The CT images were again reviewed and the authors found that, the characteristic of hyperattenuation crescent sign was actually not compatible with the criteria. The images of this patient showed a high density crescent area at the most inner part of the thrombus, but relatively lower density compared to the intraluminal blood (Fig. 5). This appearance may be due to slow flow of intraluminal blood in the AAA. If the authors corrected this missed interpretation, the specificity and positive predictive value will increase to 100%. From this observation, the criteria for diagnosis of hyperattenuation crescent sign are very important.

About the correlation between the size of aneurysm and the presence or absence of hyperattenuation crescent sign, the authors found that all ruptured aneurysms in the present study had an aneurysm size of more than 5 cm and 5 of 8 patients had a positive hyperattenuation crescent sign. Only one patient in the non-ruptured group who had an aneurysm size larger than 5 cm showed the positive crescent sign. The p-value was less than 0.041 when comparing the crescent sign positive group with the negative group. According to this result, the finding of positive hyperattenuation crescent sign in AAA size larger than 5 cm is significant enough to be used as one of the predictors of a ruptured aneurysm. Emergency or semiemergency surgical intervention should be performed in these patients.

As for the focal discontinuity of mural calcification, the prevalence of this sign in the present study was 12.5% while the study by Siegel et al<sup>(18)</sup> was about

8%. The relatively high prevalence in the present study may be due to the rather small population. However, there was only one patient in whom the surgical finding showed concealed rupture of the aneurysm at the site of discontinuity of mural calcification compatible with CT image. Therefore, if disruption of continuous mural calcification is detected at the wall of the aneurysm, rupture may be present. In the authors' opinion, if focal discontinuity of continuous mural calcification without evidence of frank rupture is depicted, this may indicate an unstable site of AAA wall in which frank rupture may be in progress. However, the present study had some limitations due to the small population in AAA, so the power of the characteristic on the CT scan to predict ruptured AAA may not represent the overall population.

### Conclusion

The CT findings of AAA size more than 5 cm with positive hyperattenuation crescent sign is a predictive feature of ruptured aneurysm, emergency or semiemergency surgical intervention should be followed. Although the low prevalence of focal discontinuity of continuous mural calcification, its presence may indicate the rupture site.

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**การประเมินลักษณะความผิดปกติที่พบจากตรวจเอกซเรย์คอมพิวเตอร์เพื่อพยากรณ์การแตกของ  
หลอดเลือดแดงใหญ่โป่งพองที่บริเวณช่องท้อง**

จุริรัตน์ ธรรมโรจน์, แสงระวี วังตาล, จิราภรณ์ ศรีนัครินทร์

**วัตถุประสงค์:** เพื่อประเมินลักษณะความผิดปกติที่พบจากการตรวจทางเอกซเรย์คอมพิวเตอร์ในการพยากรณ์  
การแตกของหลอดเลือดแดงใหญ่โป่งพองที่บริเวณช่องท้อง

**วัสดุและวิธีการ:** คณะผู้วิจัยได้ศึกษาประวัติและผลตรวจเอกซเรย์คอมพิวเตอร์ แบบ multislices ของผู้ป่วย 27 ราย  
ซึ่งได้รับการผ่าตัดรักษาโรคหลอดเลือดแดงใหญ่โป่งพองแบบย้อนหลัง ระหว่างเดือนกรกฎาคม พ.ศ. 2543 ถึงเดือน  
กรกฎาคม พ.ศ. 2546 การวินิจฉัยความผิดปกติทำโดยรังสีแพทย์ 2 คน ลงความเห็นร่วมกัน โดยการวัดขนาดของ  
หลอดเลือดที่ผิดปกติในภาพตัดขวาง พบ hyperattenuation crescent sign ที่เด่นชัด และลักษณะความไม่ต่อเนื่อง  
ของหินปูนที่ผนังหลอดเลือด

**ผลการศึกษา:** พบว่าค่าเฉลี่ยของเส้นผ่าศูนย์กลางที่กว้างที่สุดในกลุ่มผู้ป่วยที่หลอดเลือดแดงโป่งพองแตก และไม่แตก  
เท่ากับ 6.95 ซม. และ 5.50 ซม. ตามลำดับ ส่วนการพบ hyperattenuation crescent sign ที่เด่นชัดและลักษณะ  
ความไม่ต่อเนื่องของหินปูนที่เกาะบนหลอดเลือดแดงใหญ่มีความจำเพาะสูงในการพยากรณ์การแตกของหลอดเลือด  
แดงใหญ่โป่งพอง โดยมีความจำเพาะในการพยากรณ์ร้อยละ 95 และ 100 ตามลำดับ และพบว่าถ้าผู้ป่วยที่มีขนาด  
เส้นผ่าศูนย์กลางของหลอดเลือดแดงโป่งพองที่กว้างที่สุดมากกว่า 5 ซม. ร่วมกับ hyperattenuation crescent sign  
ที่เด่นชัดจะมีโอกาสเสี่ยงสูงต่อการแตกของหลอดเลือดแดงโป่งพองอย่างมีนัยสำคัญทางสถิติ ( $p < 0.041$ )

**สรุป:** ถ้าขนาดเส้นผ่าศูนย์กลางของหลอดเลือดที่ผิดปกติมากกว่า 5 ซม. ร่วมกับมี hyperattenuation crescent sign  
ช่วยสนับสนุนว่าผู้ป่วยมีโอกาสรักษาสูงต่อการแตกของหลอดเลือดนั้น

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