Three-dimensional rotational angiography in the control of the results of endovascular coiling of intracranial aneurysms

Haris Huseinagić¹*, Mirza Moranjkić², Nihad Mešanović³

¹Department of Radiology and nuclear medicine, University Clinical Centre, Tuzla, Bosnia and Herzegovina
²Department of Neurosurgery, University Clinical Centre, Tuzla, Bosnia and Herzegovina
³Department of IT, University Clinical Centre, Tuzla, Bosnia and Herzegovina

Abstract
The process of endovascular treatment of cerebral aneurysms requires intensive use of 3D rotational angiography in planning and monitoring the entire process. 3D RA allows unlimited manipulation of model blood vessels and defining the morphology of the aneurysm without using radiation. The purpose of the study was to compare the results of the analysis of residue or recurrence of the aneurysm after endovascular treatment using 3D RA and 2D digital subtraction.

Method. In 68 patients with 76 cerebral aneurysms, we made regular controls using both techniques, 2D DSA and 3D RA. Residual and recurrent aneurysms are classified into five stages, and the pictures taken by both modalities are compared.

Results. 2D DSA detected the residual and recurrent aneurysm in 53.70% of cases (29/54 aneurysms), and 3D RA in 66.67% (36/54 aneurysms). In nine cases in 2D DSA did not detect residues of which was discovered in 3D RA, and 3 cases of 2D DSA reveals little short neck aneurysm, which is on the 3D RA, in fact, a small aneurysm. In five cases from the use of 3D RA reduced the level of classification aneurysm.

Conclusion: 3D RA reveals more residues aneurysms.

Keywords: 3D RA, 2D DSA, endovascular treatment of cerebral aneurysms.

Introduction
Recent neurointerventional and neurosurgical technologies require an understanding of lesions and adjacent structures in three dimensions [1]. 3D angiography is a true technical revolution that allows improvement in the quality and safety of diagnostic and endovascular treatment procedures[2]. Geometric characteristics and arrangement of the cerebral vessels are assumed to be related to the development of vascular diseases[3]. The use of image-guided interventional radiological techniques is increasing in prevalence and complexity. Imaging system developments have helped improve the information available to interventionalists to plan and guide procedures. Information on doses to patients resulting from alternative imaging techniques or protocols is useful for both the process of justifying particular procedures and in optimizing the resultant exposures. Such information is not always available, especially for new or developing imaging techniques[4]. 3D imaging is a valuable adjunct in neuroangiography for visualization and measurement of cerebral aneurysms and for determination of the optimum projection for intervention. To enable spatially accurate 3D reconstruction the system must correct for geometrical distortion in the image intensifier television system as well as for deviations in gantry motion[5]. Dome-to-neck ratio of intracranial aneurysms is an important predictor of outcomes of endovascular coiling. 3D imaging techniques are increasingly used in evaluating the dome-to-neck ratio of aneurysms for intervention[6]. Cerebral aneurysms must be monitored for varying periods after surgical and/or endovascular treatment and the duration of follow-up will depend on the type of therapy and the immediate post-operative outcome. Surgical clamping for intracranial aneurysms is a valid treatment but the metal clips generate artefacts so that follow-up monitoring still relies on catheter angiography [7].

*Corresponding author:
Haris Huseinagić
Faculty of Medicine, University of Tuzla, Univerzitetska 1, 75000 Tuzla, Bosnia and Herzegovina
Phone: +38735303504
e-mail: haris.huseinagic@ukctuzla.ba

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gold standard of cerebral vessel imaging remains the digital subtraction angiography (DSA) performed in three projections. However, in specific clinical cases, many additional projections are required, or a complete visualization of a lesion may even be impossible with 2D angiography. Three-dimensional (3D) reconstructions of rotational angiography were reported to improve the performance of DSA significantly[8].

**MATERIALS AND METHODS**

**Patients**

Between February 2014 and December 2014, 68 consecutive patients [35 female (26–77 years, mean 53) and 33 male (24–67 years, mean 49); age range, 24–77 years; mean age, 51 years] were prospectively enrolled in this study and were examined with cerebral 3DRA. All patients had an known intracranial aneurysm, for which it was decided they should undergo 3DRA to plan endovascular or neurosurgical treatment. Clinically, 33 patients had Hunt and Hess score of 0; 8 had score I; 8 had score II; 5 had score III; 3 had score IV; and 11 had score V. 16 of 33 patients with Hunt and Hess score 0 had asymptomatic cerebral aneurysm. Written informed consent was obtained from patients or their relatives after full explanation of the nature of the diagnostic and interventional procedures.

We included 68 3D datasets of 1 vascular tree of 68 patients with at least 1 intracranial aneurysm on the 3D dataset and a complete cerebral DSA performed between February 2014 and December 2014. A complete DSA consisted of 3-vessel angiography in 53 patients and 4-vessel angiography in 15 patients, for a total of 219 vessels. 68 3D datasets were reevaluated on the workstation. The presence, location, and size of additional aneurysms were also assessed. The size of aneurysm was defined as the maximal diameter as measured on 3DRA. Data base that served as a reference consisted of results of re-evaluation of 3DRA data. The location of aneurysm were classified into carotid artery, middle cerebral artery, anterior cerebral artery, and posterior circulation. We reviewed and the DSA images of the corresponding 68 vascular trees in 2 or 4 projections on a PACS workstation for the presence and location of additional aneurysms. Results were compared with the findings in the reference database. Number, location, and size of false-negative and false-positive additional aneurysms were recorded. The location of neurysm was classified as carotid artery, middle cerebral artery, anterior cerebral artery, and posterior circulation.

**3DRA**

3D rotational angiograms were performed under general anesthesia by using an angiographic system (Integris BV 5000, Philips Medical Systems, Best, The Netherlands) running the software Integris 3DRA, release 4.2. By means of a transfemoral approach with the Selnder technique, DSA was performed by using a standard diagnostic 5-F catheter (GEN selective, IMAGERII, Boston Scientific, Natick, Mass.). The tip of the diagnostic catheter was placed in the cervical portion of the internal carotid artery or vertebral artery proximal to the skull base. Selective four-vessel injections were performed in the anteroposterior, lateral, and oblique projections.

3DRA of the corresponding vessels was then performed. Contrast material was injected with a total amount of 18 ml and a flow-rate of 3 ml/s using power injector (Angiomat Illumena, Liebel-Flarsheim, Cincinnati, Ohio). The image acquisition was performed during the 3DRA using a range of 180 degrees with a rotational speed of up to 30 degrees/s. Systemic blood pressure was monitored during the entire examination.

**Figure 1.** 3DRA of the vessels with aneurysm on arteria cerebri media. Contrast material was injected with a total amount of 18 ml and a flow-rate of 3 ml/s using power injector.

**Statistical Analysis**

A χ² test (2-tailed) was used for comparison of the proportion of aneurysms ≤ 3 mm in additional aneurysms, the proportion of aneurysms ≥ 3 mm missed on DSA and in all additional aneurysms as detected on 3DRA, and the location (classified as carotid artery, middle cerebral artery, anterior cerebral artery, and posterior circulation) of additional aneurysms missed on DSA versus the location of all additional aneurysms.
Results

In 68 3D datasets, 68 target aneurysms and 8 additional aneurysms were detected for a total of 76 aneurysms. The mean size of 68 target aneurysms was 7.4 mm (median, 6; range, 1–32 mm). The mean size of 8 additional aneurysms was 3.54 mm (median, 3; range, 0.5–17 mm). Of 8 additional aneurysms, 5 (65%) were ≤ 3 mm; and of 68 target aneurysms, 1 (17%) were ≤ 3 mm.

The proportion of aneurysms ≤ 3 mm was significantly higher in additional aneurysms (5 of 8, 65%) than in target aneurysms (1 of 68, 17%) \(|\chi^2|, p<.0001\).

Discussion

In this study, we found that 2 of 8 small additional aneurysms that were apparent on 3DRA of 68 vascular trees in 68 patients with a target aneurysm were missed on DSA. All except 1 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 with all additional aneurysms.

The phenomenon of angiographically occult additional aneurysms found during surgery of symptomatic aneurysms is well known in the surgical literature. An incidence of 3.7% and 4.9% of angiographically occult microaneurysms of 2 mm or smaller was reported [9, 10]. In a series of 1012 symptomatic aneurysms, 377 additional aneurysms, of which 169 (12.2% of all aneurysms) were 2 mm or smaller [11]. If technically possible, these microaneurysms were clipped or wrapped to prevent their growth and rupture. Although the clinical significance of the presence of additional small aneurysms may be subject to debate [12, 13], in our opinion, accurate detection of these small aneurysms may have consequences in the selection of patients for choice of therapy (coiling or clipping) and in the frequency and duration of follow-up. For example, in patients with target aneurysms suitable for both coiling and clipping, the presence of additional aneurysms that cannot be coiled may direct the therapy of choice to clipping if these additional aneurysms can be clipped in the same surgical procedure (Figs 2– 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 detect growth of these small aneurysms in a timely manner. 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 [13, 14].

In our experience, 3DRA is a major step forward in the detection and evaluation of intracranial aneurysms. The post processing capabilities of a 3D dataset allow viewing in any desired projection in high resolution without hindering over projecting bony structures. This makes small aneurysms more obvious than those on the limited number of projections of DSA [15–19]. In addition, complex vascular areas such as the anterior communicating artery complex can easily be unraveled and evaluated for the presence of aneurysms or vascular variations such as fenestrations [20]. Measurement of aneurysm diameter and aneurysm volume can be performed accurately without the need for correction for magnification [16]. 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 require more experience and skill of the operator with respect to the decision of whether and which additional projections should be made. Image post-processings limited to window and width adjustment and pixel shifting, and storage of raw data is usually limited in time. A disadvantage of 3DRA with respect to DSA is the higher contrast load per acquisitioned run (18 – 24 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, most 3DRA datasets were acquired in patients under general anesthesia before coiling of the target aneurysm. Total patient contrast load and radiation dose can be decreased when only 3DRA acquisitions are obtained of all vessels, without preceding DSA runs. In this way, not only are the total contrast load and radiation dose roughly the same as those for DSA, but aneurysm imaging is also 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 techniques such as CTA and MRA. Both of these imaging techniques are inaccurate and unreliable in the detection of aneurysms of 3 mm and smaller[21, 22]. In our sixty eight 3D datasets of single vascular trees, 68 aneurysms were detected and 1 of these (17%) 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 with 3DRA instead of DSA.

**Conclusions**

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

**Declaration of interest**

The authors declare no conflict of interest for this study.
REFERENCES


