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Transluminal Imaging With Perspective Volume Rendering of Computed Tomographic Angiography for the Delineation of Cerebral Aneurysms

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Abstract

Transluminal imaging with perspective volume rendering of computed tomographic angiography was used to investigate three patients with unruptured cerebral aneurysms. Selective changes in the opacity chart of computed tomography values, based on a spiked peak curve, represented the contour of the vessel and aneurysmal walls as a series of rings, and allowed a transluminal view from outside or inside the vessel lumen through the spaces between the rings. This imaging technique provided direct visualization of the underlying structures and an extensive perspective view of the cerebral aneurysms, including the parent arteries and surrounding bony structures, through the overlying vessel and aneurysmal walls. Transluminal imaging may be a useful method for the extra- and intraluminal diagnosis of a cerebral aneurysm, and for simulation of the interventional and surgical procedures considered for cerebral aneurysms.

Key words: computed tomographic angiography, cerebral aneurysm, perspective volume rendering, virtual endoscopy

Introduction

Recent advancements in three-dimensional (3-D) reconstruction software, such as volume rendering and perspective volume rendering,[4] have improved the diagnostic accuracy of computed tomographic (CT) angiography for cerebral aneurysms.[1-3,5,6] Virtual images processed with perspective volume rendering, including virtual neuro-endoscopy[1,5] and vascular endoscopy,[2,3,6] allow visualization of an aneurysm and the parent arteries from extra- and intraluminal perspectives. However, these conventional virtual images[1-3,5,6] fail to demonstrate structures underlying the vessel or aneurysmal walls.

We have developed a technique of transluminal imaging with perspective volume rendering of CT angiography, which can directly visualize structures through the vessel or aneurysmal walls, either from outside or inside the vessel lumen. This transluminal imaging technique allows the spatial representation of a cerebral aneurysm, the parent arteries, and the surrounding bony structures in a single view.

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Methods

Three patients with unruptured cerebral aneurysm detected by magnetic resonance angiography underwent CT angiography using a helical CT scanner (Legato Duo; General Electric-Yokogawa Medical Systems, Tokyo). The protocol used was as follows: helical acquisition using 100 ml of Optiray (iodine concentration 320 mg/ml; Yamanouchi Pharmaceutical, Tokyo) injected at a rate of 2 ml/sec into the antecubital vein with a power injector (Dynamic CT injector MCT320P; Medrad, Pittsburgh, Pa., U.S.A.), acquisition started 21 seconds after the beginning of the injection, table speed of 1 mm/sec, 1 mm collimation, 135-kV peak, 130 mA, 23-cm field of view, and a 512 × 512 matrix. A total of 38 sections were obtained with a section thickness of 1 mm. The data of the source axial images were reconstructed every 0.5 mm with a 10-cm field of view, and then transferred to a workstation (Pegasus Viewer 2.0; AMIN, Tokyo). The data were reconstructed again every 0.25 mm on the workstation, then processed into a 3-D volume rendering data set in 20 seconds.

Transparency of the vessel and aneurysmal walls was created by selecting the 3-D volume rendering data set from the opacity chart of CT values using a spiked peak curve with a threshold range of 90–110 HU (peak value at 100 HU with 100% opacity level). The resulting transluminal image represented the contour of the vessel and aneurysmal walls as a series of rings, and provided a transluminal view from outside or inside the vessel lumen through the spaces between the rings. Color rendering of the vessel and aneurysmal walls in light blue was used to enhance the realistic representation. The bony structure of the cranial base and calcification of the artery were emphasized using another square peak curve from the same chart of CT values with a threshold range of 450–500 HU, and color rendering in red. Coordinated viewing points from outside or inside the vessel lumen were indicated by arrows on the source axial image, the coronal and sagittal reconstructed images, and the 3-D volume rendering CT angiograms. Transluminal images took about 30 seconds to develop from the 3-D volume rendering data set. Reconstruction parameters of the opacity curve, such as opacity level and range of CT values, could be saved on the workstation, so that the transluminal images could be reproduced and used for similar examinations.

A virtual neuro-endoscopic image was obtained from the same 3-D volume rendering data set by using an increasing curve starting at 80 HU (0% opacity level) and up to 120 HU (100% opacity level). A virtual vascular endoscopic image was obtained by using a decreasing curve from 80 HU (100% opacity level) to 120 HU (0% opacity level). These conventional virtual images were compared with the corresponding transluminal images in the same viewing projections.

Results

The virtual neuro-endoscopic images constructed from the extraluminal projection represented a perspective view of the outer surface of the aneurysm and the parent arteries in relation to the cranial base bone, but the view of the aneurysm was restricted by the vascular and bony structures in the foreground.

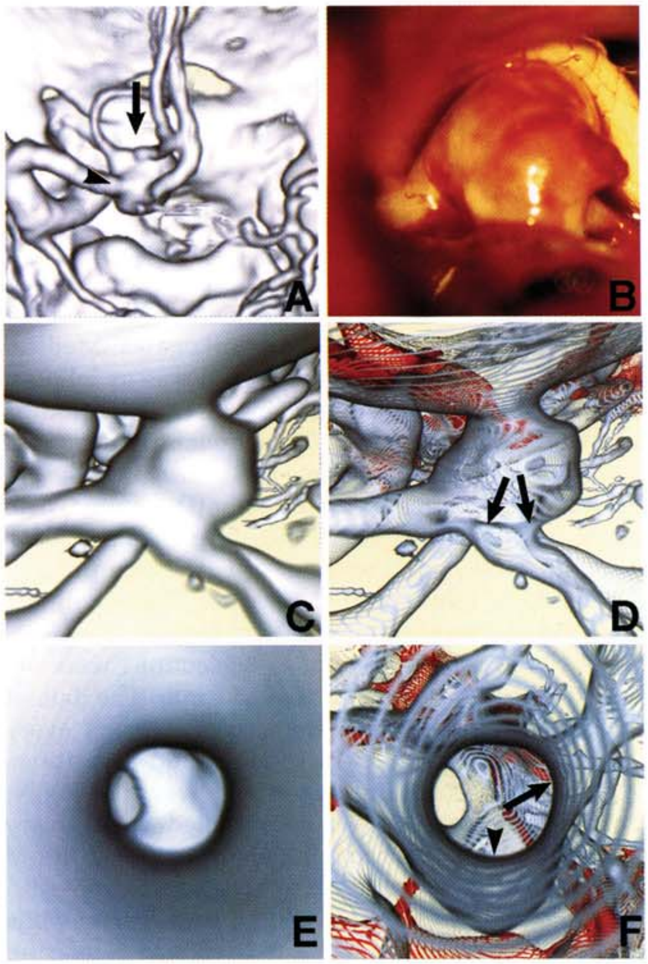

Fig. 1 **Case 1. A 55-year-old man with an unruptured anterior communicating artery aneurysm. A: Three-dimensional computed tomographic angiogram showing the aneurysm and the projections used in the following images (*arrow*, *arrowhead*). B: Intraoperative photograph showing the aneurysm. C: Virtual neuro-endoscopic image, left frontal view indicated by the *arrow* on A, showing the aneurysm with a broad neck at the anterior communicating artery extending anteroinferiorly. D: Transluminal image, from the same projection as that in C, showing the vessel and aneurysmal walls as a series of rings, so that the orifices of the left and right A_2 (*arrows*), and the whole shape of the aneurysm are seen through the vessel and aneurysmal walls. E: Virtual vascular endoscopic image viewed from the inside the left A_1 to the neck, shown by the *arrowhead* on A. F: Transluminal image, from the same projection as that in E, providing an extensive view of the aneurysm, including the orifices of the right A_1 (*arrow*) and the bleb (*arrowhead*) through the vessel and aneurysmal walls.**

The virtual vascular endoscopic images constructed from the intraluminal projection showed the inner surface of the aneurysm with a bleb, and orifices opening into the parent arteries, but the vessel and aneurysmal walls were hidden, so the orientation of the endoscopic image was difficult to determine, and required several different images from coordinated viewpoints on the reference images.

In contrast, the transluminal images visualized the aneurysm, the orifices opening into the parent arteries, and the surrounding vessels in relation to the cranial base bone, directly through the vessel and aneurysmal walls. This representation provided the spatial expansion of the aneurysm in a single view.

Case Illustration

Case 1: A 55-year-old man presented with an unruptured anterior communicating artery aneurysm. The 3-D CT angiogram clearly showed the aneurysm (Fig. 1A). The virtual neuro-endoscopic image showed the aneurysm appeared to have a neck at the anterior communicating artery and extended anteroinferiorly (Fig. 1C). The transluminal image in the same projection demonstrated the orifices of the second segments (A_2) of the left and right anterior cerebral arteries, and the whole shape of the dome through the vessel and aneurysmal walls (Fig. 1D). The virtual vascular endoscopic image projected from inside the first segment (A_1) of the left anterior cerebral artery showed the opening of the neck (Fig. 1E). The transluminal image in the same projection demonstrated an extensive view of the aneurysm, including the orifice of the right A_2 and a bleb directed anteroinferiorly (Fig. 1F). The operative findings confirmed the findings of the virtual images (Fig. 1B).

Case 2: A 72-year-old woman presented with an unruptured posterior communicating artery aneurysm. The 3-D CT angiogram demonstrated the aneurysm (Fig. 2A). The virtual neuro-endoscopic image showed the aneurysm arose at the terminal portion of the left internal carotid artery (Fig. 2B). The transluminal image in the same projection demonstrated

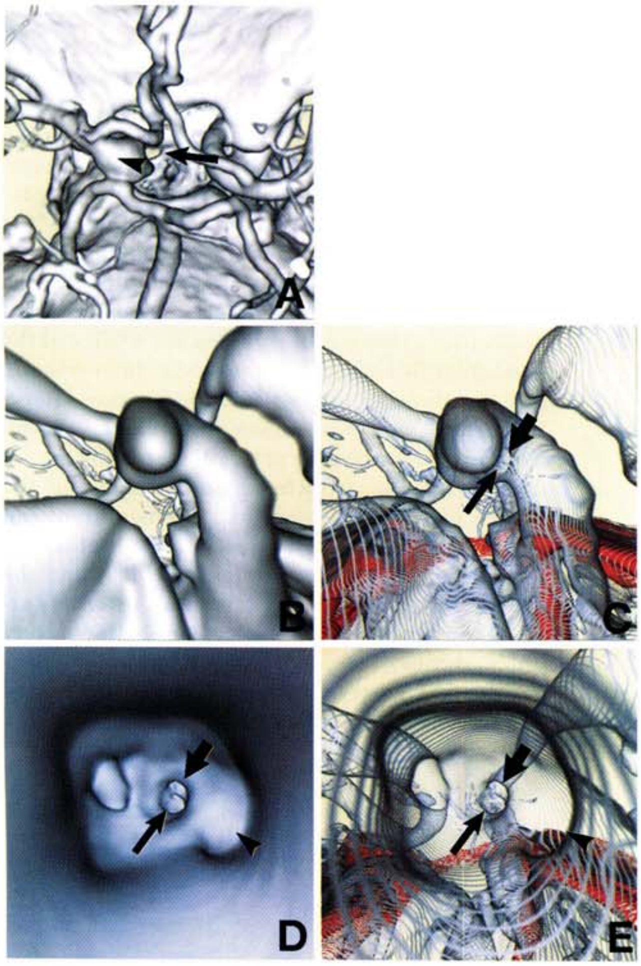

Fig. 2 Case 2. A 72-year-old woman with an unruptured posterior communicating artery aneurysm. A: Three-dimensional computed tomographic angiogram showing the aneurysm. B: Virtual neuro-endoscopic image, right lateral view indicated by the *arrow* on A, showing the aneurysm arising at the terminal portion of the left internal carotid artery and extending posteriorly to the left posterior cerebral artery with a bleb projecting laterally. C: Transluminal image, from the same projection as that in B, showing the orifices of the left anterior cerebral artery (*thick arrow*) and the left middle cerebral artery (*arrow*) at the neck through the aneurysm. D: Virtual vascular endoscopic image viewed from inside the bleb towards the carotid bifurcation, as shown by the *arrowhead* on A, showing the openings of the left A_1 (*thick arrow*), M_1 (*arrow*), and the terminal carotid artery (*arrowhead*) at the aneurysmal neck. E: Transluminal image, from the same projection as that in D, providing an extensive view of the aneurysm, including the orifice of the left A_1 running anterosuperiorly (*thick arrow*), the orifice of the left M_1 extending laterally (*arrow*), and the wide opening of the terminal carotid artery (*arrowhead*).

the orifices of the left internal carotid artery and the left middle cerebral artery at the neck through the vessel and aneurysmal walls (Fig. 2C). The virtual vascular endoscopic image projected from inside the bleb showed the openings of the parent arteries at the neck (Fig. 2D). The transluminal image provided an expansive view of the aneurysm, including the orifices of the arteries and their running courses through the aneurysmal wall (Fig. 2E).

Case 3: A 64-year-old man presented with an unruptured basilar top aneurysm. The 3-D CT angiogram showed the aneurysm (Fig. 3A). The virtual neuro-endoscopic image showed the aneurysm arising at the top of the basilar artery (Fig. 3B). The transluminal image in the same projection demonstrated the neck of the aneurysm though the wall of the basilar artery (Fig. 3C). The virtual vascular endoscopic image viewed from inside the proximal basilar artery showed the opening of the neck (Fig. 3D). The transluminal image in the same projection demonstrated the aneurysm and a bleb, and the both posterior cerebral arteries and the left superior cerebellar artery through the vessel and aneurysmal walls (Fig. 3E).

Discussion

The perspective volume rendering reconstruction tool used in this study allowed selection of the specific object of interest from the whole 3-D volume rendering data set by adjusting the range of CT values and the opacity level. Reconstruction of the volume data sets with a function of the spiked peak curve could represent the contour of the vessel wall as a series of rings, so that the objects underlying the vessel and aneurysmal walls were visualized through the spaces between the rings. Conventional virtual images provide a restricted view of the neck where the aneurysmal neck is overlapped by the parent arteries and the aneurysmal dome.[1-3,5,6] In contrast, the transluminal image showed the whole structure of the aneurysmal neck through the overlying vessel and the aneurysmal dome (Figs. 1–3). Transluminal observation of the aneurysm through the operating approach might be useful for intraoperative navigation of aneurysm clipping (Fig. 1).

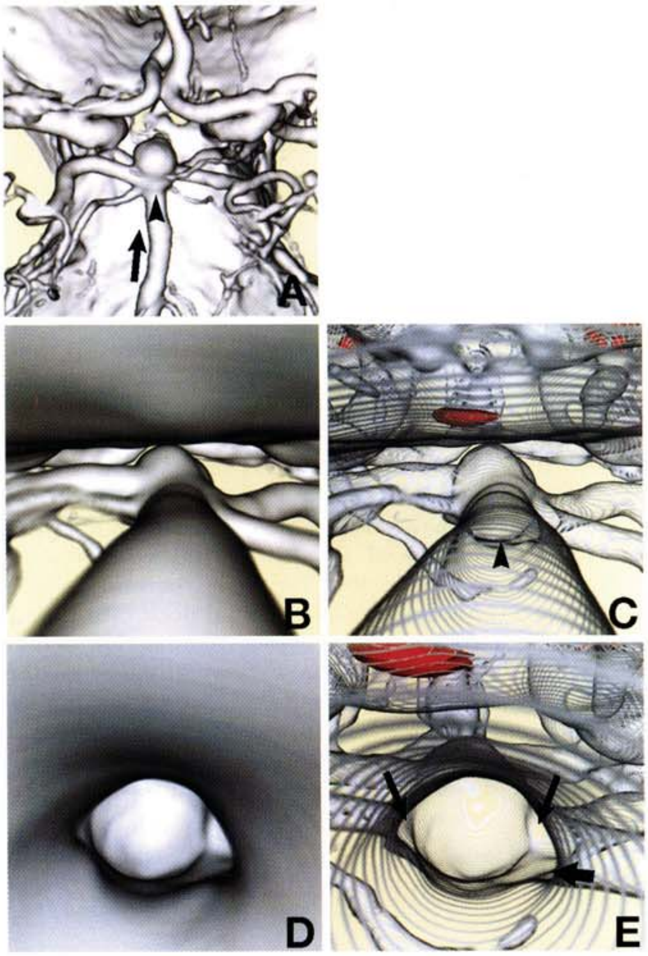

Fig. 3 Case 3. A 64-year-old man with an unruptured basilar top aneurysm. A: Three-dimensional computed tomographic angiogram showing the aneurysm. B: Virtual neuro-endoscopic image, inferosuperior view outside the basilar artery indicated by the *arrow* on A, showing the aneurysm arising at the top of the basilar artery and extending superiorly with a bleb at the front. C: Transluminal image, from the same projection as that in B, showing the orifice of the aneurysm identical at the neck (*arrowhead*), passing through the wall of the basilar artery. D: Virtual vascular endoscopic image, viewed from inside the basilar artery towards the top indicated by the *arrowhead* on A, showing the orifice of the aneurysm. E: Transluminal image, from the same projection as that in D, demonstrating the aneurysm and bleb, and the orifices of the posterior cerebral arteries (*arrows*) and the left superior cerebellar artery (*thick arrow*), as well as an anterior communicating artery complex through the vessel and aneurysmal walls.

The diameter of the lumen, consisting of a series of rings, depends on the CT values selected for the vessel wall, so the threshold range of the opacity curve must be optimized based on the source axial images.

Transluminal imaging creates an extensive perspective view of the architecture of an aneurysm through the vessel lumen, and can visualize the orifice and bleb of the aneurysm, the proximal and distal parent arteries, and the surrounding bony structures through the overlying vessel or aneurysmal walls, or through both, in a single view. Transluminal imaging could become a useful method for the extra- and intraluminal diagnosis of a cerebral aneurysm, and for simulation of the intravascular treatment and transcranial surgery.

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Commentary on this paper appears on the next page.

Commentary

Dr. Satoh has presented an elegant method of non-invasive imaging of intracranial aneurysms. The transluminal imaging with perspective volume rendering provides substantial information on the angioarchitecture of intracranial aneurysms as well as imaging of surrounding bony structures and an intraluminal perspective. With the rapid advances occurring in non-invasive imaging, I anticipate a day in the near future when catheter angiography will only be used when endovascular therapeutic options are entertained.

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The author described a technique of transluminal imaging with perspective volume rendering of CT angiography, which can directly visualize structures through the vessel or aneurysmal walls, either from outside or inside the vessel lumen. He concluded that the technique allowed the spatial representation of a cerebral aneurysm, the parent arteries, and the surrounding bony structures in a single view. CT angiography using a helical CT scanner has been recognized as a diagnostic tool for intracranial aneurysms. In contrast to conventional angiography, CT angiography allows reconstruction of images demonstrating the morphology of the aneurysm as well as the relationship of the aneurysm to the surrounding vessels from different angles. Furthermore, the virtual neuro-endoscopic images could demonstrate the size and shape of aneurysm and calcification of vessel wall. Because of the limited surgical exposure and visual access, it is necessary to obtain preoperatively exact information regarding the whole shape of the aneurysm, orifice of the aneurysm and parent arteries, thickness of the aneurysmal wall, vessels hidden behind the aneurysmal sac, and surrounding bony structures of the skull base. This study demonstrates the possibility of fulfilling such a need of aneurysm surgeons as well as neurointerventionists.

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