Detectability of unruptured intracranial aneurysms on thin-slice non-contrast-enhanced CT

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Aims and objectives

Intracranial aneurysm is a common disease. Most aneurysms do not rupture, but once aneurysmal rupture and subarachnoid hemorrhage occurs, the prognosis is poor [1]. The natural history of intracranial aneurysm has been well studied [2-5], and interventions for unruptured intracranial aneurysms (UIAs) are considered based on the natural history and patient characteristics [6]. Thus, the incidental detection of UIAs is clinically relevant.

The gold standard for the diagnosis of intracranial aneurysms is digital subtraction angiography (DSA), and CT angiography can also detect intracranial aneurysms accurately [7,8]. To the best of our knowledge, the detection of intracranial aneurysms using non-contrast-enhanced CT (non-CECT) has not been previously studied because of the poor contrast between vessels and surrounding structures and the thick slice reconstruction.

However, recent CT developments have enabled a reduction in artifacts [9] and better thin-slice images using helical scans. Such developments have led to the possibility of the incidental detection of UIAs without contrast-enhancement during daily routine head CT examinations.

The aim of the present study was to investigate the detectability of UIAs on thin-slice non-CECT images.

Methods and materials

Patients

Patients who underwent non-contrast and contrast-enhanced CT examinations on the same day between May 2013 and April 2014 were included. Patients with acute subarachnoid hemorrhage, acute stroke, intracranial tumor, or a postoperative status were excluded. Ninety-eight patients (58.5 ± 15.1 years; range, 20-83 years; male:female ratio, 49:49) were examined. The hematocrit (Ht) value was retrieved from the medical records, if available.

CT protocol

The CT acquisition parameters were as follows: 64-slice multi-detector CT; collimation, 0.5-1 mm; pitch factor, 0.844-1; rotation time, 1-1.5 seconds per rotation; tube voltage, 120 kV; tube current, 250 mA or auto-exposure control modulation systems; field of view, 150-230 mm. For CT angiography, a total of 60 mL of iodine contrast material were
injected at a rate of 3.0 mL/s, and the scan was manually started using bolus tracking of the carotid artery.

**Image evaluation**

Two radiologists independently evaluated 1-mm or 0.5-mm reconstructed non-CECT images for evidence of UIAs without clinical information; a consensus was reached for cases with discrepant findings. Another radiologist evaluated the CT angiography results to determine the presence, location, and size of each aneurysm.

The locations of the aneurysms were categorized as anterior communicating artery (Acom), anterior cerebral artery distal portion (ACAdist), middle cerebral artery (MCA), internal carotid artery distal portion (ICAdist) including the internal carotid - posterior communicating artery (IC-PC), internal carotid - anterior choroidal artery (IC-AchA) and ICA tip, ICA proximal portion (ICAprox) including the proximal portion from the IC-PC, vertebral artery (VA), basilar artery (BA), and posterior cerebral artery (PCA).

**Statistics**

Data were analyzed using commercial software. The aneurysmal size (<5 mm/5 mm or more), location (internal carotid proximal region/other regions) and Ht value (<45%/45% or more) were categorized and compared using the Pearson $\chi^2$ test. To identify variables associated with the detectability of unruptured aneurysms, a multivariate analysis was performed using a logistic regression model with a stepwise selection procedure.

A P value less than 0.05 was considered to be a significant difference.

**Results**

Sixty-one aneurysms were detected using CT angiography in 51 patients, and 39 of them were correctly detected on non-CECT (Table 1.). Four false-positive cases occurred. The total sensitivity and positive predictive values for the thin-slice non-CECT findings were 63.9% and 90.7%, respectively. The aneurysmal size (<5 mm/5 mm or more), location (internal carotid proximal region/other regions), and Ht value (<45%/45% or more) were significantly associated with the detection of unruptured aneurysms in univariate ($P < 0.001, P < 0.01, P < 0.05$, respectively) and multivariate analyses. All 14 aneurysms that were 7 mm or more in diameter could be detected on non-CECT. In the case of 5 mm or larger aneurysms in the non-ICA proximal region, the sensitivity of the thin-slice non-CECT images was 96.0%.
Table 1. Aneurysmal sites and detection results.

<table>
<thead>
<tr>
<th>Site</th>
<th>An (n)</th>
<th>TP (n)</th>
<th>FP (n)</th>
<th>FN (n)</th>
<th>Sensitivity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICAprox</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>22.2</td>
</tr>
<tr>
<td>ICAdist</td>
<td>14</td>
<td>7</td>
<td>1</td>
<td>7</td>
<td>50</td>
</tr>
<tr>
<td>Acom</td>
<td>13</td>
<td>10</td>
<td>3</td>
<td>3</td>
<td>76.9</td>
</tr>
<tr>
<td>ACAdist</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>MCA</td>
<td>16</td>
<td>14</td>
<td>0</td>
<td>2</td>
<td>87.5</td>
</tr>
<tr>
<td>VA - PICA</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>66.7</td>
</tr>
<tr>
<td>BA</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>PCA</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>66.7</td>
</tr>
<tr>
<td>Total</td>
<td>61</td>
<td>39</td>
<td>4</td>
<td>22</td>
<td>63.9</td>
</tr>
</tbody>
</table>

ACAdist, anterior cerebral artery distal portion; Acom, anterior communicating artery; An, aneurysm; BA, basilar artery; FN, false negative; FP, false positive; ICAdist, internal carotid artery distal portion; ICAprox, internal carotid artery proximal portion; MCA, middle cerebral artery; n, number; PCA, posterior cerebral artery; PICA, posterior inferior cerebellar artery; TP, true positive; VA, vertebral artery.

Images for this section:

Fig. 1: A true-positive case of a 77-year-old male with an unruptured 6.2-mm anterior communicating artery aneurysm. (A) Non-contrast-enhanced CT, (B) contrast-enhanced CT, and (C) volume rendering CT angiography image.
Fig. 2: A true-positive case of a 41-year-old male with an unruptured 2.9-mm right middle cerebral artery aneurysm. A high hematocrit value (48%) facilitated the tracking of the cerebral vessels and the correct detection of the aneurysm on a non-contrast-enhanced CT image. (A) Non-contrast-enhanced CT, (B) contrast-enhanced CT, and (C) volume rendering CT angiography image.

Fig. 3: True-positive case of a 63-year-old male with multiple large aneurysms. The large aneurysms were easily detected on the non-contrast-enhanced CT image. (A) Non-contrast-enhanced CT and (B) contrast-enhanced CT.
Fig. 4: A false-negative case of a 71-year-old male with an unruptured 5.9-mm left internal carotid proximal aneurysm. Because of the lack of cerebrospinal fluid surrounding the vessels, the tracking of the cerebral arteries and the detection of aneurysms were difficult in the internal carotid proximal region. (A) Non-contrast-enhanced CT, (B) contrast-enhanced CT, and (C) MR angiography.
Conclusion

We conducted a preliminary study examining the detection of UIAs using non-CECT and demonstrated a better sensitivity than anticipated. Non-CECT examinations are widely performed in daily clinical practice as part of examinations for trauma or screening for intracranial disease. Since UIA is not a rare disease, the incidental detection of UIAs is thought to be relatively high. Larger aneurysms, in particular, are associated with a higher risk of rupture and are also more likely to be detected using non-CECT. Thus, careful evaluation of the subarachnoid space and common sites of aneurysms is recommended.

We conducted a logistic regression analysis including factors such as the size and location of each aneurysm as well as the Ht value (reflecting the vessel density) and the patient age (which is associated with brain atrophy and an enlarged subarachnoid space). These four factors were considered to be the main factors associated with detectability, but patient age was not significantly related. This result suggests that patient age might be negatively correlated with the Ht value and may not directly reflect brain atrophy itself.

In conclusion, UIAs were identifiable using non-CECT with thin-slice images, especially aneurysms that were 5 mm or larger in size and that were located in the non-IC proximal region. Careful evaluation of the subarachnoid space may enable the detection of incidental UIAs with a relatively high risk of rupture that require further investigation.

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