Treatment decision in ruptured intracranial aneurysms: comparison between multi-detector row CT angiography and digital subtraction angiography

Décision de traitement des anévrismes rompus intracrâniens : comparaison entre l’angioscanner multibarrette et l’angiographie conventionnelle

C.-A. Taschner\textsuperscript{a,*}, L. Thines\textsuperscript{b}, M. Lernout\textsuperscript{a}, J.-P. Lejeune\textsuperscript{b}, X. Leclerc\textsuperscript{a}

\textsuperscript{a} Department of neuroradiology, hôpital Roger-Salengro, CHRU Lille, rue Émile-Laine, 59037 Lille cedex, France
\textsuperscript{b} Department of neurosurgery, hôpital Roger-Salengro, University Hospital Lille, Lille, France

Available online 29 August 2007

**KEYWORDS**
CT angiography; Digital subtraction angiography; Endovascular treatment; Intracranial aneurysms; Multidetector-row technology; Surgical clipping

**Abstract**

**Objective.** — The aim of this study was to determine the accuracy of multi-detector row computed tomography angiography (CTA) for the triage of patients with acutely ruptured aneurysms, and to assess how therapeutic decisions based on this method compared with digital subtraction angiography (DSA).

**Methods.** — Twenty-seven consecutive patients with acute subarachnoid hemorrhage were included, and underwent both CTA and DSA. CTA was performed on a 16-detector row CT scanner with a 0.75-mm collimation and a 0.558-beam pitch. Two readers reviewed the CTA data, and two different readers reviewed the DSA data. Aneurysm characteristics were recorded and treatment by surgical clipping or endovascular coil embolization was proposed.

**Results.** — A total of 24 aneurysms were identified on DSA in 21 patients. Sensitivity and specificity for CTA were 100% and 83%, respectively, on a per-aneurysm-basis. The correlation between DSA and CTA for the determination of sac and neck sizes was very good \((r = 0.92, \text{ and } r = 0.95, \text{ respectively, } P < 0.0001)\). Sensitivity and specificity for the detection of arterial branches incorporated into the aneurysmal sac or neck were 50% and 100%, respectively. In three aneurysms, readers judged CTA inappropriate for triage, because peri-aneurysmal branches were not properly visualized. Overall agreement between CTA and DSA regarding the therapeutic decision between surgical clipping and endovascular coil embolization in 24 aneurysms was good \((k = 0.76)\).

**Conclusion.** — Multi-detector row CTA provides accurate anatomic information for aneurysm location as well as sac and neck sizes; however, the technique appears to have a low sensitivity in detecting branches incorporated into the aneurysmal sac.

© 2007 Elsevier Masson SAS. All rights reserved.
Introduction

Intracranial aneurysms have a reported prevalence of 0.65-9% in the general population [11,14,22]. The incidence of aneurysm rupture lies in the range of 1:10,000 per year [12]. Case-fatality rates reported in the literature for aneurysm rupture lies in the range of 1:10,000 per year worldwide [6,13].

Precise information on the aneurysms morphology is mandatory for patient triage between endovascular coil embolization and surgical clipping. So far, digital subtraction angiography (DSA) has been regarded as the standard-of-reference for the detection and characterization of intracranial aneurysms in patients with acute subarachnoid hemorrhage (SAH). Three-dimensional (3D) DSA data acquired with rotational angiography techniques is an important adjunct for the pre-therapeutic evaluation of ruptured aneurysms. The ample availability of novel CT techniques with multi-detector row acquisition, considerably improving the spatial resolution of CTA data, has started to change the diagnostic algorithm in patients with acute SAH. A number of comparative studies have shown that multi-detector row CTA has high sensitivity and specificity for the detection of intracranial aneurysms in patients with acute SAH [4,8,9,15,17,21,23]. CTA has also been used as unique pre-therapeutic tool in the preparatory phase of aneurysm clipping [1,5,10,16,20,21].

The purpose of this study was to determine the accuracy of multi-detector row computed tomography angiography (CTA) for triage in patients with acutely ruptured intracranial aneurysms, and to assess, how therapeutic decisions based on this method compared with DSA.

Subjects and methods

Patients

From November 2005 through February 2006, 27 consecutive patients (15 women and 12 men; mean age: 49 years, range: 19-72 years) admitted for a non-traumatic SAH were enrolled in this prospective study and had both, multi-detector row CTA and DSA as part of the diagnostic and pre-therapeutic work-up. The diagnosis of SAH was made by CT (N = 25), or lumbar puncture (N = 2). Exclusion criteria were poor clinical grade, patient agitation, renal insufficiency, and known allergy to iodinated contrast agents. Two patients presenting with SAH could not be enrolled into the study due to a poor clinical grade. The study was approved by the local ethics committee.
Multi-detector row CTA

CT examinations were carried out on a 16-detector row scanner (Volume Zoom, Siemens, Erlangen, Germany). Parameters for the CTA acquisition were 0.75 mm section thickness, 0.5 mm section interval, 100 kVp, 200 mAs, and 160 mm field of view with a scanning time of approximately 8 s. The table feed was 13.4 mm/s at a scan revolution time of 0.5 s resulting in a beam pitch of 0.558. The scanned volume provided full anatomic coverage of all potential intracranial aneurysmal sites from the axis to the vertex. A total of 80 mL iomeprol (Iomeron 400, Bracco S.p.a, Milan, Italy) were administered intravenously with a power injector at a rate of 3.5 ml/s via a venous line. The correct timing of contrast media injection was achieved by applying a bolus tracking technique. Acquisition of the CTA was started when the density of a predefined region of interest set within the aortic arch passed a value of 120 HU.

Intra-arterial DSA

Intra-arterial DSA was performed on a monoplane digital angiographic unit (Allura, Philips Medical Systems, Best, the Netherlands), via a transfemoral approach with bilateral selective injections of the internal carotid and vertebral arteries with frontal and lateral views. In addition, a rotational acquisition with 3D reconstructions was performed for any aneurysm diagnosed. Images were acquired with a 22 cm field-of-view, and a 1024 × 1024 matrix.

Image interpretation

Two sets of readers composed of one interventional neuroradiologist and one cerebrovascular neurosurgeon each, retrospectively and independently reviewed the CTA data (X.L., J.P.L.) and the DSA data (C.A.T., L.T.). This protocol recreates the pre-therapeutic situation when the cerebrovascular neurosurgeon and the interventional neuroradiologists make a joint decision regarding the treatment strategy for the revealed intracranial aneurysms.

CTA data was evaluated on a computer workstation (Syngo, Siemens, Erlangen, Germany) by using preset volume-rendered and maximum intensity projection display algorithms on InSpace (Siemens, Erlangen, Germany). In addition source images and planar reconstructions from both modalities were reviewed at a window width of 500 HU and a window level of 200 HU. Conventional DSA data was reviewed on hardcopies; 3D reformats of rotational DSA were assessed on a dedicated workstation (Integris 3D-RA, Philips, Best, the Netherlands). Angiographic images were displayed using volume rendered and maximum intensity projection display algorithms. Aneurysm sizes and neck sizes were determined with the caliper tool on 3D reconstructions for both modalities. The presence and location of aneurysms, their largest diameter, neck size, and the presence of side branches originating from the aneurysmal sac were recorded on a scoring sheet.

Patient triage

Triage of patients with ruptured aneurysms between endovascular coil embolization and surgical clipping is based on the evaluation and critical consideration of the clinical grade, the patient age, the extent of the intracranial hemorrhage, the location of the intracranial aneurysm, as well as morphologic features of the underlying malformation. As the aim of the present survey was to evaluate the impact of CTA on medical decision making, patient triage in this study was exclusively based on morphologic criteria of the underlying aneurysm. Readers were asked to identify any contraindications to endovascular coil embolization related to the aneurysms morphologic features. Contraindications to endovascular coil embolization were branches arising from the aneurysmal neck or sac, unfavorable dome - neck ratio, small aneurysmal size (< 2 mm), and inaccessibility of the aneurysmal sac due to vascular pathologies. In the absence of these contraindications, aneurysms were assigned to endovascular coil embolization, when present, aneurysms were allocated to surgical clipping. The treatment option finally recommended, was based on a consensual decision made by the interventional neuroradiologist and the vascular neurosurgeon.

Statistical analysis

Two-by-two tables were constructed from true-positive, false-positive, false-negative, and true-negative results for multi-detector row CTA compared with intra-arterial DSA serving as standard-of-reference. We calculated sensitivity, specificity, positive and negative predictive values regarding the detection of intracranial aneurysms with multi-detector row CTA on a per-aneurysm basis. The calculation of the positive and negative predictive values was based on a supposed prevalence of ruptured intracranial aneurysms in 85% of patients presenting with SAH [19]. Sensitivity and specificity were calculated for the detection of branches originating from the aneurysmal sac on a per-aneurysm basis. Linear regression analysis with calculation of a Pearson correlation coefficient was used to assess the intermodality correlation for the largest aneurysmal diameter and the neck size. Statistical significance was set at \( P < 0.001 \). Kappa statistics were calculated to determine the agreement in the proposed treatment of the diagnosed aneurysms based on anatomical information deriving from either multi-detector row CTA or DSA on a per-aneurysm basis. MedCalc (Medisoftware, Mariakerke, Belgium) was used for statistical analysis.

Results

Technical efficacy

In 27 CT angiograms and 27 DSA, no procedural complications, or allergic reactions to the contrast agent were observed. All exams were of diagnostic quality.

Diagnostic efficacy

In 21 of 27 patients, a total of 24 aneurysms were identified by DSA (Table 1). All aneurysms were identified on CTA. One aneurysm of the anterior communicating artery diagnosed by CTA was not confirmed by DSA. In the remaining five patients no further aneurysm was diagnosed with either
Table 1 Aneurysm characteristics in 27 patients admitted for subarachnoid hemorrhage  
Tableau 1 Caractéristiques des anévrismes chez 27 patients admis pour une hémorragie sous-arachnoïdienne

<table>
<thead>
<tr>
<th>Patient number</th>
<th>Aneurysm number</th>
<th>Aneurysm location</th>
<th>Aneurysm size (in mm)</th>
<th>Incorporated branches</th>
<th>Proposed treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Pcom</td>
<td>5/3</td>
<td>-</td>
<td>Coil</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Acom</td>
<td>7/4</td>
<td>-</td>
<td>Coil</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Pcom</td>
<td>3/2</td>
<td>n.a.</td>
<td>Clip</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Pcom</td>
<td>4/2</td>
<td>-</td>
<td>Coil</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>MCA</td>
<td>4/3</td>
<td>+</td>
<td>Clip</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>MCA</td>
<td>9/3</td>
<td>10/2</td>
<td>Coil</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>MCA</td>
<td>7/3</td>
<td>-</td>
<td>Clip</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>MCA</td>
<td>8/8</td>
<td>-</td>
<td>Clip</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>MCA</td>
<td>10/6</td>
<td>9/5</td>
<td>Clip</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>MCA</td>
<td>6/4</td>
<td>5/3</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>Acom</td>
<td>6/3</td>
<td>5/3</td>
<td>n.a.</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>Pcom</td>
<td>3/2</td>
<td>4/2</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>13</td>
<td>AC</td>
<td>9/5</td>
<td>10/6</td>
<td>Clip</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
<td>MCA</td>
<td>5/3</td>
<td>4/3</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>M1-MCA</td>
<td>6/3</td>
<td>6/3</td>
<td>Clip</td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td>M1-MCA</td>
<td>3/3</td>
<td>3/3</td>
<td>Clip</td>
</tr>
<tr>
<td>17</td>
<td>17</td>
<td>BA</td>
<td>7/3</td>
<td>7/4</td>
<td>-</td>
</tr>
<tr>
<td>18</td>
<td>18</td>
<td>Acom</td>
<td>3/2</td>
<td>3/2</td>
<td>-</td>
</tr>
<tr>
<td>19</td>
<td>19</td>
<td>Acom</td>
<td>5/3</td>
<td>5/3</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>Acom</td>
<td>5/2</td>
<td>6/3</td>
<td>-</td>
</tr>
<tr>
<td>21</td>
<td>21</td>
<td>Acom</td>
<td>6/4</td>
<td>4/3</td>
<td>-</td>
</tr>
<tr>
<td>22</td>
<td>22</td>
<td>Acom</td>
<td>4/2</td>
<td>4/3</td>
<td>-</td>
</tr>
<tr>
<td>23</td>
<td>23</td>
<td>BA</td>
<td>3/3</td>
<td>3/3</td>
<td>-</td>
</tr>
<tr>
<td>24</td>
<td>24</td>
<td>Acom</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>25</td>
<td>25</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>26</td>
<td>26</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>27</td>
<td>27</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>

Pcom: posterior communicating segment of the internal carotid artery (ICA); Acom: anterior communicating artery; M1-MCA: M1 segment of the middle cerebral artery; CB: bifurcation of the intracranial ICA; AC: anterior cerebral artery; M1-MCA: M1 segment of the middle cerebral artery; BA: basilar artery; +: aneurysm present; -: no aneurysm found, n.a.; not assessable; Coil: Absence of contraindication to endovascular coil embolization; Clip: Presence of contraindication to endovascular coil embolization.

Therapeutic efficacy

The assignment to endovascular coil embolization or surgical clipping was based on morphologic features only. Endovascular coil embolization was considered the preferential therapeutic option, and patients were assigned to coil embolization in the absence of any contraindication to endovascular treatment (Fig. 3).

Readers were unable to decide on the therapeutic choice based on CTA data in 3 of 24 aneurysms because important perianeurysmal vessels - an important element for the risk allocation - could not be identified. Of the remaining 21 aneurysms, 14 were allocated to endovascular coil embolization and seven were assigned to surgical clipping. When compared to the therapeutic decision based on DSA data, identical therapeutic choices were made for these 21 aneurysms. We included the three CTAs that were non-diagnostic for the presence of perianeurysmal branches for the calculation of the intermodality agreement. The kappa score for the overall agreement between CTA and DSA regarding the therapeutic decision between surgical clipping and endovascular coil embolization in 24 aneurysms was 0.76.
Principal contraindication to endovascular coil embolization was an unfavorable dome-neck-ratio in five of seven aneurysms, present on both imaging modalities (Fig. 4). An additional incorporated artery was demonstrated on DSA in four cases, three of these were visualized on CTA (aneurysms 6,10+14). Endovascular coil embolization was not considered in another aneurysm due to an unfavorable dome-to-neck ratio without incorporated artery visible on neither imaging modality (aneurysm 17), and in one case, surgical clipping was proposed due to a major branch originating at the base of a MCA bifurcation aneurysm - visualized on both CTA and DSA (aneurysm 16).

Discussion

The present study corroborates findings of previous studies that multi-detector row CTA is an appropriate means for the diagnostic work-up of SAH [1,4,8,9,15,17,20,21,23]. In our study, the sensitivity and specificity for the detection of intracranial aneurysms were 100% and 83.3%, respectively, applying 16-row detector CTA techniques.

A meta-analysis by Chappell et al. based on 21 studies published between 1995 and 2002 including 1252 patients resulted in a sensitivity of 93.3% and a specificity of 87.8% for the detection of intracranial aneurysms [2]. However, most of the studies included were based on single beam, spiral CTA techniques. Major advances have been made by the introduction of multi-detector row scanners. This new technology allows investigation of a large volume with a high x-axis resolution in a very short time with multiple detector rows receiving the attenuated radiation. Multi-detector row CT allows for faster scan coverage and larger z-axis coverage/rotation. With its high spatial resolution and thin slices, the method provides data sets with isotropic voxel size improving the quality of multiplanar reformat and 3D-rendered images [3]. Recent studies applying multi-detector row CTA have reported improved detection rates of intracranial aneurysms in patients presenting with SAH. Kadri et al. reported a sensitivity of 86% and a specificity of 100% for the detection of acutely ruptured aneurysms with CTA [9]. Jayaraman et al. obtained a sensitivity...
of 90% and a specificity of 93% when applying CTA with four detector rows [8]. Tipper et al. used a 16-row detector CTA and reported a sensitivity of 96.2%, and a specificity of 100% for the detection of intracranial aneurysms in patients presenting with intracranial hemorrhage [17]. Teksam et al. report on a series applying multi-detector row CT with 4-detector row technique [15]. They stratified the aneurysms detected and calculated sensitivities according to aneurysmal size. They found an overall sensitivity of 84% for small (< 4 mm), 97% for medium-size (4-10 mm), and 100% for large (> 10 mm) aneurysms. These results seem to justify the exclusive application of multi-detector row CTA for the detection of intracranial aneurysms in patients presenting with SAH, reserving DSA for cases of uncertainty.

The exact characterization of the largest aneurysmal diameter, the neck size, variations of the circle of Willis, and of branches arising from the aneurysmal sac are important issues for the pre-therapeutic risk assessment. In our survey, CTA provided precise information on aneurysms morphology including the largest diameter and the neck size. The efficacy of CTA in detecting small branches originating in the vicinity of, or directly from the aneurysmal sac was restricted in aneurysms located close to the skull base (Fig. 5). This limitation of CTA has been described earlier and is technically related to beam-hardening artifacts from the dense bone of the skull base [21]. For the non-invasive characterization of paraclinoid aneurysms MR angiography might be more appropriate [16]. Another factor limiting the clinical performance of CTA might have been the application of volume rendering techniques, which often include an automatically generated threshold, which may suppress valuable image information such as small vessels. In our study we systematically included complementary information deriving from maximum intensity projections which are more consistent, as they directly rely on source images [18].

Previous reports on CTA serving as the only diagnostic and pre-treatment planning study for cerebral aneurysms have been reported in the literature [5,21]. This study agrees that patient triage based on multi-detector row CTA data is possible, and that a good correlation with therapeutic decisions based on DSA data can be obtained. Villa-blanca et al. have published a study that determined whether multi-detector row CTA could be used to identify and characterize aneurysms of the posterior circulation and to guide optimal treatment selection [21]. They successfully used CTA to triage patients between endovascular and neurosurgical treatment in a significant proportion of cases and based treatment planning in more than 70% of treated cases on CTA data.
The present study includes various limitations. Our observations are based on a small sample size obtained from a single centre. Management strategies for the treatment of intracranial aneurysms obviously differ according to local preferences, which might have biased the therapeutic decision. Therefore, we have tried to base patient triage on objective criteria, used for the general risk allocation of endovascular coil embolization as described in the methods section.

It remains debatable, whether CTA can be applied exclusively for the pre-therapeutic risk allocation and therapeutic assignment of ruptured intracranial aneurysms. The major restriction of the technique seems to lie in the low sensitivity in detecting branches incorporated into the aneurysmal sac. In clinical practice, if multi-detector row CTA was used as the sole diagnostic procedure before coil embolization, a major contraindication to endovascular treatment might in some cases not be revealed until the three-dimensional DSA at the beginning of the endovascular procedure.

Despite these limitations, multi-detector row CTA will probably replace DSA in the work-up of patients with non-traumatic SAH. Intra-arterial DSA is time consuming, invasive, and might not be available on a 24 h basis in all institutions. CTA is a more practicable option, as it is widely available, less expensive and offers a great procedural safety. It can be performed in the emergency setting right after diagnosing a SAH, thereby accelerating the diagnostic work-up and the process of medical decision making in patients with acutely ruptured intracranial aneurysms.

Conclusion

Multislice CTA is a practical tool for the detection of intracranial aneurysms in patients presenting with acute non-traumatic SAH. In addition, the technique provides anatomical information necessary for the assignment of ruptured aneurysms to either endovascular coil embolization or surgical clipping; however, the technique appears to have a low sensitivity in detecting branches incorporated into the aneurysmal sac.

References