Perimesencephalic Hemorrhage and CT Angiography: A Decision Analysis

Ynte M. Ruigrok, MD; Gabriël J.E. Rinkel, MD; Erik Buskens, MD; Birgitta K. Velthuis, MD; Jan van Gijn, MD, FRCP, FRCPE

Background and Purpose—The method of choice for detecting or excluding a vertebrobasilar aneurysm still is a matter of debate in patients with a characteristically perimesencephalic pattern of subarachnoid hemorrhage (SAH) on CT. We used decision analysis to compare possible diagnostic strategies in these patients.

Methods—A decision analytic model was developed to evaluate the effect of 4 different diagnostic strategies following a perimesencephalic pattern of SAH on CT: 1, no further investigation; 2, digital subtraction angiography (DSA) by catheter; 3, CT angiography as initial modality, not followed by DSA if negative; and 4, CT angiography as initial modality, followed by DSA. We used a 4% prevalence of a vertebrobasilar aneurysm given a perimesencephalic pattern of hemorrhage, a 97% sensitivity and specificity of CT angiography, and a 99.5% sensitivity and 100% specificity of DSA. In a prospectively collected series, the complication rate from DSA in patients with a perimesencephalic pattern of hemorrhage was 2.6%. We calculated the expected utility of each of the 4 diagnostic options and used sensitivity analyses to examine the influence of the plausible ranges of the various estimates used.

Results—The expected utilities were 99.09 for CT angiography only, 98.96 for no further investigation, 98.22 for DSA, and 96.34 for CT angiography plus DSA. The results of the sensitivity analysis indicate that over a wide range of assumptions, CT angiography only is the most beneficial option. Only when the complication rate of catheter angiography is <0.2% is DSA the preferred strategy.

Conclusions—Our decision analysis shows that in patients with a perimesencephalic pattern of hemorrhage on CT, CT angiography only is the best diagnostic strategy. DSA can be omitted in patients with a perimesencephalic pattern of hemorrhage and a negative CT angiogram. (Stroke. 2000;31:2976-2983.)

Key Words: angiography, computed tomographic decision analysis diagnosis perimesencephalic hemorrhage

In patients with subarachnoid hemorrhage (SAH) and a characteristically perimesencephalic pattern of hemorrhage on CT, the likelihood of finding a vertebrobasilar aneurysm is approximately 4%. The remaining 96% have a nonaneurysmal cause of hemorrhage with a benign clinical course and an excellent outcome. The method of choice for detecting or excluding a vertebrobasilar aneurysm is still a matter of debate in patients with perimesencephalic pattern of hemorrhage on CT. Catheterization methods, now mostly digital subtraction angiography (DSA), are associated with a risk of persistent neurological deficit. The need to identify the aneurysm has to be weighed against the risk of complications from DSA in the remaining patients with no aneurysm and inherent good prognosis. An alternative imaging modality is CT angiography. CT angiography can accurately detect and exclude vertebrobasilar aneurysms. We assessed the risk of complication of catheter angiography in a large consecutive series of patients with perimesencephalic hemorrhage, using a decision analytic model to compare the diagnostic strategies of DSA and CT angiography and to determine the optimal strategy of diagnosis in patients with a perimesencephalic pattern of hemorrhage.

Subjects and Methods

The Model

A decision analytic model was developed to evaluate the effect of 4 different diagnostic strategies: 1, no further investigation; 2, DSA by catheter; 3, CT angiography only; 4, CT angiography plus DSA: CT angiography as initial modality, not followed by DSA if negative; and 4, CT angiography plus DSA: CT angiography as initial modality, followed by DSA if negative. In cases of positive CT angiography, DSA was performed if deemed necessary by the neuroradiologist or neurosurgeon. To assign quantitative values to all factors used in the decision model, we combined relevant data from the literature and, in the absence of reliable information, expert opinions. A decision model with the branches representing the 4 different diagnostic strategies, followed by a sequence of actions and events with risks and rates was generated, resulting in various outcomes (Figure 1). At the root of the decision model is an adult patient with SAH and a perimesencephalic pattern of hemorrhage on CT. The patient is in good clinical condition, with a characteristically perimesencephalic pattern of hemorrhage on CT. The patient is in good clinical condition, with a characteristically perimesencephalic pattern of hemorrhage on CT.
condition, with a normal level of consciousness and no focal neurological signs. The chance that a vertebrobasilar aneurysm is present in patients with a perimesencephalic pattern of hemorrhage approximates 4% (Table 1). This aneurysm may rupture, which may lead to death, morbidity, or recovery of the patient. DSA can detect such an aneurysm but is also associated with a risk of permanent neurological complications, which in a small proportion may result in death. From a series of patients with perimesencephalic hemorrhage undergoing DSA in the University Medical Center Utrecht, we assessed this risk of permanent neurological complication (see Available Data and Estimates). In case of an aneurysm being demonstrated by CT angiography or DSA, operation of the aneurysm is assumed to follow. Operation may be successful or may result in perioperative complications or death. In the decision model, 5 different end points are used: uncomplicated, recovery, single and double disability, and death. “Uncomplicated” means good health after recovery after an episode of aneurysmal SAH or status after a successfully operated aneurysm. Most patients who recover from an aneurysmal SAH still have a somewhat reduced quality of life, even if no complications have occurred and the patient is independent.12 “Disability-single” means that a single episode of deterioration has occurred, such as a complication from DSA, surgery, or a moderate recovery after an episode of aneurysmal SAH, and “disability-double” means that 2 complications have occurred, such as a complication from DSA, followed by rerupture or a complication from surgery. All types of complication were considered equally serious, irrespective of the underlying cause.

The decision model was used to obtain a proportional distribution of the various outcomes. Furthermore, the expected utility of each of the 4 diagnostic options was calculated by multiplying the probability of each branch of the model by the utility of outcome attached to it and summing the values of all branches at the node. Sensitivity analysis was used to examine the influence of variation across the plausible ranges of the estimates. One-way sensitivity analysis
denotes the effect of analyzing a single variable, whereas simultaneous changes in the values of 2 independent variables are assessed by 2-way sensitivity analysis.

Available Data and Estimates

**Sensitivity and Specificity of CT Angiography**

Estimates of the sensitivity and specificity of CT angiography (Table 1) were derived from a recent review article. These test characteristics refer to the first evaluation of the CT angiogram, resulting in a negative or a positive finding. We assumed, according to the practice in our institution, that a positive result (aneurysm identified) will lead to reevaluation of the CT angiogram together with the neurosurgeon, followed by an additional DSA in half the patients with a nonconclusive positive CT angiogram. For the first evaluation and the reevaluation as 2 successive tests with a 2×2 table applicable to each test. For the calculation of the sensitivity and specificity of the reevaluation of the positive outcome, we combined the two 2×2 tables, using the test characteristics of the first evaluation (97% sensitivity and specificity), the 4% chance of an aneurysm given a perimesencephalic pattern of bleeding, and a reported positive predictive value of 99% (74/75) of CT angiography.

**Sensitivity and Specificity of DSA**

Data on the test characteristics of DSA are scarce. Sensitivity and specificity of DSA were therefore estimated at 99.5% and 100%, respectively. These estimates are probably too high, but we chose these high rates to indicate that the test characteristics of DSA are more favorable than those of CT angiography. When DSA is preceded by negative or nonconclusive positive CT angiography, sensitivity and specificity of DSA are presumably lower.

**Complications of CT Angiography and DSA**

For CT angiography 130 to 145 mL of contrast is used, while for 4-vessel angiography there is an average usage of 130 to 210 mL. Thus, the amounts of contrast for CT angiography and DSA are comparable. The risk of a severe adverse or allergic reaction requiring treatment from nonionic contrast material is small and similar for CT angiography and DSA. Patients with a perimesencephalic pattern of bleeding will have to undergo 4-vessel angiography, that is, both vertebral arteries need to be visualized. For this specific procedure, we could not find a complication rate in the literature. An estimate of the risk of permanent neurological complications was therefore derived from all patients with perimesencephalic hemorrhage who underwent 4-vessel angiography in the University Medical Center Utrecht during 1983–1998. In our series of 77 patients we found 2 patients (2.6%; 95% CI, 0.3% to 9.6%) with a permanent neurological deficit: 1 patient with dysphasia and 1 patient with hemianopia. We found 192 patients with a perimesencephalic hemorrhage reported in the literature. 2–3, 6, 8, 17–22 Of these patients, 4 had a transient ischemic deterioration after angiography and none had permanent neurological complications (0%; 95% CI, 0% to 1.9%).

### Table 1. Probabilities and Utilities Used in the Decision Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>Lower Limit</th>
<th>Upper Limit</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity CTA first evaluation</td>
<td>97</td>
<td>76</td>
<td>98</td>
<td>13</td>
</tr>
<tr>
<td>Specificity CTA first evaluation</td>
<td>97</td>
<td>85</td>
<td>100</td>
<td>13</td>
</tr>
<tr>
<td>Sensitivity CTA reevaluation</td>
<td>98</td>
<td>90</td>
<td>100</td>
<td>*</td>
</tr>
<tr>
<td>Specificity CTA reevaluation</td>
<td>99.5</td>
<td>90</td>
<td>99.5</td>
<td>†</td>
</tr>
<tr>
<td>Sensitivity DSA</td>
<td>100</td>
<td>90</td>
<td>100</td>
<td>†</td>
</tr>
<tr>
<td>Specificity DSA preceded by CTA</td>
<td>90</td>
<td>80</td>
<td>95</td>
<td>†</td>
</tr>
<tr>
<td>Morbidity DSA</td>
<td>2.6</td>
<td>0.7</td>
<td>9.6</td>
<td>2–3, 6, 8, 17–22‡</td>
</tr>
<tr>
<td>Mortality DSA</td>
<td>0.13</td>
<td>0</td>
<td>0.13</td>
<td>23‡</td>
</tr>
<tr>
<td>Prevalence aneurysm</td>
<td>4.0</td>
<td>1.0</td>
<td>10</td>
<td>1–6</td>
</tr>
<tr>
<td>Probability rerupture</td>
<td>30</td>
<td>25</td>
<td>35</td>
<td>24</td>
</tr>
<tr>
<td>Mortality rerupture</td>
<td>15</td>
<td>10</td>
<td>20</td>
<td>25, 26</td>
</tr>
<tr>
<td>Mortality surgery</td>
<td>55</td>
<td>50</td>
<td>82</td>
<td>27, 28</td>
</tr>
<tr>
<td>Morbidity surgery</td>
<td>22</td>
<td>17</td>
<td>28</td>
<td>31–33</td>
</tr>
<tr>
<td>Mortality surgery</td>
<td>5</td>
<td>2.5</td>
<td>8.8</td>
<td>31–33</td>
</tr>
<tr>
<td>Utility uncomplicated</td>
<td>100</td>
<td>. . .</td>
<td>. . .</td>
<td>9</td>
</tr>
<tr>
<td>Utility recovery</td>
<td>90</td>
<td>50</td>
<td>100</td>
<td>12</td>
</tr>
<tr>
<td>Utility disability-single</td>
<td>65</td>
<td>40</td>
<td>95</td>
<td>. . .</td>
</tr>
<tr>
<td>Utility disability-double</td>
<td>50</td>
<td>32</td>
<td>76</td>
<td>. . .</td>
</tr>
<tr>
<td>Utility death</td>
<td>0</td>
<td>. . .</td>
<td>. . .</td>
<td>. . .</td>
</tr>
</tbody>
</table>

Values are percentages.

*Estimate and range derived from prevalence of aneurysm, test characteristics of CT angiography (CTA) first evaluation, positive predictive value of CTA, and institutional patient series.

†Estimate and range derived from expert opinion.

‡Estimate and range derived from institutional patient series (unpublished).
We used this figure as the lower limit for the risk of complications of DSA. In our own series of patients with perimesencephalic hemorrhage who underwent 4-vessel angiography, no patient died from DSA. We assumed that most cerebral infarctions due to 4-vessel angiography occur in the posterior fossa, and therefore we estimated the risk of death from infarction after 4-vessel DSA by using the risk of death from cerebellar infarction (5%), which can be considered an upper limit of this particular outcome in cerebellar infarction. The risk of death from DSA would then be 2.6% times 5% or 0.13%.

### Aneurysm Prevalence

The prevalence of a vertebrobasilar aneurysm given a perimesencephalic pattern of bleeding was derived from 6 studies in which the prevalence of vertebrobasilar aneurysms in patients with perimesencephalic patterns of hemorrhage was reported.1–6 When these studies are combined, the overall chance of finding a vertebrobasilar aneurysm is 4.0% (95% CI, 1.0% to 10.0%).

### Aneurysm Rerupture

For the risk of a rebleed of the aneurysm, we used aggregated data from the guidelines of the American Heart Association.24 Because the category of patients considered in the decision model is in general in good clinical condition (despite a possible first rupture of a vertebrobasilar aneurysm), we assumed the outcome of a rebleed of the aneurysm to be equal to the outcome after a first rupture.25,26 Overall, the case fatality rate of an aneurysmal rebleed is 80%.27,28 But many patients who rebleed have a poor clinical condition from the outset and accordingly a small chance for complete recovery. We used 80% as the upper limit for the case fatality rate after rebleeding.27,28

### Aneurysm Surgery

Surgical mortality and morbidity data associated with the clipping of a vertebrobasilar aneurysm have been reported in several series.29–33 We used the results of these series, in which patients were graded according to the Hunt and Hess scale,34 and pooled the case fatality and morbidity outcome of the patients in Hunt and Hess grades 0, 1, and 2.31–33 We assumed that clipping the aneurysm prevents further SAH.

### Utilities

A subjective factor is the evaluation of the quality of life or utilities of the 5 different outcomes. We assigned a utility of 0% to the outcome death. Because a perimesencephalic hemorrhage does not reduce quality of life,7 we assigned a utility of 100% to the outcome uncomplicated. A recent study indicates that most patients who recover without handicap from an aneurysmal SAH still have a somewhat reduced quality of life.12 We therefore assigned a utility of 90% to the outcome disability with a patent aneurysm, after complete recovery from a rerupture of the aneurysm or with a successfully operated aneurysm (recovery). A permanent disability from a single complication (disability-single) was valued at 65%, irrespective of the cause of the complication, and permanent disability from 2 successive complications (disability-double), eg, angiographic complication followed by morbidity from a surgical complication, was valued at 50%. Thus, we considered a first complication to have more impact on quality of life than a second successive complication.

### Results

#### Standard Analysis

Of the 4 different diagnostic options, the best strategy is CT angiography only, with an overall expected utility of 99.09 (Table 2). The option of no further investigation has a somewhat lower expected utility of 98.96, while the option of DSA implies a decrease of expected utility to 98.22. The option of CT angiography plus DSA has the lowest expected utility (96.34). The smallest proportion of patients who have an uncomplicated outcome and the largest proportion of death, disability-single, disability-double, and recovery occur in the latter strategy. The CT angiography only strategy gives the lowest risk of death, while no further investigation yields a marginally greater proportion of patients in good health and, understandably, the smallest proportion of patients becoming disabled by complications.

#### One-Way Sensitivity Analysis

The results of the sensitivity analyses indicate that over a wide range of assumptions, CT angiography only is the optimal approach of diagnosis in patients with perimesencephalic pattern of hemorrhage (Table 3). When the sensitivity of CT angiography is varied over its range, CT angiography only remains the preferred diagnostic option. Only at a very low sensitivity (<42%) is CT angiography only no longer the preferred option. In that case, the strategy of no further investigation becomes optimal. The threshold specificity of CT angiography is 93%; below that threshold, the strategy of no further investigation again has the highest utility. At a very low prevalence of a vertebrobasilar aneurysm with a perimesencephalic pattern of hemorrhage (<1.8%), it would be preferable to opt for no further investigation. When the probability of the risk of permanent neurological complication from DSA is varied over its full range, the option of CT angiography only remains superior. Only at very low probability of complications from DSA (<0.22%) does DSA become more beneficial than CT angiography only. The utility assigned to becoming disabled from a complication of DSA or operation also has impact on the utility of CT angiography only. A utility of <49.6% would make no further investigation the most beneficial strategy compared with CT angiography only. The option of CT angiography plus DSA is under no circumstances the preferred diagnostic strategy.

#### Two-Way Sensitivity Analysis

Two-way sensitivity analysis demonstrates that the specificity of CT angiography above which CT angiography only is

---

**TABLE 2. Utilities and Distribution of Outcomes by Diagnostic Options**

<table>
<thead>
<tr>
<th>Diagnostic Option</th>
<th>Utility %</th>
<th>Uncomplicated</th>
<th>% Recovery</th>
<th>% Disability-Single</th>
<th>% Disability-Double</th>
<th>% Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>No further investigation</td>
<td>98.96</td>
<td>96.0</td>
<td>3.2</td>
<td>0.2</td>
<td>...</td>
<td>0.7</td>
</tr>
<tr>
<td>DSA</td>
<td>98.22</td>
<td>93.5</td>
<td>2.8</td>
<td>3.3</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td>CTA</td>
<td>99.09</td>
<td>95.6</td>
<td>3.2</td>
<td>1.0</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td>CTA + DSA</td>
<td>96.34</td>
<td>84.1</td>
<td>9.6</td>
<td>5.2</td>
<td>0.1</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Values are percentages. CTA indicates CT angiography.
the preferred diagnostic strategy varies according to the utility of disability from a single complication (disability-single) (Figure 2A). If the specificity of CT angiography is low, CT angiography only is the favored option only if the utility of disability-single is high. In contrast, the sensitivity of CT angiography may become quite low if the utility of disability-single remains reasonably high (Figure 2A). A 2-way sensitivity analysis shows that if specificity of CT angiography falls below approximately 96%, the utility of recovery has to remain high for CT angiography only to remain superior over no further angiography (Figure 2B). Two-way sensitivity analysis also demonstrates that if the prevalence of a vertebrobasilar aneurysm given a perimesencephalic pattern of hemorrhage is low, CT angiography only is more beneficial than the option of no further investigation only if the specificity of CT angiography is high (Figure 2A). A 2-way sensitivity analysis shows that if specificity of CT angiography falls below approximately 96%, the utility of recovery has to remain high for CT angiography only to remain superior over no further angiography (Figure 2B).

Two-way sensitivity analysis also demonstrates that if the prevalence of a vertebrobasilar aneurysm given a perimesencephalic pattern of hemorrhage is low, CT angiography only is more beneficial than the option of no further investigation only if the specificity of CT angiography is high (Figure 2A). To a lesser extent, the same applies to a 2-way sensitivity analysis on the prevalence of vertebrobasilar aneurysms and the sensitivity of CT angiography (Figure 2C). Finally, a 2-way sensitivity analysis on the specificity of CT angiography and risk of complications from DSA shows that if the probability of complications from DSA is >0.22%, specificity of CT angiography has to be high for CT angiography only to remain the favored strategy over the option of no further investigation (Figure 2D). However, this analysis also shows that if the probability of complications from DSA falls to <0.22% and specificity of CT angiography falls to <96%, the DSA strategy would be the favored strategy.

**Discussion**

In this study we found that CT angiography only is the most beneficial approach in patients with SAH and a characteristic perimesencephalic pattern of hemorrhage on CT. DSA can be omitted in patients with a perimesencephalic pattern of hemorrhage and a negative CT angiogram.

The various outcomes of the different diagnostic strategies of a decision analysis are obtained by multiplying the risk and rates of a sequence of actions and events with the utilities assigned to the various outcomes. The difference between the expected utilities of CT angiography only and the other 3 diagnostic options in our decision analysis is small. However, the sensitivity analysis shows that variation across the plausible ranges of the estimates hardly alters the conclusion of our analysis. The preference for CT angiography only is not sensitive to small alterations in key probabilities.

Additionally, 2-way sensitivity analysis did not reveal specific scenarios within plausible ranges that might alter the conclusion but made it clear that the test characteristics of CT angiography and the specificity in particular should remain optimal. A systematic review reported an overall sensitivity for CT angiography ranging from 76% to 98% and specificity ranging from 85% to 100%.13 A recent study showed that CT

---

**TABLE 3. One-Way Sensitivity Analysis of Variables by Diagnostic Options**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range, %</th>
<th>CTA</th>
<th>No Further Investigation</th>
<th>DSA</th>
<th>CTA + DSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity CTA first evaluation*</td>
<td>42–98</td>
<td>99.0–99.1</td>
<td>...</td>
<td>...</td>
<td>96.3–96.3</td>
</tr>
<tr>
<td>Specificity CTA first evaluation†</td>
<td>85–100</td>
<td>98.7–99.2</td>
<td>...</td>
<td>...</td>
<td>96.3–96.4</td>
</tr>
<tr>
<td>Sensitivity CTA reevaluation</td>
<td>67–84</td>
<td>99.1–99.1</td>
<td>...</td>
<td>...</td>
<td>96.3–96.3</td>
</tr>
<tr>
<td>Specificity CTA reevaluation</td>
<td>90–100</td>
<td>99.0–99.1</td>
<td>...</td>
<td>...</td>
<td>96.3–96.4</td>
</tr>
<tr>
<td>Sensitivity DSA</td>
<td>90–99.5</td>
<td>...</td>
<td>98.2–98.2</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Specificity DSA</td>
<td>90–100</td>
<td>...</td>
<td>96.3–98.2</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Sensitivity DSA preceded by CTA</td>
<td>80–90</td>
<td>99.1–99.1</td>
<td>...</td>
<td>...</td>
<td>96.3–96.3</td>
</tr>
<tr>
<td>Specificity DSA preceded by CTA</td>
<td>80–95</td>
<td>99.0–99.1</td>
<td>...</td>
<td>...</td>
<td>94.5–97.3</td>
</tr>
<tr>
<td>Morbidity DSA‡</td>
<td>0.22–9.6</td>
<td>99.1–99.0</td>
<td>...</td>
<td>99.1–95.6</td>
<td>97.2–93.8</td>
</tr>
<tr>
<td>Prevalence aneurysm§</td>
<td>0.89–10</td>
<td>99.7–97.9</td>
<td>99.8–97.4</td>
<td>98.8–97.4</td>
<td>96.9–95.3</td>
</tr>
<tr>
<td>Mortality rupture</td>
<td>50–82</td>
<td>99.1–99.1</td>
<td>99.0–98.7</td>
<td>...</td>
<td>96.3–96.3</td>
</tr>
<tr>
<td>Morbidity surgery</td>
<td>17–28</td>
<td>99.1–99.0</td>
<td>...</td>
<td>98.3–98.2</td>
<td>96.5–96.1</td>
</tr>
<tr>
<td>Mortality surgery</td>
<td></td>
<td></td>
<td>2.5–4.8</td>
<td>99.2–99.0</td>
<td>...</td>
</tr>
<tr>
<td>Utility recovery</td>
<td>50–100</td>
<td>97.8–99.4</td>
<td>97.7–99.3</td>
<td>97.1–98.5</td>
<td>92.4–97.3</td>
</tr>
<tr>
<td>Utility disability-single¶</td>
<td>40–95</td>
<td>98.8–99.4</td>
<td>98.9–99.0</td>
<td>97.4–99.2</td>
<td>95.0–97.9</td>
</tr>
<tr>
<td>Utility disability-double</td>
<td>32–76</td>
<td>...</td>
<td>98.2–98.2</td>
<td>96.3–96.4</td>
<td></td>
</tr>
</tbody>
</table>
angiography can accurately exclude and detect vertebrobasilar aneurysms, with a sensitivity and a specificity of 100%. The 97% sensitivity and specificity of CT angiography that we assumed are therefore plausible. We found that only at sensitivity $\leq 42\%$ and specificity $\leq 93\%$ is CT angiography only no longer the preferred option. Under these circumstances, the strategy of no further investigation has the best expected outcome. This indicates that limited specificity of CT angiography is no valid reason to favor the strategy of CT angiography plus DSA.

Since DSA is considered the gold standard for diagnosing cerebral aneurysms as the cause of SAH, we chose to use high estimates for the test characteristics of DSA. Sensitivity of 99.5% (ie, DSA fails to detect only 1 of 200 aneurysms present) and specificity of 100% of DSA are probably too optimistic. Combined data of studies showed that in patients with SAH and an initially negative DSA, 22 aneurysms were revealed in 145 repeated angiograms. When DSA is preceded by mostly negative CT angiography, sensitivity of DSA will be $< 99.5\%$ because in that case the relatively large aneurysms will have been eliminated. Our assumptions of 90% sensitivity and specificity for DSA when preceded by CT angiography are probably still an overestimation.

From our own series of patients with perimesencephalic pattern of hemorrhage who underwent bilateral vertebral angiography, we derived a 2.6% risk of permanent neurological complication from DSA. In a review of 3 large series concerning the neurological complications associated with DSA, the complication rate for patients with SAH was 0.25%. A likely explanation for the higher complication rate in our series is that most patients in our series had to undergo 4-vessel angiography, including both vertebral arteries. In
only approximately 30% is the contralateral posterior inferior cerebellar artery sufficiently visualized after injection in the contralateral vertebral artery. In the series included in the review, bilateral vertebral injections were not reported; in an unspecified proportion of patients bilateral carotid and left vertebral artery injections were performed, and in an unknown proportion only 1 or 2 carotid arteries were selectively injected.\textsuperscript{36}

In our sensitivity analysis we found that only when the complication rate of catheter angiography is <0.22% is DSA more beneficial than CT angiography only. Such a low risk of complications will be difficult to reach in patients with a perimesencephalic pattern of hemorrhage given the need for 4-vessel angiography and the 0.25% risk in series where a proportion of patients underwent only carotid angiography.

Currently, in many centers vertebrobasilar aneurysms are treated by the endovascular coiling technique.\textsuperscript{37–38} This treatment probably results in a lower case fatality and morbidity than conventional surgical clipping.\textsuperscript{39} Such a lower complication rate will not influence the diagnostic strategies of DSA, CT angiography only, and CT angiography plus DSA since surgery occurs in all 3 strategies.

Velthuis et al. proposed earlier that CT angiography is an adequate screening examination for vertebrobasilar aneurysms in patients with perimesencephalic pattern of hemorrhage and that DSA can be withheld in patients with this type of hemorrhage and negative CT angiography. Since vertebrobasilar aneurysms may arise from unusual locations, such as the distal posterior cerebral artery or vertebrobasilar artery junction, CT angiograms of patients presenting with a perimesencephalic pattern of hemorrhage should be meticulously assessed, including axial source images, to attain the accuracy assumed in our model.\textsuperscript{20}

In conclusion, our decision analysis shows that in patients with a perimesencephalic pattern of hemorrhage on CT, CT angiography only is the best diagnostic strategy. DSA can be omitted in patients with a perimesencephalic pattern of hemorrhage, and negative CT angiography should be performed only if uncertainty exists about the presence or location of a vertebrobasilar aneurysm on the CT angiogram.

Acknowledgment

This study was supported in part by an established clinical investigator grant from the Netherlands Heart Foundation to Dr Rinkel.

References

Perimesencephalic Hemorrhage and CT Angiography: A Decision Analysis
Ynte M. Ruigrok, Gabriël J. E. Rinkel, Erik Buskens, Birgitta K. Velthuis and Jan van Gijn

Stroke. 2000;31:2976-2983
doi: 10.1161/01.STR.31.12.2976

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/31/12/2976