TECHNICAL NOTE

Surgical views from three-dimensional digital subtraction angiography for the planning of aneurysm surgery

Vues chirurgicales à partir de l’angiographie tridimensionnelle pour le planning de la chirurgie anévrismale


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KEYWORDS
Cerebral aneurysm; Three-dimensional angiography; Volume-rendering; Image processing; Surgical simulation

Abstract

Aim. — To develop a semi-automatic protocol helping to present directly and quickly three-dimensional digital subtraction angiography (3D-DSA) data in an orientation that reproduces exactly the neurosurgeon’s intraoperative view.

Method. — Post-processing of 3D-DSA data (volume-rendering) was performed on an Integris workstation (Philips, Best); surgical views were obtained by visualization of the patient’s head through a frontopterional approach: the 3D volume was turned 135° in the sagittal plane (around the X axis) and rotated by 45° and 60° in the coronal plane (around the Y axis). The protocol was evaluated on a consecutive series of nine patients who had ruptured or asymptomatic anterior circulation aneurysms requiring surgical treatment. Frontopterional views of angiographic 3D data were compared with intraoperative views.

Results. — The proposed semi-automatic algorithm is simple, fast and reproducible, and displays the 3D data in an orientation identical to the intraoperative views. The surgical anatomy of the anterior communicating artery was best reproduced with a coronal rotation of 60°, with a coronal rotation of 45° for the other aneurysm locations. In each case, the surgical reconstructions allowed a more accurate analysis of the vascular anatomy around the aneurysm, and facilitated pre- and perioperative planning.

Conclusion. — The present protocol displays angiographic 3D data in a projection that exactly reproduces the vascular anatomy through a frontopterional approach. It may help neurosur-
Introduction

Various factors determine the success of cerebral aneurysm surgery. One of them is the ability of the neurosurgeon to anticipate potential difficulties in dissecting and clipping the aneurysm. Three-dimensional radiological techniques, 3D-computerized tomography angiography (3D-CTA) and three-dimensional digital subtraction angiography (3D-DSA) are useful tools for analysis of the arterial relationships and projection of intracranial aneurysms and, therefore, may help to predict the pitfalls and risks of surgery.

This study aimed to develop a semi-automatic 3D-DSA protocol to display views of the arterial tree in the same orientation as through a frontopterional approach, and to validate this algorithm using intraoperative views. The objective was to increase the quality of the pre- and peroperative planning of anterior circulation aneurysm surgery.

Method

Patients

The 3D-DSA surgical view protocol was evaluated on a consecutive series of nine patients who had ruptured or asymptomatic anterior circulation aneurysms requiring surgical treatment (Table 1). Thirteen aneurysms were studied: seven middle cerebral artery aneurysms, three posterior carotid artery aneurysms, two anterior communicating artery (ACoA) aneurysms and one carotid artery termination aneurysm.

Angiographic technique

The patient’s head was positioned on a standard headrest. Rotational DSA covering 240° at 55° per s was performed on an Allura V 5000 (Philips, Best, the Netherlands) during selective injection of a non-ionic contrast material into the internal carotid artery (ICA) at a flow-rate of 4 ml/s using the propeller rotation technique. Post-processing of dynamic angiographic data, including volume-rendering, was performed on an Integris workstation (Philips). The initial reconstructed volume could be viewed interactively. This allowed the vessel morphology to be displayed in any spatial orientation. The surgical reconstructions were printed on film.

Surgical reconstruction technique

At the 3D-DSA workstation, the head of the patient was centered according to a three-dimensional coordinate system included in the reconstruction software (Fig. 1a, b). The X axis was defined as the horizontal axis, the Y axis as the vertical axis and the Z axis as the anteroposterior axis. The surgical reconstructions were obtained by successive rotations of the 3D-DSA volume from the lateral view (automatically displayed by the software) as follows (Fig. 1c, d):
● the rotation around the Z axis was 0;
● the rotation of the Y axis around the X axis was 135°, positive for a left approach and negative for a right approach;
● the rotation of the Z axis around the Y axis was 45°, 60° or 90°, positive for a left approach and negative for a right approach.

Surgical technique

The patient was positioned in the dorsal position; the head was fixed in a Mayfield device with a slight extension and a 30° rotation to the opposite side of the frontopterional approach. A semicircular incision was extended from the tragus to the frontal midline. A classic frontopterional

Table 1

<table>
<thead>
<tr>
<th>Side</th>
<th>Aneurysm 1: site/measurements</th>
<th>Aneurysm 2: site/measurements</th>
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<tbody>
<tr>
<td>Patient 1</td>
<td>Left</td>
<td>Posterior ICA/S: 4.2 N: 1.6</td>
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<tr>
<td>Patient 2</td>
<td>Left</td>
<td>Posterior ICA/S: 20 N: 3</td>
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<td>Patient 3</td>
<td>Left</td>
<td>Posterior ICA/S: 10 N: 5</td>
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<tr>
<td>Patient 4</td>
<td>Left</td>
<td>MCA/S: 5 N: 3</td>
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<tr>
<td>Patient 5</td>
<td>Left</td>
<td>ACoA/S: 6 N: 2</td>
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<tr>
<td>Patient 6</td>
<td>Right</td>
<td>MCA/S: 10 N: 4</td>
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<tr>
<td>Patient 7</td>
<td>Left</td>
<td>MCA/S: 6.5 N: 8.3</td>
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<tr>
<td>Patient 8</td>
<td>Right</td>
<td>MCA/S: 6 N: 4</td>
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<tr>
<td>Patient 9</td>
<td>Left</td>
<td>ACoA/S: 8 N: 5</td>
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</table>

S: size of the sac in mm; N: size of the neck in mm.

Figure 1

a, b: Three-dimensional coordinate system included in the reconstruction software; c, d: Rotation of the Y axis around the X axis was 135°, positive for a left approach and negative for a right approach. The rotation of the Z axis around the Y axis was 45°, 60° or 90°, positive for a left approach and negative for a right approach. Angle $a =$ initial contralateral rotation of the head in the Mayfield device (30°). Angle $b =$ additional rotational angle of the microscope axis (15°, 30°, 60°).

Figure 1 a, b : Référentiel tridimensionnel inclus dans le logiciel de reconstruction ; c, d : La rotation de l’axe Y autour de l’axe X était de 135°, positive pour un abord gauche et négative pour un abord droit. La rotation de l’axe Z autour de l’axe Y était de 45°, 60° ou 90°, positive pour un abord gauche et négative pour un abord droit. Angle $a =$ rotation controlatérale initiale de la tête dans la têtière de Mayfield (30°), Angle $b =$ angle de rotation additionnel de l’axe du microscope (15°, 30°, 60°).
bone flap and an arciform dural opening were made. Large
dissection of the sylvian fissure and the anterior part of the
cerebral arterial circle were achieved. After aneurysm deli-
nation, a titanium Yasargil clip was applied.

Validation

Direct comparisons were made between the 3D-DSA surgical
views and the operative field shots. We determined the
most suitable rotational Y angle for the best representation
of the surgical view for each aneurysm location. We studied
the quality of the visualizations of the arterial tree and the
aneurysms (sac and neck). These reconstructions were also
compared with standard 3D-DSA views (lateral, anterior,
posterior and superior).

Results

The application of this protocol was feasible in all patients.
The reconstruction technique was very fast (about 5 min).
The suitable rotational angle around the Y axis for visualiza-
tion of ACoA aneurysms was 60° (Fig. 2), and 45° for the
other aneurysm locations (Figs. 3 and 4). Radiosurgical cor-
relations were excellent for each specific rotational angle
(Table 2). There was no discordant case with the technique
itself although, in case 4, the arterial tree was only par-
tially visualized during surgery because of a narrow dissec-

Figure 2  ACoA aneurysm: a: 3D-DSA anterior view; b: 3D-DSA surgical view; c: operative view. White arrowhead: AcoA aneu-
ysm. White arrow: Heubner recurrent artery. ACA 1: A1 segment of the anterior cerebral artery; ACA 2: A2 segment of the ante-
rior cerebral arteries.

Figure 2  Anévrisme de l’artère communicante antérieure. a : vue antérieure en angiographie tridimensionnelle ; b : vue chirur-
ghicale en angiographie tridimensionnelle ; c : vue opératoire. Tête de flèche blanche : anévrisme de l’artère communicante anté-
cérébrale antérieure.

Figure 3  Posterior carotid artery and carotid artery bifurcation aneurysms. a: 3D-DSA lateral view; b: 3D-DSA surgical view; c:
global operative view; d: operative view after carotid bifurcation mobilization. White arrowhead: posterior carotid artery aneu-
ysm. White arrow: carotid artery bifurcation aneurysm (hidden by the bifurcation). ICA: internal carotid artery; ACA: anterior
cerebral artery; MCA: middle cerebral artery.

Figure 3  Anévrismes de la face postérieure et de la terminaison carotidienne. a : vue latérale en angiographie tridimensionnelle ; b : vue chirurgicale en angiographie tridimensionnelle ; c : vue opératoire globale ; d : vue opératoire après
mobilisation la terminaison carotidienne. Tête de flèche blanche : anévrisme de la face postérieure de l’artère carotide interne.
Flèche blanche : anévrisme de la terminaison de l’artère carotide interne (caché par la bifurcation). ica : artère carotide
interne ; aca : artère cérébrale antérieure ; mca : artère cérébrale moyenne.
Comparison between the standard 3D-DSA and frontopterional views are summarized in Table 3.

**Discussion**

DSA is used in many centers for intracranial aneurysm detection [3,9,11]. Adjunctive three-dimensional reconstructions improve the accuracy of the radiological analysis: neck and sac measurement, and neck and sac relationship to parent artery and neighboring branches. 3D-DSA is perfectly adapted to planning (neck location, road-mapping, coil placement) [1,2,7] and to postoperative management [5,6] of endovascular treatment. This technique is also widely used for preoperative evaluation [10] and postoperative follow-up of clipped aneurysms [4].

It can also optimize planning of aneurysm surgery. Recently, colleagues of the University of Patras (Rion, Greece) published a 3D-CTA protocol allowing reproduction of the surgical view of anterior circulation aneurysms [8]. Simultaneously and independently at our institution, we were evaluating the value of an equivalent 3D-DSA protocol (presented in this paper). Overall, the methodology of our study was similar, except that the coordinate system axes were automatically included in the reconstruction software we used. Also, although the Greeks used a different terminology for their axes, we found approximately the same rotational angles for each location with one exception: we used exactly opposite angles for the analysis of a right or a left frontopterional approach.

This protocol displayed semi-automatic and direct 3D-DSA reconstructed surgical views of the anterior circulation arteries oriented for a frontopterional approach. The rotational angles were approximated by observation of the patient’s head position and the microscope’s axis orientation during surgery (Fig. 5). The X angle corresponds to the microscope positioned beside and above the patient’s head. The Y angle corresponds to a lateral course of the neck visualization
Sac visualization
Arterial tree visualization
Preferential coronal angle (°)

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<th>Patient</th>
<th>Aneurysm</th>
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<th>Sac visualization</th>
<th>Arterial tree visualization</th>
<th>Preferential coronal angle</th>
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nc = non-comparable data.

**Figure 4** Middle cerebral artery aneurysms. a: 3D-DSA anterior view; b: 3D-DSA surgical view; c: operative view. White arrow-head: large MCA aneurysm. White arrow: small MCA aneurysm. ICA: internal carotid artery; ACA: anterior cerebral artery; MCA: middle cerebral artery.

**Figure 4** Anévrismes de l’artère cérébrale moyenne. a : vue antérieure en angiographie tridimensionnelle ; b : vue chirurgicale en angiographie tridimensionnelle ; c : vue opératoire. Tête de flèche blanche : large anévrisme de l’artère cérébrale moyenne. Flèche blanche : petit anévrisme de l’artère cérébrale moyenne. ica : artère carotide interne ; aca : artère cérébrale antérieure ; mca : artère cérébrale moyenne.
microscope for the surgical dissection, and takes into account the initial contralateral rotation of the head in the Mayfield device (about 30°). We then determined which angle corresponded to each specific aneurysm location. A more tangential angle (60°) was suitable for the exploration of ACoA aneurysms whereas, in other locations, a 45° rotational angle gave the best results.

According to the good radiosurgical correlations obtained with this small series of patients, this 3D-DSA protocol appears to be a reliable technique for the surgical representation of anterior circulation aneurysms. However, these angles do not summarize the multiple positions of the microscope used for this surgery, and such reconstructions cannot replace viewing the 3D data from multiple angles on the workstation. Nevertheless, they provide a global and direct view of the vascular conformation through a frontopterional approach as seen by the neurosurgeon after exposure of the anterior circulation and the aneurysm. Preoperatively, this protocol facilitates mental representation of the exact three-dimensional arterial relationships of the aneurysm, and allows anticipation of any potential difficulties in the clipping procedure. Perioperatively, it avoids beginning the dissection at the site the aneurysm bleb, and it shows the exact three-dimensional orientation of the aneurysm sac and the precise positions of neighboring branches (particularly those next to the aneurysm sac), thus allowing adjustment of clip position.

This semi-automatic protocol is fast, simple and reproducible. It gives additional information on the vascular anatomy that the neurosurgeon will encounter during the frontopterional approach. It allows for better pre- and perioperative planning for surgical clipping by predicting the surgical position of the aneurysm and its surrounding blood vessels. It should be of particular interest in difficult operations such as giant or calcified aneurysm surgery.

References


