MR imaging for the determination of lumenal and outer wall boundaries in intracranial aneurysms.

L. Boussel[1], M. Wintermark[2], B. Dispensa[2], J. Leach[2], V. Rayz[2], G. Acevedo Bolton[2], M. Lawton[2], R. Higashida[2], W. Young[2], and D. Saloner[2]

[1]Radiology, UCSF, San Francisco, California, United States, [2]UCSF, San Francisco, California, United States

Introduction

Intralumenal thrombus has important clinical sequellae. The presence of intralumenal thrombus in patients with aneurysmal disease can complicate a situation that already has dismal prospects for long term survival. In intracranial aneurysm, intralumenal thrombus adds a risk of stroke from thrombo-embolism, and a risk of devastating neurological symptoms secondary to mass effect from the distending outer wall, on top of the grave risk posed by rupture. In conventional methods for monitoring aneurysmal disease, such as catheter-injected x-ray angiography, the presence of thrombus is underappreciated, and can often be completely missed. The multi-contrast capabilities of MR imaging offers great potential in accurately quantifying both the lumenal (or inner) wall, and the outer wall of blood vessels in aneurysmal disease. These capabilities are of critical importance in longitudinal studies that monitor progression in geometric descriptors of aneurysmal geometry over time.

Methods

Nine patients with giant fusiform basilar artery aneurysms that were considered unsuited for surgical or endovascular therapy were recruited to this study under an institutionally approved IRB consent. These patients were studied at annual intervals. The number of follow-up studies performed varied from two to three, with an aggregate total of 14 serial studies performed. At each study, the subjects underwent multi-contrast MR imaging on a 1.5 Tesla system. Imaging included 2D T1-weighted fast spin echo (2D FSE), Contrast Enhanced MR angiography (CE-MRA) and over the past two years, all subjects have also undergone steady-state imaging (bFFE).

Imaging parameters: 2D TSE (TR=400ms; TE=14ms; resolution 0.42*0.42*2.2 mm), bFFE (TR=6 ms; TE=2 ms; Flip angle=60°, resolution 0.85*0.85*1 mm) and CE-MRA (TR=5.1 ms; TE=1.8 ms; Flip angle=30°, resolution 0.85*0.85*1 mm). Injection protocol for CE-MRA included a test bolus for injection delay calculation and a main injection 20 cc of gadolinium at a rate of 2 cc/sec.

In all cases, the lumenal surface was determined from the CE-MRA study using a thresholding-based algorithm. The outer wall of the aneurysms was delineated manually from 2D FSE and bFFE images on each slice. Total aneurysm volume was calculated using custom-built software. A co-registration between the outer and inner wall volume was then performed using RapidForm® software (Fig. 1). In longitudinal studies, co-registration was performed using internal fiducial landmarks such as the vertebro-basilar junction, and the bifurcation of the basilar artery,

Inner and outer volumes were compared using a Bland-Altman representation. Pearson correlation coefficient and image quality (5 points scale) was reported for the 2D TSE and the 3D bFFE sequence.

Results

The mean outer wall volume of the aneurysms was 7700 +/- 6430 mm^3 (range 860-18170 mm^3). The mean lumen volume was 1850 +/- 1180 mm^3 (range 320-4035 mm^3). Pearson coefficient of correlation between 2D TSE T1w and 3D bSSFP sequence for the volume of the outer wall of the aneurysm was 0.99 ($p<0.0001$). Mean image quality was 3.1 +/- 0.25 for 2D TSE and 4.1 +/- 0.5 for 3D bSSFP sequence ($p<0.001$). Bland-Altman representation (Fig. 2) showed a trend for larger aneurysms to have a larger fraction of thrombus relative to the lumen volume. Finally, analysis of the evolution of the volumes of both the inner and outer aneurysm walls showed that the rate of increase was highly variable between different aneurysms and that there were substantial changes in the thrombus to lumen ratio over time.

Conclusions

In intracranial aneurysms, combining MRA and MRI methods permits the combination of co-registered data sets that delineate the inner and outer vessel wall. Unlike conventional angiographic methods which use linear estimates of geometry, consistent volumetric measurements are possible using CE-MRA to define the flow lumen, and steady state methods to define the outer wall. T1-weighted methods provide high-resolution delineation of the outer wall but steady state methods have preferable properties for measurement of thrombus volume in basilar arteries. The advantages of steady state methods derive from the fact that they are intrinsically 3D, have high SNR, and present with high contrast between the vessel wall and adjacent CSF. MRI and CE-MRA methods provide powerful tools for monitoring the progression of aneurysmal disease.

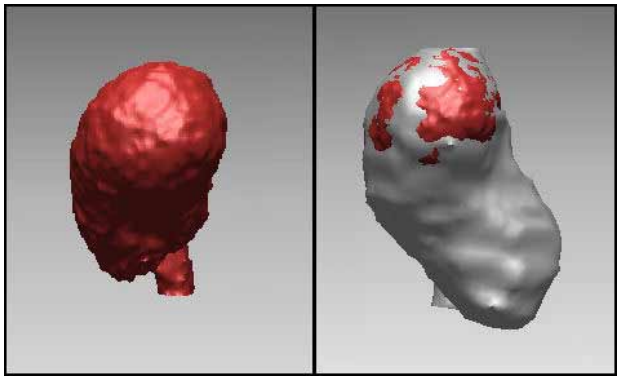

Fig 1: Surface renderings of giant fusiform basilar artery aneurysm. Left: lumenal surface (in red) determined from CE-MRA; and Right: lumenal surface from CE-MRA (red) and thrombus volume (gray) from steady state MRI.

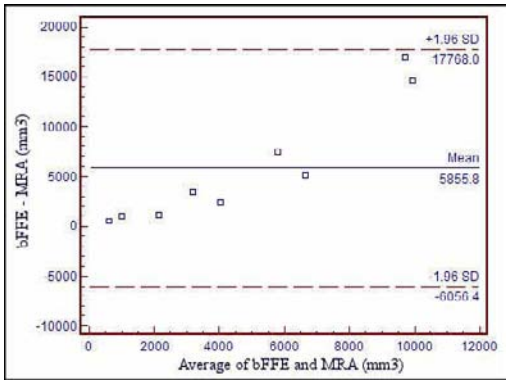

Fig 2: Bland-Altman representation of the outer and inner volume of the aneurysms respectively measured by bFFE and CE-MRA showing an increase of volume filled by thrombus relative to the volume of the patent lumen with increasing aneurysm size.