Long term follow-up of patients with coiled intracranial aneurysms
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Chapter 10

3D rotational angiography: the new gold standard in the detection of additional intracranial aneurysms

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ABSTRACT

Background and purpose: the purpose of this study is to compare 3D Rotational Angiography (3DRA) and Digital Subtraction Angiography in the detection of small additional intracranial aneurysms.

Patients and Methods: 350 3D datasets of one vascular tree of 350 patients with at least one intracranial aneurysm on the 3D dataset were re-evaluated for the presence of additional aneurysms by two observers in consensus. Two other observers, blinded to 3D images, re-evaluated DSA images of the same 350 vascular trees for these additional aneurysms. Results were compared.

Results: In 350 3D datasets, 350 target aneurysms and 94 additional aneurysms were detected. Mean size of 94 additional aneurysms was 3.54 mm (median 3, range 0.5-17 mm). Proportion of aneurysms ≤ 3 mm was significantly higher in additional aneurysms (61 of 94, 65%) than in target aneurysms (61 of 350, 17%) (Chi Square, P<0.0001).

Of 94 additional aneurysms, 27 (29%) were missed on DSA by both observers. Mean size of the missed aneurysms was 1.94 mm (median 2, range 0.5-4 mm). Proportion of aneurysms ≤ 3 mm in missed additional aneurysms (26 of 27, 96%) was significantly higher than in all additional aneurysms (61 of 94, 65%) (Chi Square, P=0.0035). Location of missed additional aneurysms was not different from location of all additional aneurysms.

Conclusion: 3DRA depicts considerably more small (≤ 3 mm) additional aneurysms than DSA. In selected patients, accurate detection of these aneurysms may have consequences for choice of treatment modality and for frequency and duration of imaging follow up.
INTRODUCTION

Digital subtraction angiography (DSA) is generally used as gold standard in detection of intracranial aneurysms. However, during surgery of symptomatic aneurysms, additional small angiographic occult aneurysms are commonly found with an incidence of 3.7-12.2%. Most neurosurgeons clip or wrap these additional micro aneurysms in order to prevent their growth and rupture. Since operative view during surgical exploration is restricted to part of the cerebral vasculature, it is likely that incidence of these small additional aneurysms is higher than reported in surgical series. Thus, apparently an unknown number of micro aneurysms are commonly missed on cerebral DSA.

PATIENTS AND METHODS

This study was compliant with institutional privacy policy. The Institutional Review Board gave exempt status for approval and informed consent for this retrospective study.

2D and 3D Angiography

In our practise, in all patients with suspected intracranial aneurysms in whom treatment is considered, a complete cerebral DSA is performed on a biplane system with 2 or 4 projections per vessel. When an aneurysm is apparent or suspected on DSA of any of the imaged vascular trees, additional 3DRA is performed of the same vessel harbouring the aneurysm to evaluate its anatomy and to determine the need for and type of treatment (coiling, surgery or parent vessel occlusion). In patients with aneurysms allocated to coiling, 3DRA of the vessel harbouring the aneurysm is repeated under general anaesthesia immediately prior to coiling to find out the best working projection. Thus, 3DRA was performed of every vascular tree with apparent aneurysms on DSA. Angiographic imaging was performed on a biplane neuro-angiographic unit (Integris BN 3000 Neuro, Philips Medical Systems, Best, The Netherlands). DSA was performed with a 1024x1024 matrix with 17-20 cm field of view and injection of 8-10 ml contrast material in internal carotid and vertebral arteries in 2 or 4 projections. After post processing when needed, relevant images were sent to the Picture Archive and Communication System (PACS). 3DRA was performed with an 8 second 180 degrees rotational run with acquisition of 200 images and with injection of 3-4 ml contrast material per second in the internal carotid or vertebral artery. On a dedicated workstation, 3D reconstructions were made in a matrix of 1283-5123. Relevant images were sent to PACS. All raw 3D datasets were stored on the hard disk of the workstation and later on compact disc. Raw datasets stored on compact discs can be reloaded in the workstation for real time evaluation and new high resolution reconstructions.

Patients

We included 350 3D datasets of one vascular tree of 350 patients with at least one intracranial aneurysm on the 3D dataset and a complete cerebral DSA performed between March 2004 and May 2007. This time frame was chosen because all DSA images could be evaluated on a PACS system that was implemented in November 2003. A complete DSA consisted of 3-vessel angiography in 273 patients and 4-vessel angiography in 77 patients for a total of 1127 vessels. The 350 3D datasets were re-evaluated on the workstation by two of the authors in consensus (ANdG and WJvR). In particular, next to location and size of the target aneurysm for which 3DRA had been performed, presence, location and size of additional aneurysms were assessed. Size was defined
as maximal diameter as measured on 3DRA. Results of re-evaluation of 3DRA were entered in a database that served as reference. Aneurysm locations were further classified into carotid artery, middle cerebral artery, anterior cerebral artery and posterior circulation. Subsequently, two experienced neuroradiologists (MS and JPP), blinded to 3DRA PACS images and radiological reports, reviewed the DSA images of the corresponding 350 vascular trees in 2 or 4 projections on a PACS workstation for presence and location of additional aneurysms in consensus. Relevant DSA images were rearranged in dedicated monitor hangings. Special DSA projections derived from 3D angiography that had served as working projections during coiling were not included in the hangings. Results were compared with the findings in the reference database. Number, location and size of false negative and false positive additional aneurysms were recorded. Aneurysm location was further classified as carotid artery, middle cerebral artery, anterior cerebral artery and posterior circulation.

**Statistical analysis**
Chi Square test (two-tailed) was used for comparison of the following data: Proportion of aneurysms ≤ 3 mm in additional aneurysms and in target aneurysms, proportion of aneurysms ≥ 3 mm in additional aneurysms missed on DSA and in all additional aneurysms as detected on 3DRA, and location (classified as carotid artery, middle cerebral artery, anterior cerebral artery and posterior circulation) of additional aneurysms missed on DSA versus location of all additional aneurysms.

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**Figure 1**
2 mm middle cerebral artery aneurysm missed on DSA in 45-year-old man
A-D: DSA in 4 projections fails to depict an aneurysm
E: demonstration of aneurysm on 3DRA (arrow)
RESULTS

Number and sizes of target- and additional aneurysms
In 350 3D datasets, 350 target aneurysms and 94 additional aneurysms were detected for a total of 444 aneurysms.
Mean size of 350 target aneurysms was 7.4 mm (median 6, range 1-32 mm). Mean size of 94 additional aneurysms was 3.54 mm (median 3, range 0.5-17 mm). Of 94 additional aneurysms, 61 (65%) were ≤ 3 mm and of 350 target aneurysms, 61 (17%) were ≤ 3 mm. Proportion of aneurysms ≤ 3 mm was significantly higher in additional aneurysms (61 of 94, 65%) than in target aneurysms (61 of 350, 17%) (Chi Square, \( P<0.0001 \)).
Location of 94 additional aneurysms was anterior cerebral artery in 15 (16%), carotid artery in 36 (38%), middle cerebral artery in 33 (35%) and posterior circulation 10 (11%).

Results of observers
Of 94 additional aneurysms, 27 (29%) were missed on DSA by both observers (figures 1-5). Mean size of the missed aneurysms was 1.94 mm (median 2, range 0.5-4 mm). Of 27 missed aneurysms, 26 (96%) were ≤ 3 mm. Proportion of aneurysms ≤ 3 mm in missed additional aneurysms (26 of 27, 96%) was significantly higher than in all additional aneurysms (61 of 94, 65%) (Chi Square, \( P=0.0035 \)).
Location of 27 missed additional aneurysms was anterior cerebral artery in 6 (22%), carotid artery in 12 (44%), middle cerebral artery in 7 (26%) and posterior circulation 2 (7%).
Using the Chi Square test, location of missed additional aneurysms was not different from location of all additional aneurysms.
Two false positive aneurysms were observed on DSA; one on the ophthalmic artery and one the middle cerebral artery.

Figure 2
Two angiographically occult additional micro aneurysms adjacent to a ruptured PICA aneurysm in a 53-year-old woman.
A and B: DSA in 2 projections demonstrates PICA aneurysm
C: 3DRA detects two additional micro aneurysms (arrows)
Figure 3
44-year old woman with subarachnoid hemorrhage.
A and B: DSA in two projections reveals posterior communicating artery aneurysm and an asymptomatic left parietal arterio-venous malformation.
C: 3DRA shows, besides the posterior communicating artery aneurysm, three additional small aneurysms on the supraclinoid carotid artery and proximal A1 (short arrows) and on a fenestrated anterior communicating artery (long arrow).

Figure 4
Four examples of small additional aneurysms missed on DSA
A: Very small (0.5 mm) A1 aneurysm (arrow) in a patient with a ruptured MCA aneurysm.
B: Two supraclinoid aneurysms (arrows) in a patient with a ruptured posterior communicating artery aneurysm.
C: Two middle cerebral artery aneurysms (arrows) in a patient with a ruptured pericallosal artery aneurysm (not shown).
D: intra cavernous carotid artery aneurysm (arrow) in a patient with a large ophthalmic artery aneurysm symptomatic by mass effect.
Figure 5
Four more examples of missed additional aneurysms on DSA.
A: small middle cerebral artery aneurysm (arrow) in a patient with a ruptured anterior communicating artery aneurysm.
B: Two small additional aneurysms on the anterior communicating artery and middle cerebral artery (arrows) in a patient with a ruptured anterior communicating artery aneurysm.
C: Very small (0.5 mm) A1 aneurysm (arrow) in a patient with a ruptured posterior communicating artery aneurysm.
D: Small additional anterior communicating artery aneurysm (arrow) in a patient with a ruptured middle cerebral artery aneurysm.

DISCUSSION

In this study, we found that 27 of 94 small additional aneurysms that were apparent on 3DRA of 350 vascular trees in 350 patients with a target aneurysm were missed on DSA. All but one of the missed aneurysms were 3 mm or smaller and the smallest aneurysm was 0.5 mm. In addition, we found no significant difference in distribution of missed aneurysms compared to all additional aneurysms. Intuitively, one could presume that in complex vascular areas such as the anterior communicating artery complex and middle cerebral artery bifurcation or trifurcation, aneurysms would be more easily missed on 2D images than aneurysms at other locations. However, this intuition could not be confirmed.

The phenomenon of angiographical occult additional aneurysms found during surgery of symptomatic aneurysms is well known in the surgical literature: Yaşargil 6 found in his series of 1012 symptomatic aneurysms 377 additional aneurysms of which 169 (12.2% of all aneurysms) were 2 mm or smaller. Karasawa et al 5 and Inamasu et al 4 reported an incidence of 3.7 and 4.9% of angiographical occult micro aneurysms of 2 mm or smaller. If technically possible, these micro aneurysms were clipped or wrapped in order to prevent their growth and rupture.
Although the clinical significance of the presence of additional small aneurysms may be subject to debate, in our opinion accurate detection of these small aneurysms may have consequences in selected patients for choice of therapy (coiling or clipping) and frequency and duration of follow up. For example, in patients with target aneurysms suitable both for coiling and clipping, the presence of additional aneurysms that can not be coiled may direct the therapy of choice to clipping if these additional aneurysms can be clipped in the same surgical procedure (Figures 2, 3, 4A-C, 5A-D). In patients who are treated for the target aneurysm but are left with untreated small additional aneurysms, imaging follow up strategy may be more frequent and more prolonged to timely detect growth of these small aneurysms. If small additional aneurysms remain undetected, patients may be wrongly considered to have a single instead of multiple aneurysms. In epidemiologic studies concerning multiplicity of aneurysms, this may have consequences for determination of risk factors and outcome.

In our experience, 3DRA is a major step forwards in detection and evaluation of intracranial aneurysms. The post processing capabilities of a 3D dataset allow for viewing in any desired projection in high resolution without hindering over projecting bony structures. This makes small aneurysms more obvious than on the limited number of projections of DSA. In addition, complex vascular areas such as the anterior communicating artery complex can easily be unravelled and evaluated for the presence of aneurysms or vascular variations such as fenestrations. Measurement of aneurysm diameter and aneurysm volume can be performed accurately without the need for correction for magnification. Another advantage of 3DRA over DSA is its relative operator independency: after catheterization of the desired vessel, acquisition of the rotational run is standard procedure. Extensive post processing can be performed easily for scientific purposes, even many years after acquisition if the dataset is exported from the workstation to an external data storage medium. On the other hand, DSA of intracranial vessels requires more experience and skills of the operator with respect to the decision whether and which additional projections should be made. Image post processing is limited to window and width adjustment and pixel shifting and storage of raw data is usually limited in time.

A disadvantage of 3DRA in respect to DSA is the higher contrast load per acquisitioned run (18-24 ml versus 6-8 ml) longer acquisition time (6-8 seconds) and increased patient radiation dose. In uncooperative patients, such as some patients with acute subarachnoid hemorrhage, patient movement may degrade image quality. In our study the vast majority of 3DRA datasets were acquired in patients under general anaesthesia prior to coiling of the target aneurysm. Total patient contrast load and radiation dose can be decreased when only 3DRA acquisitions are performed of all vessels, without preceding DSA runs. In this way not only total contrast load and radiation dose is roughly the same as for DSA, but also aneurysm imaging is optimized. Currently, this is our protocol in cooperative patients with suspected intracranial aneurysms.

Our findings indicate that DSA may no longer be considered the gold standard for detection of intracranial aneurysms in studies that evaluate aneurysm detection rates of non invasive image modalities such as CTA and MRA. Both these image modalities are inaccurate and unreliable in the detection of aneurysms of 3 mm and smaller. In our 350 3D datasets of single vascular trees, 444 aneurysms were detected and 122 of these (27%) were 3 mm or smaller. Thus, a considerable proportion of intracranial aneurysms can potentially be missed with CTA and MRA. Future studies concerning CTA and MRA in intracranial aneurysms should be compared to 3DRA instead of DSA.
CONCLUSION

3DRA depicts considerably more small additional aneurysms than DSA. In selected patients, accurate detection of these aneurysms may have consequences for choice of treatment modality and for frequency and duration of imaging follow up. In cooperative patients suspected of intracranial aneurysms, 3-4 vessel 3DRA only (without preceding DSA runs) should be recommended as the optimal image strategy.
REFERENCES