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Case Report

Virtual coil images can optimize the visualization of the neckline of intracranial aneurysms during coil embolization: A technical note

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ABSTRACT

Background: During coil embolization of intracranial aneurysms, the aneurysmal neck needs to be evaluated because coil protrusion into the parent artery may lead to ischemic complications. However, the neck cannot always be clearly visualized due to the limitation of the angiography system and due to the structure of the aneurysm. As a visual aid, we propose a color-coded fusion imaging method that generates “virtual coil” images using preoperative three-dimensional digital subtraction angiography (3D-DSA) images.

Case Description: Coil embolization for intracranial aneurysms was performed using the working angles determined from the preoperative 3D-DSA. The aneurysms were located at the middle cerebral artery, anterior communicating artery (A-com), and posterior communicating artery (P-com). The A-com and P-com aneurysms were recurrent. During the later phase of the procedure, physicians could not judge whether coils protruded into the parent artery on two-dimensional digital subtraction angiography (2D-DSA) images because an optimal working angle could not be realized. Virtual coil images were displayed on the angiography system's monitor to show the expected completed embolization, which could be compared to the current 2D-DSA images as a visual aid.

Conclusion: Virtual coil images can provide visual aid to the treating physician during aneurysm coil embolization, which is useful when an accurate working angle cannot be reached.

Keywords: Three-dimensional digital subtraction angiography, Coil protrusion, Fusion, Intracranial aneurysm, Virtual coil embolization, Image fusion, Simulation

INTRODUCTION

Progress in diagnostic imaging technology has contributed to improved safety of intracranial endovascular treatments. Stent-assisted coil embolization of cerebral aneurysms heavily relies on precise imaging, and an important factor for evaluating the success of the treatment is whether coils protrude into the neck of the aneurysm. This is because coil protrusion into the parent artery is considered being one of the risk factors for ischemic complications.[6,7] Coil protrusion tends to occur during the later phase of the procedure, after several coils have already been deployed.[6] Cone-beam computed tomography (CBCT), which provides three-dimensional (3D) images acquired by an angiography system, is one imaging technique that can be used to detect coil protrusion, but metal artifacts from the coil mass around the aneurysmal neck may mask details and make precise evaluation challenging. Intraoperative two-dimensional digital subtraction angiography (2D-DSA) is another imaging technique and may reduce the disadvantages of cone-beam CT related to metal artifacts, but the spatial relationship of the aneurysm, parent artery, and coils cannot be evaluated precisely on 2D images, and coil protrusion may be detected when in reality it is not present.

The workflow of coil embolization often starts with the acquisition of a preoperative 3D-DSA and planning the two optimal working angles for the 2D-DSA views. One view will aim at having a cross-section of the aneurysmal neck along the parent artery, and the other view will aim at a down the barrel view.[5] However, it may not be possible during the procedure to realize these optimal views because of the structural relationship between the aneurysmal neck and the parent artery. As a result, the neck of the aneurysm may not be accurately visualized. This is especially common in anterior communicating artery (A-com) aneurysms and in middle cerebral artery (MCA) aneurysms that may be covered by a bifurcated vessel. In these situations, it is often difficult to evaluate whether the coil protrudes into the parent artery on 2D-DSA during the procedure.

To overcome these limitations, we propose a color-coded image post processing method for 3D-DSA images, "virtual coil." The virtual coil would allow us to understand the area to be embolized at one glance, even in cases when an accurate working angle cannot be reached by the angiography system. Virtual coil also would allow us to judge the presence or absence of coil protrusion more accurately when on 2D-DSA the coil seems to protrude into the parent artery.

VIRTUAL COIL IMAGING

This study was approved by the Institutional Review Board (IRB) (27-236[8121]). In this case series, all image data were acquired by a biplane angiography system (Artis Q, Siemens Healthcare GmbH, Forchheim, Germany) and post processed on the workstation (syngo XWP, Siemens Healthcare GmbH) of the system. The 3D-DSA preoperative image data were used to reconstruct two subtraction images using the following parameters: HU kernel type, normal image characteristics, and slice matrix of 512 × 512, resulting in a voxel size of approximately 0.15 mm in each dimension. In the first image, the aneurysm was cut out manually and colored as a solid image, and the second image was displayed as a translucent image including the aneurysm and all vessel structures by modifying the trapezoid transfer function in the volume rendering technique. Both images were fused on the workstation resulting in "virtual coil" images of a translucent parent artery with a solid-colored aneurysm overlay.

In re-embolization cases, virtual coil images were created using contrast-enhanced images and subtraction images. The contrast-enhanced images were used to show the parent artery and coil mass of the first embolization and the subtraction images were used to show the area to be re-embolized. The parent artery was displayed as a translucent image, and coil mass and new aneurysm were displayed as solid-colored images [Figure 1].

In this case series, a virtual coil image was used for the determination of the working angle and the comparison with the 2D-DSA images during each coil embolization procedure.

RESULTS

Case 1: MCA aneurysm

A 50-year-old woman was diagnosed with an incidental aneurysm located at MCA via magnetic resonance imaging (MRI). The aneurysm with a maximum size of 5.2 mm was located at the junction of M1-M2, and diagnostic angiography examination revealed a complex shape of the aneurysm. The parent artery was found to cover the aneurysm, and complete embolization was expected to be difficult.

Stent-assisted coil embolization was performed under general anesthesia. The working angles predicted from the diagnostic angiography were around the left anterior oblique (LAO) 60° and the right anterior oblique (RAO) 50°. For the procedure, the patient's head was tilted to the right side about 30° before the embolization to optimize the position of the two planes of the angiography system. The working angles decided based on the 3D-DSA image acquired at the beginning of the procedure could not separate the aneurysm and parent artery due to the complex shape of the aneurysm [Figure 2]. The barrel view could not be acquired because of the limitations of the angulation of the angiography system, and alternative working angles were decided.

To facilitate visualization of the aneurysm for embolization, virtual coil images were generated from the 3D-DSA image [Figure 3]. First, the stent was placed from M2 superior trunk to M1, and then the coil embolization was performed by jailing technique and trans-cell technique using the virtual coil images as a visual guide. The final volume embolization ratio was 22%.

Case 2: A-com aneurysm

A 59-year-old man had been diagnosed with an incidental aneurysm located at the A-com which was treated with coil embolization. Follow-up by non-contrast MRI was continued for several years. Recanalization increased gradually and retreatment with stent assist coil embolization was scheduled. Recanalization occurred at a slightly different location than that of the first aneurysm. A *de novo*-like bump was observed in

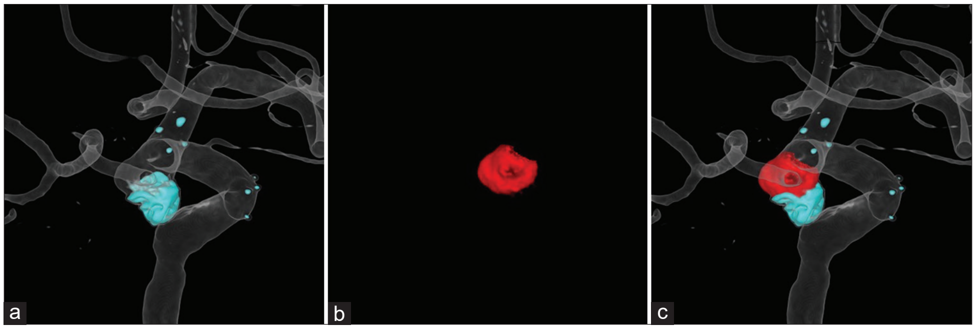

Figure 1: Generation of virtual coil images: (a) Images of the coil mass from the first embolization and parent artery after adjusting the trapezoid transfer function of the contrast-enhanced images in the volume rendering technique. (b) The area to be re-embolized was manually cut from the subtraction images (red). (c) Virtual coil images after fusion to differentiate coils (blue) and area to be re-embolized (red).

Figure 2: Case 1: Planned working angles from preoperative three-dimensional digital subtraction angiography image. (a and b) View aiming at separating M1 and M2 superior trunk for stent placement. (c and d) View aiming at separating the aneurysm from the M2 inferior trunk.

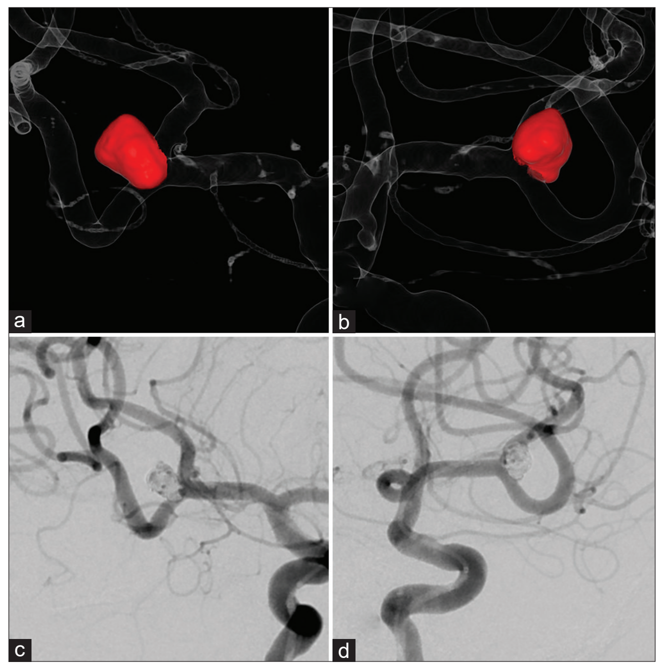

Figure 3: Case 1: (a and b) Virtual coil images generated from the preoperative three-dimensional digital subtraction angiography (DSA) images with the aneurysm area to be coiled (red). (c and d) Two-dimensional DSA after the embolization shows the coil masses as suggested by the virtual coil images.

front of the coil mass [Figure 4]. It was difficult to determine the working angle because the contralateral A2 overlapped with the recurrent aneurysm. In addition, it was difficult to predict the area of the new coil embolization because the existing coil mass in the aneurysms obstructed the view of the *de novo*-like bump. Virtual coil images were created from preoperative 3D-DSA [Figure 5] that suggested the final shape of the coil mass and facilitated the distinction between the existing coil and the area to be embolized.

Coil embolization and stent placement were performed using the two working angles of neck view and barrel view. Virtual coil images were displayed on the monitor during the procedure and compared to the 2D-DSA images [Figure 6]. After the procedure, a postoperative 3D-DSA was acquired to evaluate the area of the coil embolization and the potential of the coil to the parent artery. Complete occlusion and no protrusion were confirmed [Figure 7].

Case 3: Posterior communicating artery (P-com) aneurysm

A 77-year-old woman was diagnosed with an incidental left P-com aneurysm with a maximum size of 6 mm during

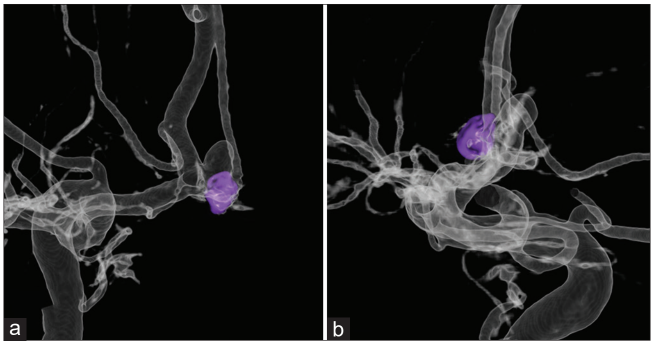

Figure 4: Case 2: (a and b) Three-dimensional digital subtraction angiography image before the retreatment with coil mass (purple) from the first treatment.

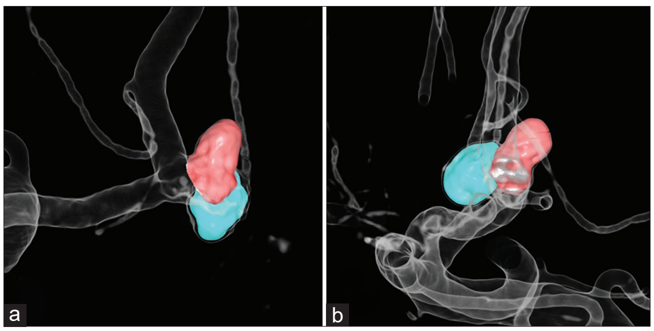

Figure 5: Case 2: (a and b) Preoperative virtual coil images with coils from the first treatment (blue) and recurred aneurysm area to be embolized (red).

Figure 6: The virtual coil image was displayed next to the two-dimensional digital subtraction angiography images both inside the operation room and on a monitor in the operators' room.

a brain checkup. The aneurysm was treated by stent-assisted coil embolization, but a neck remnant remained, and observation by annual checkups was decided. After 8 years, the patient experienced oculomotor nerve paralysis.

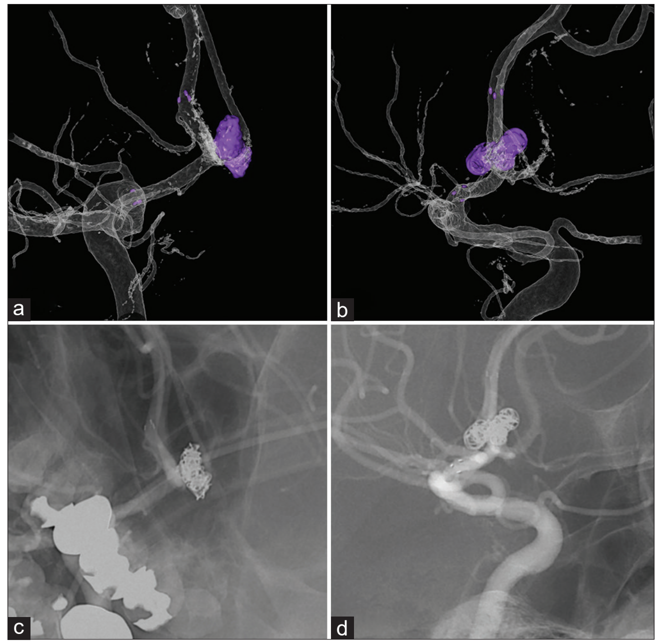

Figure 7: Case 2: (a and b) Three-dimensional digital subtraction angiography images of the total coil mass (purple) after the retreatment. (c and d) Corresponding two-dimensional digital subtraction angiography images. The shape of the new coil mass matches the mass shown on the virtual coil images in Figure 5.

A diagnostic angiography revealed cross flow of the P-com and retreatment by coil embolization including the P-com was scheduled.

The procedure started with the acquisition of a cone-beam CT image to assess the situation of the placed stent, and acquisition of a 3D-DSA image to create a virtual coil image. The retreatment was planned as the embolization of the P-com together with the aneurysm. Two working angles were determined using the 3D-DSA image, but the angles that would clearly separate the aneurysm and parent artery could not be achieved during the procedure due to the limitation of the angiography system [Figure 8]. Virtual coil images were generated to distinguish the previous coils and the area to be embolized and for visual guidance during the embolization. However, during the later phase of the procedure, the physician could not clearly judge whether coils protruded into the parent artery. The 2D-DSA images were then compared to the virtual coil images [Figure 9], and the aneurysm was diagnosed as complete occlusion based on these images and on inspection of the postoperative 3D-DSA.

DISCUSSION

Coil protrusion during coil embolization for cerebral aneurysm is not rare, with incidence estimates ranging from 5.2% to 18.9%.[6] Overall, 2.5–28% of coil protrusion cases result in thromboembolic complications.[1] It is therefore

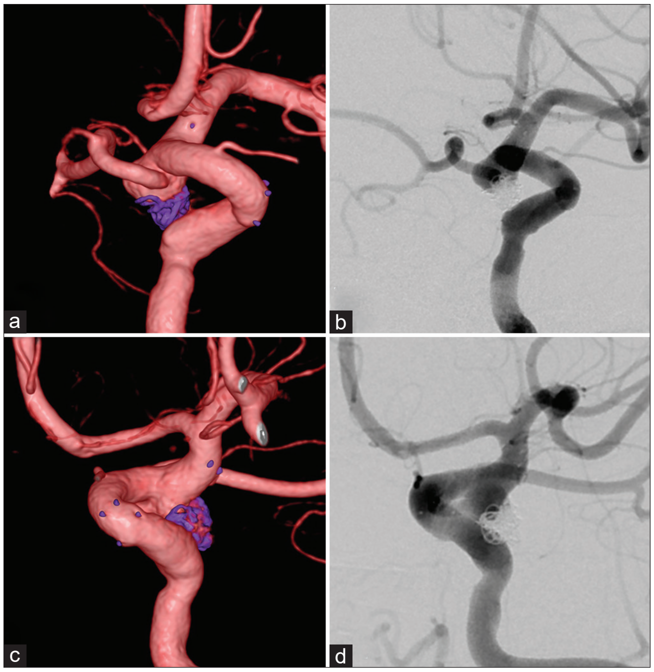

Figure 8: Case 3: (a and b) Barrel view (three-dimensional digital subtraction angiography [3D-DSA] and two-dimensional digital subtraction angiography [2D-DSA]) achieved by the angiography system. (c and d) View aiming at separating the aneurysm and parent artery (3D-DSA and 2D-DSA) could not be achieved.

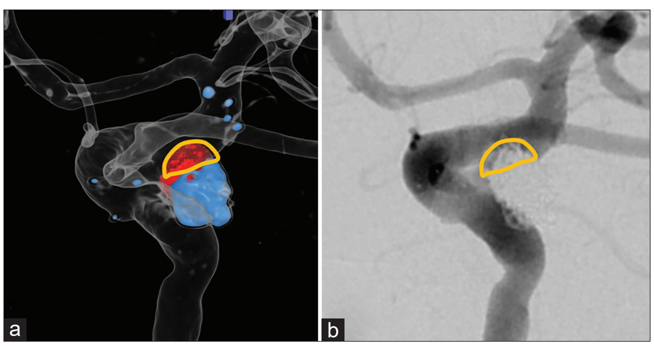

Figure 9: Case 3: (a) Preoperative virtual coil image with coil mass from the first coil embolization (blue), coil mass to be deployed during retreatment (red). (b) Postoperative 2-dimensional digital subtraction angiography of the same view as the virtual coil images. Yellow outline shows the overlap area of the aneurysm and parent artery.

desirable to detect and repair coil protrusion during the procedure.

Virtual coil images could be generated in a few minutes during the procedure with commercially available software installed on the workstation of the angiography system and may facilitate the determination of working angles of the procedure. The images display the aneurysm and parent vessel in different colors to show the area where coils will be deployed, which helps the treating physician understand the spatial relationship between the aneurysm, the existing coils if present, the area that needs to be embolized and the parent artery. Virtual coil images can be displayed side-by-side next to live and 2D-DSA images, allowing the treating physician to confirm coil protrusion in real-time in the operation room. Furthermore, it is useful as a tool to explain the area of the embolization to patients. In this case series, virtual coil images were useful for deciding working angles for treatments of medium-sized internal carotid artery aneurysms with a shared neck, A-com, and MCA aneurysms with bifurcation. Virtual coil images also suggested the final shape of the embolization.

Workstations equipped with an application that automatically separates the aneurysm and parent vessel and calculates the aneurysm volume have been reported to be useful in selecting the appropriate device size for web implantation.[2] However, the shape of the aneurysm and the actual area to be embolized may differ due to the presence of branches originating from the aneurysms. In these cases, manual segmentation is required, because the treating physician must decide whether to include the branch in the coil embolization. In addition, automatic segmentation may not give reliable results for an aneurysm that is scheduled for retreatment due to the complex shape of the growth area. Manual segmentation allows free tracing of the embolization area and may be more accurate than automatic segmentation.[4]

This method has some limitations. The separation of the aneurysm and parent vessel depends on the operator because the segmentation is done manually. Furthermore, the shape and angle of the vessels may change when the coils and microcatheters are deployed into the aneurysm because the virtual coil images were fused using preoperative 3D-DSA images. Virtual coil images thus become less precise as the procedure progresses. Furthermore, some shapes of aneurysms are less suitable for the generation of virtual coil images, such as aneurysms which have a complex aneurysmal neck and spindle-shaped aneurysms, because the aneurysmal neck cannot be defined accurately. Finally, the 3D-DSA image tends to overestimate the area filled with contrast medium due to volume averaging.[3] Therefore, the impression of a virtual coil may be different from 2D-DSA.

Nevertheless, we believe that virtual coil image may help the treating physician, as it provides a visual aid for the treatment.

CONCLUSION

Virtual coil images can display the area of coil embolization when an accurate working angle cannot be reached because of limitations of the angiography system or because of the structural relationship of the aneurysm and surrounding vessels and provide visual aid to the treating physician during aneurysm coil embolization.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

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Conflicts of interest

Dr. Katharina Otani is an employee of Siemens Healthcare.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The author(s) confirms that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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