Estimating the Volume of Cerebral Aneurysms: Method Error versus Volume Variation over Time

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To the Editor:

The theoretical volumetric filling of a cerebral aneurysm after endovascular coiling ("packing density") has been considered an indicator of long-term aneurysm occlusion. The volumetric filling is the volume of all coils implanted expressed as a percentage of the aneurysm volume. While the volumes of the coils are easily and precisely calculated using the cylindrical volume equation (assigning outer coil diameters and lengths according to product specification), the method error in estimating aneurysm volume has been a matter of concern. The recent article by Hanley et Al.¹ brings another contribution to this question. In this study, the volumes of silicone models of cerebral aneurysms were accurately measured, and compared to volume estimates obtained by DSA, CTA and MRA as interpreted by four independent observers

Their results indicated error rates of 14% to 19% in aneurysm volume calculations regardless of imaging modality. These results are not unexpected. Substantial differences in aneurysm volume estimation can result from adding or subtracting a few pixels in caliper measurements, it is almost impossible to obtain the same volume estimate on repeated manual imaging segmentation and threshold settings of 3D reconstructions, and systematic differences should not be surprising when using different image acquisition modalities.

I write to point out a major difficulty in doing accurate and repeatable measurements of aneurysm volume that has not been given appropriate attention, that is, that aneurysm volume can change considerably over the heart cycle. Studies with cine phase-contrast MRA², and with transcranial power Doppler ultrasound^{3,4}, showed that intracranial saccular aneurysms undergo changes in size during the cardiac cycle, expanding in systole and contracting in diastole.

In the MRA study² pulsatile volume changes were seen to be larger in ruptured aneurysms (51% on average, ranging in individual cases from 38% to 68%) than in unruptured aneurysms (17.6% in average, ranging from 0% to 33%). For the same aneurysm the expansibility is larger at higher levels of intracranial pressure⁴, and after a decrease in intracranial pressure (after insertion of ventricular drainage in patients with hydrocephalus after subarachnoid hemorrhage) the aneurysm volume becomes less unstable from systole to diastole, but the aneurysm increases in size⁴. Dynamic aneurysm volume changes probably explain the fact that the coil mesh can be larger than the measured aneurysm size before coiling⁵. These dynamic changes in aneurysm size are usually not observable on DSA because this technique does not obtain rapid images through the cardiac cycle, but in my experience (which is probably also the reader's), visible pulsatile changes in aneurysm volume can be

observed in some instances on source images of rotational 3D angiography, especially in ruptured aneurysms (however, the volume change in such conditions is difficult to quantify since the images in systole and diastole are taken in different projections during the rotational run). However, there is at least one published report of huge volume increase of an aneurysm from diastole to systole (230%) on DSA images in a patient with an anterior communicating aneurysm, when the cerebral circulation time was prolonged because of severe intracranial hypertension⁶.

Hanley et Al¹ also noted a modality-specific error in measuring aneurysm volume in their model of known and stable aneurysm volume: CTA tended to overestimate and MRA tended to underestimate aneurysm volume, while larger scatter was the case for DSA. The modality-specific error is probably not the same in this study as in real aneurysms, since different imaging modalities should also be affected by

different aspects of the dynamics of aneurysm volume.

In conclusion, estimates of aneurysm volume probably cannot be done with the high level of accuracy that has been looked for. Thus, one should be less dogmatic in searching for safety thresholds of packing density. When the immediate result of an operation is a well-filled aneurysm with a visually dense coil mesh, there is no angiographic opacification of the aneurysm or only a small neck remnant, and the operator cannot safely do more, it is probably not relevant whether the estimate of packing density is imprecise by, say, more or less one fifth of the estimate. Nevertheless, I think that the packing density is to be carefully calculated after each case using the available estimate of aneurysm volume, and the value is to be annotated in the operation file as a routine procedure, because it is intuitively a quality indicator of the procedure (a high packing density is surely better than a low one).

References

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