Fusion of Three-dimensional Calcium Rendering with Rotational Angiography to Guide the Treatment of a Giant Intracranial Aneurysm: Technical Case Report

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Received, December 28, 2004.
Accepted, August 19, 2005.

OBJECTIVE AND IMPORTANCE: Although three-dimensional (3D) rotational angiography enables the visualization of intracranial vascular anatomy with high spatial resolution, its ability to resolve calcified features is limited. We present a case in which a 3D calcium density rendering was fused with rotational cerebral angiography to guide the treatment strategy of a giant, calcified, partially thrombosed, middle cerebral artery bifurcation aneurysm.

CLINICAL PRESENTATION: On screening magnetic resonance imaging, a 57-year-old woman with familial subarachnoid hemorrhage was found to harbor a giant trilobed, partially thrombosed, calcified aneurysm. Three-dimensional (3D) cerebral angiography revealed only partial contrast filling of one lobe with a daughter component.

TECHNIQUE: A distinct rotational acquisition volume with parameters optimized for calcium density visualization was acquired just before the conventional contrast acquisition. The resulting 3D calcium volume rendering was fused with the vascular model. Multiplanar interactive visualization of the combined model uncovered heavy calcification at the neck of the aneurysm that precluded direct clipping, and the patient underwent endovascular coil embolization.

CONCLUSION: Preoperative assessment of intracranial aneurysms can be facilitated by the current technique, which enables the detection of calcified tissue near the neck, which would otherwise not be possible with 3D rotational cerebral angiography alone.

KEY WORDS: Calcium, Giant cerebral aneurysm, Three-dimensional angiography

Neurosurgery 58[ONS Suppl 1]:ONS-173–ONS-174, 2006 DOI: 10.1227/01.NEU.0000193524.98940.BB

The advent of three-dimensional (3D) digital rotational angiography (DRA) and reconstruction algorithms has led to improved spatial visualization of the intracranial vascular tree at high spatial resolution. These techniques have enabled the predictive modeling of aneurysmal occlusion after coil embolization (5), the accurate measurement of parent vessel and neck morphology to guide therapeutic decision making (1), and the endoluminal assessment of vascular stenosis (9).

Among the limitations of 3D angiography has been the inability to resolve, with a sufficiently high degree of contrast, bony and calcium-rich structures surrounding the target vascular lesion, such as atheroma within or adjacent to the vascular wall. To overcome this problem, recent acquisition optimizations have been developed to enable the 3D imaging of calcium-rich structures. When fused with the corresponding 3D-DRA volume, these rendering schemes make it possible to visualize calcium-dense structures surrounding atherosclerotic blood vessels and stenoses being considered for endovascular stent angioplasty. In the treatment of intracranial giant aneurysms, the simultaneous high-resolution imaging of the luminal anatomy and the calcium-rich components of a target lesion can prove indispensable. In this report, we illustrate the usefulness of fusing a 3D calcium density model with a shaded surface rendering of the parent vessel to guide the decision-making process and treatment strategy of a giant calcified middle cerebral artery (MCA) aneurysm.

CASE REPORT

Clinical Presentation

A 57 year-old woman was referred for screening magnetic resonance imaging and magnetic resonance angiography be-

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cause of a family history of subarachnoid hemorrhage. She denied any headache or neurological symptoms, and had no previous intracranial imaging. The magnetic resonance imaging demonstrated an incidental giant multilobular aneurysm arising from the right MCA trifurcation. A gadolinium-enhanced magnetic resonance angiography was obtained, which showed a complex calcified fundus with a multilamellar appearance, suggestive of intramural hemorrhage and thrombosis (*Fig. 1*); however, the intra-aneurysmal flow pattern could not be resolved.

Diagnostic Angiography with 3D Models

Transfemoral cerebral angiography was performed using a 4-French Berenstein diagnostic catheter (Cordis Corp., Miami Lakes, FL). High-resolution two-dimensional (2D) digital subtraction angiography (DSA) was performed on a Philips Integris Allura biplane system (Philips Medical Systems, Andover, MA). Initial anteroposterior and lateral views after injection of the right internal carotid artery with Optiray 240 (Mallinckrodt Inc., St. Louis, MO) showed some intraluminal flow within the portion of the aneurysm immediately adjacent to the parent vessel, measuring approximately 13 mm. No filling was observed in the other two lobes, suggesting that the lesion was almost completely thrombosed (*Fig. 1*).

Three-dimensional reconstructions were generated from a rotational 3D-DRA data set, using the standard protocol of a 240-degree C-arm sweep and a contrast injection rate of 4 ml/s for a duration of 4 seconds. The 3D data set was visualized using the Philips Integris 3D-DRA software package on a Dell workstation (Dell Inc., Round Rock, TX) running a Windows 2000 operating platform (Microsoft Corp., Redmond, WA). The resulting 3D shaded surface rendering, representing the angiographic lumen of the parent vessel and aneurysm, was manipulated in 3D space. The superior M2 division segment was dilated in a fusiform aneurysmal fashion, before dividing and leading to the M3 segments. Despite a suggestion of higher density within portions of the aneurysm, it was not possible to resolve any calcified aneurysmal component with any detail.

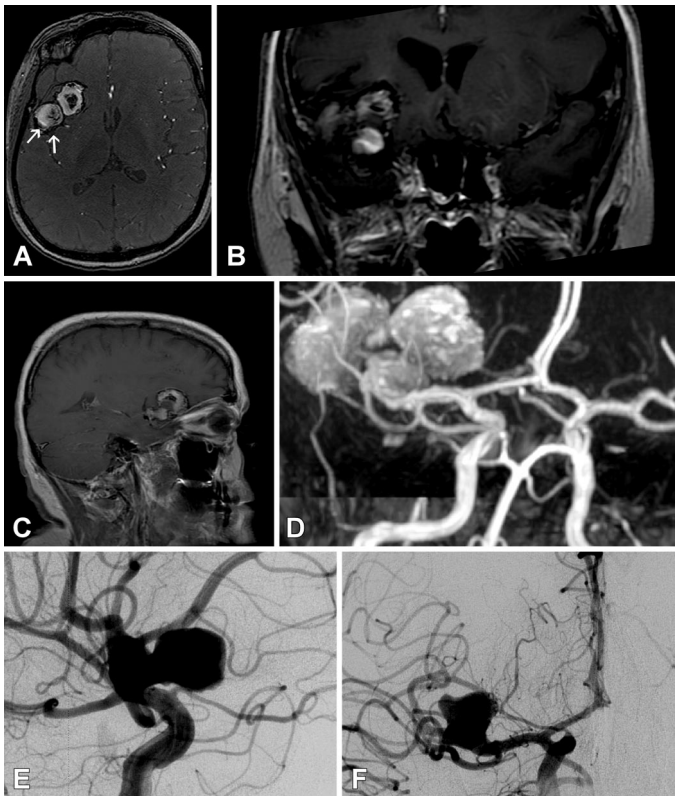


FIGURE 1. *Magnetic resonance imaging of a giant right MCA aneurysm. Gadolinium-enhanced T1-weighted images (*A*, axial;* B*, coronal; and* C*, sagittal images) demonstrate a multilobular mass with enhancement within the aneurysm fundus (*white arrows*). Three-dimensional reconstruction of the maximum intensity projection sequence (*D*) is corrupted by artifact. DSA of the right internal carotid injection (*E*, lateral view;* F*, anteroposterior view).*

Three-dimensional Calcium Imaging and Vascular Model Fusion

To enable the visualization of calcium-rich structures, a specific algorithm (Philips CalciView) was used to acquire a 3D data set, using the same rotational protocol and image capture rate without injection of contrast agent, just before the conventional 3D-DRA contrast acquisition. The calcium acquisition algorithm consisted of exposure and acquisition parameters that were optimized to enhance the imaging of calcium-dense structures. The 3D data sets representing the angiographic and calcium density were reconstructed and fused on the workstation, and imaged in 3D space (*Fig. 2*). When applied to this case, a clear representation of the three calcified aneurysm domes and the adjacent temporal and petrous bone structures was observed. Within the two larger superior domes, a thin calcified shell was visualized over the

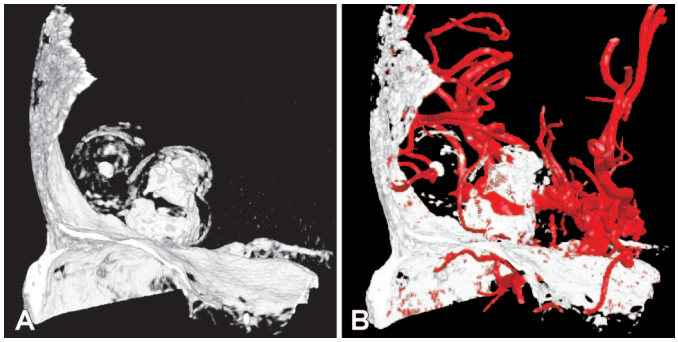


FIGURE 2. A*, calcium density 3D reconstruction and angiographic fusion. A rotational calcium density run is used to generate a 3D rendering of calcium-rich tissue. Note the three distinct domes with varying degrees of calcification.* B*, 3D fusion of the calcium density volume with the vascular reconstruction of the right internal carotid injection enables the visualization and manipulation of the calcium-rich tissues and vascular structures concurrently. Note that the most-heavily calcified dome is the one that fills with angiographic contrast medium.*

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entire extent of the domes. We observed the highest calcium content within the anteromedial dome, which was the only component that filled angiographically, and was adjacent to the neck of the aneurysm. Fusion of the calcium rendering and the 3D-DRA data set enabled the simultaneous spatial examination of both the angiographic luminal component and the calcified portions of the aneurysm. We used this technique, along with 3D model manipulation and the virtual cut-plane, to explore the features of the aneurysm neck (*Fig. 3*). Several important anatomic relationships were uncovered using this technique, including a very dense deposit of calcium on both sides of the aneurysm neck, with partial extension into the parent vessel wall (*Fig. 3E*). The calcification encircled nearly the entire aneurysm neck, excluding a small portion of the anterior-inferior aspect. This finding, which was not evident using the conventional 3D-DRA approach (*Fig. 3, A–C*), was critical in determining that the aneurysm neck would most likely not be amenable to direct surgical clipping. Although extracranial-intracranial (EC-IC) bypass was considered, it would have necessitated independent bypass to the superior and inferior M2 divisions, as shown in *Figure 3, A* and *B*. In the current fusion technique, the spatial gap between the angiographic lumen and the calcium shell represents the shell of thrombus or fibrous tissue within the confines of the aneurysm. After discussion with the patient, we performed endovascular coil treatment of the anteromedial dome and observation of the fusiform superior M2 segment. This was achieved without technical complications, using bioactive Matrix coils (Boston Scientific Inc., Natick, MA), while the patient was under general endotracheal anesthesia (*Fig. 4*).

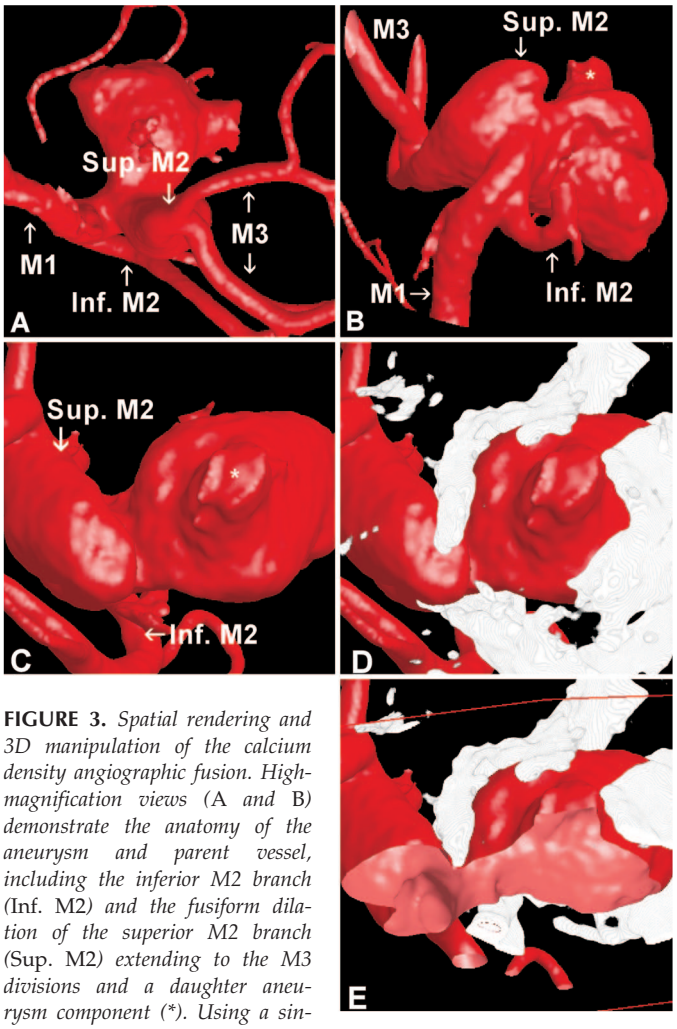


FIGURE 3. *Spatial rendering and 3D manipulation of the calcium density angiographic fusion. High-magnification views (*A *and* B*) demonstrate the anatomy of the aneurysm and parent vessel, including the inferior M2 branch (*Inf. M2*) and the fusiform dilation of the superior M2 branch (*Sup. M2*) extending to the M3 divisions and a daughter aneurysm component (*). Using a single projection for analysis (*C–E*), the 3D angiographic lumen rendering of the parent vessel is visualized (*C*) and fused to the calcium density 3D rendering (*D*). Using the cut-plane function enables multiplanar cross sectional imaging of the fused model, which, in this case, clearly demonstrates the high calcium content at the neck of the aneurysm and the fusiform M2 division (*E*).*

DISCUSSION

Giant aneurysms are complex lesions that demand thorough surgical planning and individualized strategies because of their poor natural history. Complications may include rupture, intraaneurysmal thrombosis, mass effect, and thromboembolic events (3, 4, 6, 7). Several therapeutic options exist for the management of giant intracranial aneurysms. These include open surgical clipping with debulking of the aneurysm fundus to simultaneously exclude the aneurysm from the circulation and decrease secondary mass effects and intramural thrombosis. EC-IC bypass to the vessel distal to the aneurysm and parent vessel occlusion proximal to the aneurysm is an adjunctive approach when direct clipping is not possible (10). For EC-IC bypass, the site of bypass

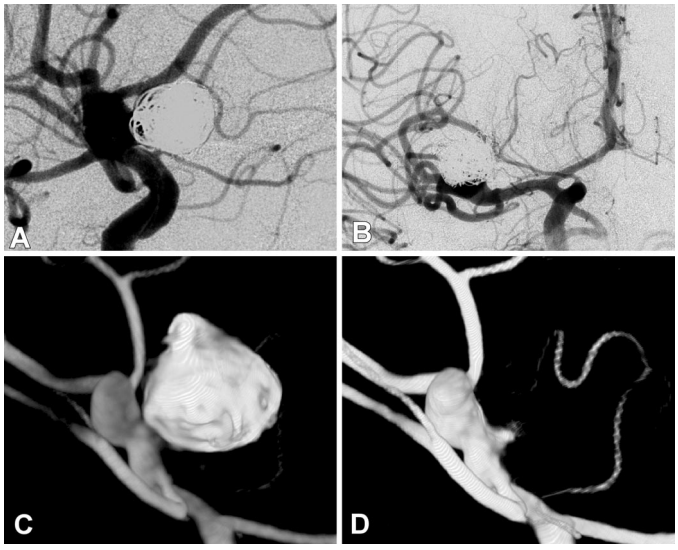


FIGURE 4. *Postembolization 2D-DSA and 3D-DRA imaging. Biplane (*A*, lateral view;* B*, anteroposterior view) DSA shows that the calcified aneurysm dome has been embolized. Three-dimensional unsubtracted (*C*) and subtracted (*D*) rotational angiography demonstrates the embolized dome and the untreated fusiform superior M2 division.*

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and occlusion can be chosen by flow occlusion studies during cerebral angiography (8). To guide appropriate decision making toward the best definitive therapy, extensive preoperative radiological assessment is mandatory. Factors influencing the technical difficulty of adequate surgical clip placement include aneurysm size, orientation, relationship to surrounding vascular and osseous structures, and vascular intimal composition. For EC-IC bypass, surgical access to adequate bypass sites, collateral vasculature, and a complete understanding of the hemodynamic contribution to the vascular territories of the bypassed vascular segment are essential. Endovascular coiling represents another therapeutic option (2), although it can be associated with a higher rate of recanalization and coil compaction in partially thrombosed aneurysms. Thrombus remodeling is more likely to occur if there is persistent inflow into the aneurysm despite embolization, such as may occur when the coil packing density is low.

In the current 5-cm giant right MCA aneurysm, it was possible to visualize the relative opacification and thrombosis within the aneurysm dome, to precisely measure the intraluminal, neck, and parent vessel dimensions, to evaluate potential bypass sites, and to determine the aneurysmal neck calcium content. Balancing these factors, endovascular coiling with bioactive coils was chosen to deflect the flow from the anteromedial dome and to promote progressive thrombosis to the level of the aneurysm neck.

Initial 2D-DSA and 3D-DRA renderings demonstrated a large aneurysm lumen with a large neck. Comparison of the contrast opacification on angiography with the magnetic resonance imaging scans clearly showed a difference in filling volume, but the precise size disparity between the thrombosed and filling compartments of the aneurysm was not clear until the calcium density rendering was fused with the angiographic model. With respect to open surgical clipping, the heavy calcification uncovered within the aneurysm neck by the present fusion technique, coupled with the relatively thick calcified lobe containing the inflow zone from the parent vessel, suggested that clip reconstruction to secure the aneurysm would most likely not be possible without occluding the parent vessel (*Fig. 3*).

CONCLUSION

When fused with rotational angiography, simultaneous 3D calcium density imaging can provide both the requisite level of spatial resolution and the relative contrast necessary for the understanding of the intricate anatomy and tissue composition for the treatment of complex intracranial calcified vascular lesions.

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Acknowledgments

Neither author has any financial interest or own shares in any of the companies mentioned in this article. Neither author received any financial or technical support in the preparation of this work. The authors and their sponsoring institution have no financial interest in the devices or equipment described.

COMMENTS

Hoit and Malek describe a 57-year-old woman with a giant MCA aneurysm for which a standard three-dimensional (3D) rotational angiogram was fused with a 3D calcium rendering to help determine the optimal treatment modality. Because heavy calcifications in the neck of the aneurysm were depicted on the fused 3D angiogram, the aneurysm was treated with bioactive coils. The authors assert that 3D rotational angiography with calcium rendering allows clinicians to obtain a more accurate depiction of the degree of calcification of the aneurysm and that this knowledge may lead to more appropriate patient management.

The management of giant aneurysms heavily depends on multimodal radiographic depictions. Surgeons must incorporate findings from CT, MRI, and catheter angiography to determine the most appropriate course of action. The authors' technique brings together previously disparate pieces of information.

However, we urge the authors not to discount the role of 3D CT angiography in depicting these lesions. The introduction of 8- and 16-row (and perhaps beyond) multi-slice CT angiography will further narrow and potentially eclipse the gap between CT angiography and conventional catheter angiography.

Vivek R. Deshmukh
Robert F. Spetzler
Phoenix, Arizona

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This report illustrates an interesting fusion technique which suggested dense neck calcification in a complex giant aneurysm. These findings lead to a decision for endovascular coiling. I believe that the imaging technique was helpful but the treatment decision was questionable. This aneurysm, in my opinion, has not been definitively treated. The coils will likely migrate into the thrombus over time allowing progressive aneurysm growth. Definitive therapy will require Hunterian strategies and revascularization.

However, this technique is a step toward the ultimate goal of perfect 3D imaging of all intra- and extravascular structures with precise characterization of thrombotic components.

H. Hunt Batjer
Chicago, Illinois

In this technical case report, the authors demonstrate the use of an imaging technique to coregister 3D angiographic images with 3D calcium density reconstructions. With this approach, excellent visualization of the calcified portions of the aneurysm is possible. In rare cases, the extent of calcification of an aneurysm is important information for treatment planning. For the most part, I have found that thin slice CT scanning provides adequate delineation of calcification in giant aneurysms. Whether or not the 3D calcium density reconstructions shown in this report represent superior information compared to CT scanning, is yet to be resolved.

Since the aneurysm in this case report was incidental, mostly thrombosed, and heavily calcified, I agree that surgical treatment was not appropriate. It is not clear, however, that partial coil embolization of giant thrombosed aneurysms has any long term benefit.

Robert A. Solomon
New York, New York

It is disappointing to both neurosurgeon and patient when surgical exploration of an aneurysm reveals unexpectedly a densely calcified aneurysm neck. This aneurysm requires an endovascular therapy or an alternative surgical therapy, like bypass and trapping, for which one might not be prepared. Hoit and Malek present a patient with a giant, thrombotic MCA aneurysm that was imaged with 3D digital rotation angiography and 3D calcium volume rendering. The fusion of these two modalities enabled complete analysis of the aneurysm's morphology and clippability, which guided their management decisions. This technique is novel and clinically relevant. Patients with positive family histories that are screened with brain MRI and MR angiography often proceed directly to catheter angiography, without CT scans, which makes neck calcifications easy to miss. This fusion technique addresses this clinical problem in a growing population of patients.

Michael T. Lawton
San Francisco, California

A new technique, fusion of 3D calcium rendering with rotational DSA, was applied to a case with giant MCA aneurysm. The calcium fusion technique successfully demonstrated heavy calcification at the neck of the complicated aneurysm. The advantage of the presented technique upon 3D CT angiograhy is to obtain simultaneous calcium and vessel imaging during angiography, which would be valuable for the operator to decide the subsequent interventional strategy such as carotid artery stenting. To establish the significance among presurgical evaluations for intracranial vascular diseases, direct comparison of the appearance of calcium and vessel using both 3D CT angiography and calcium fusion technique would be necessary. Further studies could provide new information of thrombus or atheroma identified as a gap between the calcium density and the angiographic lumen, as shown in *Figure 4*.

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