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Added value of three-dimensional digital subtraction angiography, using dual-volume reconstruction technique, in post-treatment follow-up of cerebral aneurysms

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Abstract

Background: To assess the added value of the dual-volume technique when used with the routine single-volume 3D DSA in the follow-up of endovascularly treated aneurysms.

Results: Seventeen patients (10 females and 7 males) who underwent coiling of their cerebral aneurysms were assessed by 3D DSA using single- and dual-volume techniques. Recanalization of the aneurysm was depicted in 10 cases on the dual-volume technique, only 4 of which were detected on the single-volume 3D DSA technique. Thus, the use of the dual-volume technique upgraded our management plan from follow-up to re-treatment in 6 cases (35%)

Conclusion: The dual-volume technique of 3D DSA is superior to the single-volume technique in visualization of the endovascular devices distinctly, resulting in better evaluation of the aneurysm recanalization and its relation to the parent vessel and occluding device.

Keywords: Cerebral aneurysms, Digital subtraction angiography (DSA), Endovascular treatment (DSA)

Background

Treatment of cerebral aneurysms aims to prevent possible aneurysm rupture or re-bleeding. Endovascular embolization is now considered the first line of treatment owing to its minimal invasiveness with reduced mortality and morbidity rates as compared with the surgical intervention [1].

Following endovascular treatment (EVT) of a cerebral aneurysm in about 20% of patients, reopening of the aneurysm or its neck occurs which necessitates retreatment in approximately half of them to ensure long-term protection from bleeding [2]. In addition, the appearance of de novo aneurysms is another concern for all patients with intracranial aneurysm which occurs in about 5 to 10% of patients. Some of these carry enough risk for bleeding despite their small size [3]. Hence, imaging follow-up is crucial

for detection and preventive treatment of recurrent or of newly developed aneurysms after EVT [4].

Ideally, the first imaging follow-up should be scheduled 3–6 months after the EVT with further follow-up studies in varying time intervals according to the department's regimen and the characteristics of the patient and the aneurysm [4].

Although CT angiography (CTA) and MR angiography (MRA) are routinely used to initially diagnose cerebral aneurysms, their use for evaluation of aneurysms following EVT is much more challenging [5]. The high attenuation of the endovascular coil mass causes marked streaky beam hardening artifact on CT and CTA, which typically obscures the aneurysm, the adjacent parent, and branch vessels as well as the surrounding brain parenchyma [6]. In MRA, the coil-induced susceptibility artifacts, slow and complex flow within the residual aneurysm (resulting in spin saturation and de-phasing respectively) coupled with the long acquisition time and the risk of gadolinium-

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induced nephrogenic systemic fibrosis in patients with renal impairment, are all major limitations in imaging of coiled aneurysms [5].

For the above reasons, digital subtraction angiography (DSA) is considered the gold standard for the assessment of occluded aneurysms by EVT. Three-dimensional (3D) reconstruction of rotational angiography significantly improved the performance of DSA. It requires a flat-panel angiographic system with a motorized rotating C-arm. The acquisition comprised of two rotational scans. The first one collects subtraction masks, while the second scan acquires images during the passage of contrast medium. Software reconstructions then enable extraction of bony structures, deletion of unnecessary vessels, and rotation and zooming of the image, as well as differentiation between vascular contrast filling and vascular devices [7].

In clinical practice, 3D DSA is more sensitive than 2D DSA to small aneurysms and aneurysm remnants [8]. Therefore, 3D DSA was proposed to become a new gold standard of interventional cerebral vascular imaging due to its high spatial resolution with 3D imaging and dynamic information [9]. However, in 3D DSA with single-volume reconstruction, the image quality is degraded by device-related artifacts making recanalization difficult to detect and with difficulty in planning further intervention [7]. The dual-volume reconstruction technique was developed to reduce artifacts and provide more details regarding the aneurysm, parent vessel, and side branches as well as the used endovascular devices [10]. It is derived from the 3D DSA 3 volume data sets which are native (mask), fill, and subtracted-fill. The mask and the subtracted-fill data sets are optimized separately by choosing the best contrast, widening and color coding, and then fusing them into a single dual-volume image. These images are particularly helpful to differentiate vessels from medical devices and appreciate their relationship with bone structures increasing the accuracy for depicting residual lesions [11].

To the best of our knowledge, few data are available in the literature addressing the advantage of the dual-volume reconstruction technique over the single-volume 3D DSA.

The purpose of this study was to assess the added value of the dual-volume technique when used with the routine single-volume 3D DSA in the follow-up of endovascularly treated aneurysms.

Methods

Patients

From March 2018 through December 2018, 17 consecutive patients on their regular follow-up after EVT of cerebral aneurysm were included in this study. They were 10 females and 7 males (age range 33–67 years;

mean = 51.24). The study was approved by our local institutional review board.

DSA technique

A motorized AXIOM Artis® C-arm (Siemens Healthcare, Erlangen, Germany) with 360° rotational run was used to acquire 3D DSA of the cerebral circulation (256 image acquisition). The acquisition comprised of two rotational scans. The first scan was acquired before contrast injection to collect subtraction masks. The second scan acquired images during the passage of iodinated contrast material. Opacification of each artery was done by injection of about 15–20 ml non-ionic contrast (Ultravist®-300) at a rate of 3–4 ml/s. Images were then transferred to the workstation (LEONARDO®, Siemens Healthcare, Erlangen, Germany), where the software reconstruction of 3D images was performed to produce the dual-volume images. These enabled the extraction of bony structures and the deletion of unnecessary arteries. Image rotation and zooming were also done with the ability to differentiate between the density of the contrast filling and that of the endovascular device.

Image interpretation

An intervention neuroradiologist (AA) with more than 15 years' experience assessed the single-volume and the dual-volume reconstructions of the 3D DSA performed for each of the 17 patients. The following factors were individually assessed in each reconstruction:

- Aneurysm location and occlusion status
- Position of the residual aneurysm in relation to the coil mass
- Status of the parent artery and nearby branches
- Coil migration

Results

Demographic data

A total of 17 aneurysms were imaged. The treated aneurysms were located in the anterior communicating artery (ACOM) in 9 cases, the posterior communicating artery (PCOM) in 3 cases, and the middle cerebral artery (MCA) bifurcation in 3 cases. One case showed basilar tip aneurysm and other one had pericallosal aneurysm. Aneurysms were treated via endovascular approach by either simple coiling or balloon-assisted coiling according to the aneurysmal neck size. Data are summarized in Table 1.

Dual- versus single-volume techniques

Recanalization of the aneurysm was depicted in 10 cases on the dual-volume technique, only 4 of which were seen on the single-volume 3D DSA technique (Figs. 1 and 2).

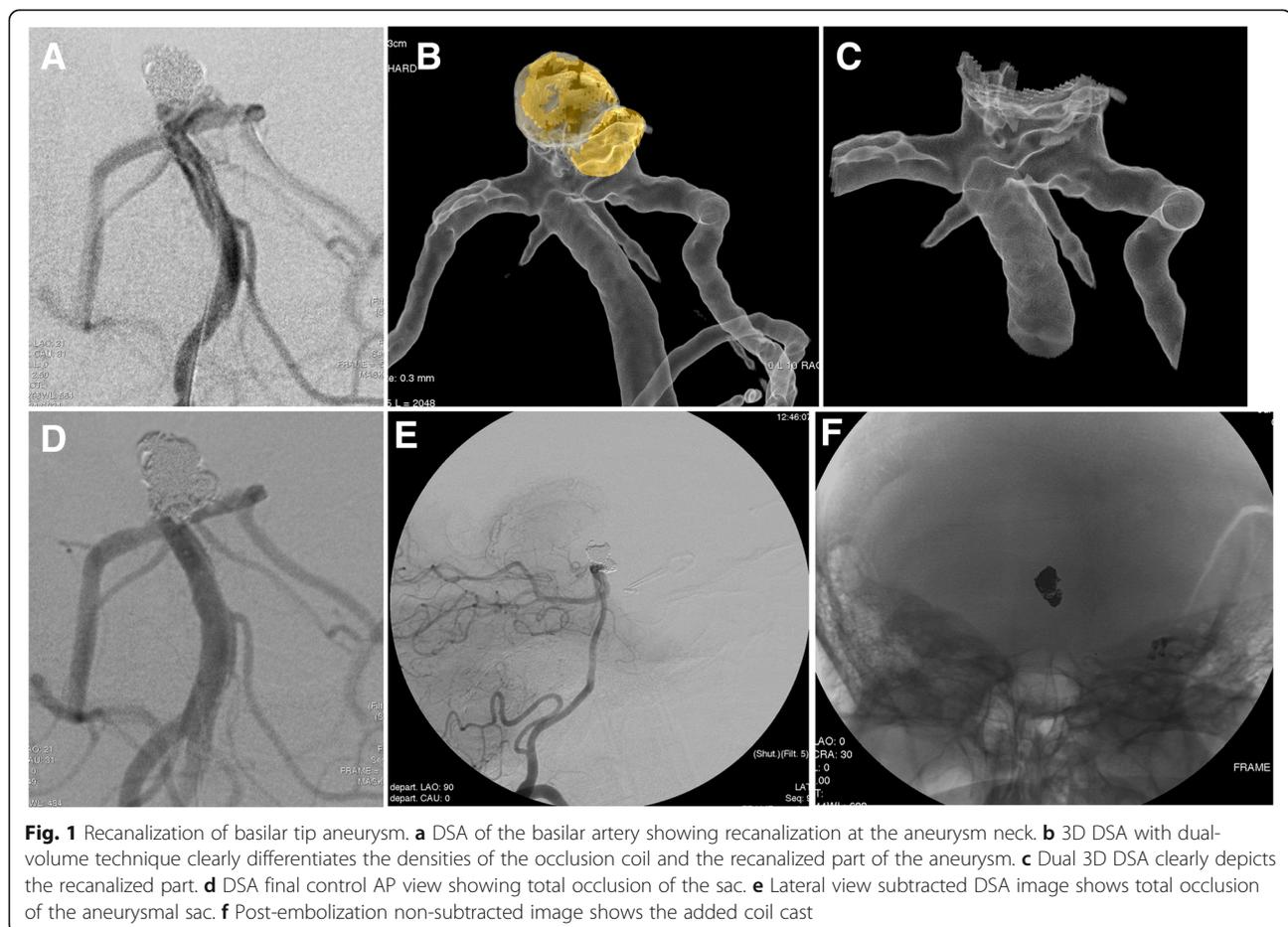
Table 1 Baseline characteristics

Factor	Number (%)
Gender	
Male	7 (41%)
Female	10 (59%)
Age (years; median)	33–67 years; median = 51
Location	
ACOM	9 (53%)
PCOM	3 (17.6%)
MCA bifurcation	3 (17.6%)
Basilar tip	1 (5.9%)
Pericallosal	1 (5.9%)
Treatment	
Simple coiling	6 (35.3%)
Balloon-assisted coiling	11 (65.7%)

Thus, the use of the dual-volume technique upgraded our management plan from follow-up to re-treatment in 6 cases (35%). Two cases were retreated by simple coiling, other 3 cases were retreated by balloon-assisted coiling, while stent-assisted coiling was done in 5 cases.

Discussion

Single-volume reconstruction technique of the 3D DSA depends on multiple image projections allowing the formation of a volumetric representation of the vessel. A complete acquisition comprised of two rotational scans. Subtraction masks are collected in the first scan (mask run). Then, images are acquired during the passage of a contrast material in the second scan (contrast run). Then, both scans are fused and reconstructed as one volume. With the increase in neuro-interventional procedures, it has been important to evaluate the vessels as well as the devices in the treatment of cerebral aneurysms during the follow-up studies [12]. In addition, the accurate position of the re-canalized aneurysm in relation to the parent vessel and endovascularly placed device is very critical for planning proper treatment. In the dual-volume reconstruction of 3D DSA, the obtained



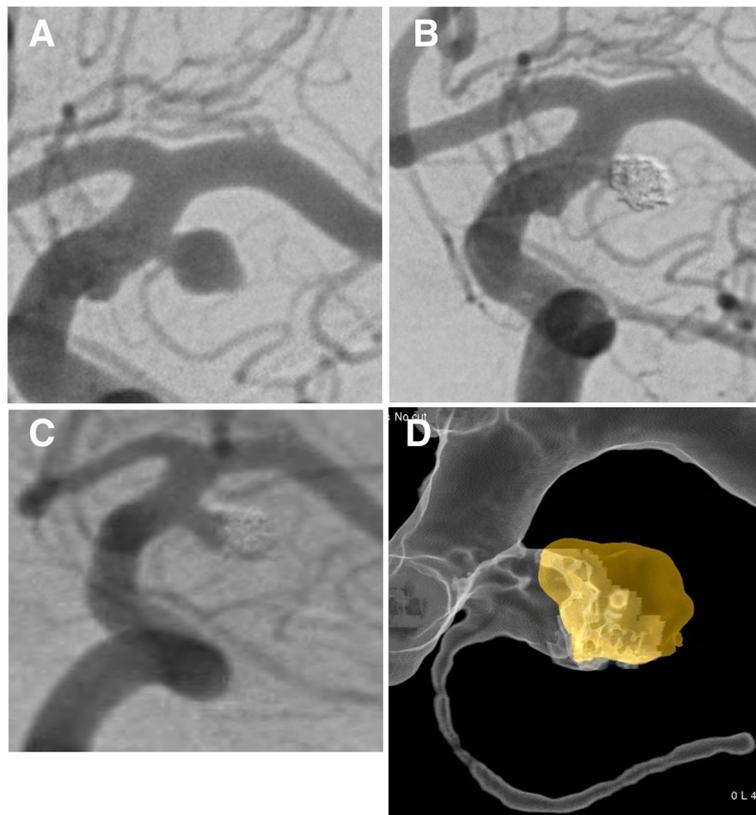


Fig. 2 PCOM aneurysm. **a** DSA: the PCOM is seen originating from the neck of the aneurysm. **b** DSA showing successful coiling of the aneurysmal sac sparing the PCOM artery. **c** Follow-up DSA 6 months later shows partial recanalization along the neck of the aneurysm. **d** Dual 3D conventional angiography clearly depicts the recanalization along the aneurysm neck with patent PCOM artery

data volumes (mask run and contrast run) are first separately reconstructed then fused together. So, we have a separate volume for the vessels and another one for the devices which are modified individually to give the required contrast, windowing, and color coding. This permits more reliable localization of the aneurysm delineating its recurrence or residual in the follow-up studies with consequent improvement in the intervention treatment planning [10].

In the present study, we compared single-volume versus dual-volume reconstruction techniques of 3D DSA in the follow-up evaluation of cerebral aneurysms after their EVT. Objective assessment of both images revealed improved identification of aneurysm recanalization in the dual-volume images. This was in agreement with the study done by Adeeb et al [10], who stated higher overall agreement rate and improved reliability between the raters in the dual-volume technique with better delineation of aneurysm location and its relation to the surrounding vasculature, occlusion status, and the presence of coil migration. Former Chinese studies were conducted addressing the role of the dual-volume technique of 3D DSA [13–15]. Zhang et al. [13] studied 20 patients

after coil embolization by Guglielmi detachable coil to explore the value of dual-volume reconstruction technique in the follow-up of these patients. They concluded that dual-volume reconstruction technique can display the location of coil bolus, degree of occlusion, and aneurysm size, with evaluation of the embolization effect by multifarious imaging modes, providing a great deal of information for the evaluation of coil embolization of intracranial aneurysm.

Conclusion

The dual-volume reconstruction 3D DSA is superior to the single-volume technique in visualization of the endovascular devices distinctly, resulting in better evaluation of the aneurysm recanalization and its relation to the parent vessel and occluding device. In our practice, we currently use the dual-volume reconstruction for patients during their follow-up evaluation after EVT of cerebral aneurysms.

Abbreviations

ACOM: Anterior communicating artery; CTA: CT angiography; DSA: Digital subtraction angiography; EVT: Endovascular treatment; MCA: Middle cerebral artery; MRA: MR angiography; PCOM: Posterior communicating artery

Acknowledgements

Not applicable

Authors' contributions

YI participated in the sequence alignment and drafted the manuscript. AO participated in the sequence alignment and helped to draft the manuscript. AA participated in the design of the study and performed the statistical analysis. All authors read and approved the final manuscript.

Funding

This study had no funding from any resource.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The local ethics committee of Ain Shams University ruled that no formal ethics approval or consent to participate were required in this retrospective study. However, non-formal IRB approval was obtained.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Received: 22 June 2019 Accepted: 30 August 2019

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