MR Assessment of Carotid Stent Therapy

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Introduction

Placement of stents under x-ray guidance is an increasingly popular alternative to endarterectomy in patients with >70% stenosis of the carotid artery. X-ray guidance, however, is limited in that it does not permit the evaluation of arterial flow and tissue perfusion and/or ischemia. MR offers these capabilities as well as being able to produce high quality angiograms. These MR angiograms are increasingly being used to screen patients suspected of having vascular disease prior to their referral to a catheterization laboratory.

In this study we assess patients undergoing stent placement for therapy of a stenosis of the internal carotid artery (ICA). MR imaging is performed immediately prior to and following stent placement under x-ray guidance. The diagnostic accuracy of the MR angiographic data is compared to the x-ray gold standard and MR measurable physiologic changes resulting from stent placement are evaluated.

Methods

All imaging was performed in an "XMR" suite consisting of a 1.5 T MR scanner (Philips Intera, Best, The Netherlands) and an adjacent x-ray catheterization laboratory (Philip Integris V5000). The two units are connected via a floating table-top, permitting rapid patient transfer between the two systems. The x-ray system was single plane with a 15 inch image intensifier and was capable of 3-dimensional rotational angiography (3DRA) via continuous x-ray acquisition during a 180^0 sweep of the C-stand.

Twelve patients scheduled to undergo placement of a carotid stent as therapy for narrowing of the ICA were studied. A complete neurological history was obtained prior to therapy and all patients signed an informed consent form that was approved by the universities CHR committee. Patients ranged in age from 47-86 (mean = 65) and included six males and six females.

MR acquisitions included diffusion-weighted imaging (DWI; b=1000 mm^2/s), contrast-enhanced MR angiography (CE-MRA), post-contrast turbo-FLAIR, phase contrast quantitative flow (Qflow) and T_2* perfusion. The DWI and turbo-FLAIR data were visually compared pre and post stent placement to determine if any ischemic sequela could be detected. The CE-MRA findings were compared with x-ray angiograms to evaluate their diagnostic accuracy and stenosis severity. Flow within both ICA and vertebral (or basilar) arteries was quantified at the same level before and after stenting. Perfusion data was fit to a gamma variate function and rCBV, MTT (mean transit time), T0 (contrast arrival time), and TTP (peak enhancement) were evaluated prior to and following stent therapy. A phased array head/neck coil or a phased array head coil was used for all patients. Due to coverage limitations, the latter was chosen only when prior imaging studies definitively demonstrated the lesion to be in the latter half of the internal carotid artery.

Vascular access was obtained via a conventional femoral artery puncture and preliminary diagnostic x-ray angiograms were performed in both arteries and vertebral arteries where appropriate. A rotational angiogram was obtained in the vessel where therapy was to be delivered. All patients received a nitinol self-expanding stent (SmartStent, Cordis, Miami Lakes, FL).

Results

MR angiographic image quality compared favorably with x-ray (figure 1), however MR exhibited lower spatial resolution and accordingly could not demonstrate the vessel lumen in very high grade stenoses. Percent stenosis determined by MR and 3DRA agreed within 10% for all patients (mean error = 4%). Due to artifact limitations following stent placement, post-therapy CE-MRA was only performed in one patient. Diffusion imaging failed to reveal any substantial changes between the pre and post-stent data. No post-therapy ischemic complications were reported either, however. Post-contrast turbo-FLAIR demonstrated ipsilateral enhancement in portions of cerebral sulci in 75% of patients. This enhancement was only evident on post-treatment acquisitions. Flow analysis demonstrated an average increase in blood flow within the affected artery from 2.5 ml/s to 4.7 ml/s, while the contralateral ICA (pre: 4.7 ml/s, post: 4.9 ml/s) and posterior circulation (pre: 3.4 ml/s, post: 3.8 ml/s) demonstrated much smaller changes. Perfusion analysis failed to demonstrate focal defects both pre or post stenting and therefore a hemispheric evaluation was performed at a level just superior to the lateral ventricles (figure 1). An ROI was placed over the entire hemisphere and global parameters were tabulated for each patient. No significant changes in CBV were noted while a modest decrease in MTT and TTP were evident in the treated hemisphere.

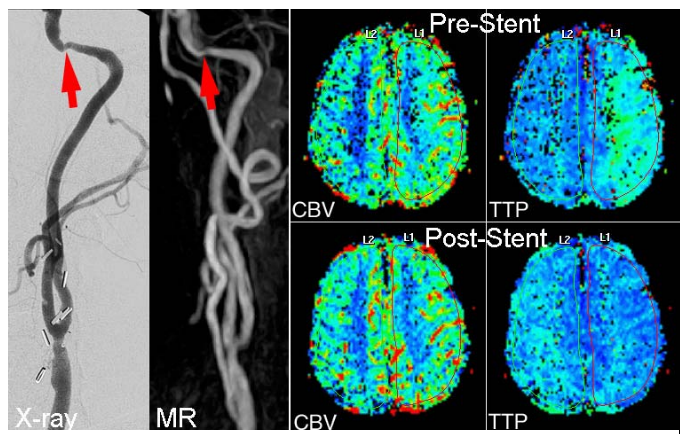

Figure 1: Left - Representative angiograms of the ICA showing narrowing at the bifurcation and severe narrowing at the petrous bone (arrows). Right – rCBV and TTP perfusion maps obtained prior to and following stent therapy. Delayed TTP is evident in this patients prior to therapy and is resolved following stent placement.

Table 1: Perfusion changes following stenting

Hemisphere	ΔCBV (s.d.)	ΔMTT (s.d.)	ΔT0 (s.d.)	ΔTTP (s.d.)
Ipsilat.	+6% (20%)	-1.4s (1.1s)	+1.0s (1.1s)	-1.1s (1.5s)
Contralat.	+6% (17%)	-0.6s (1.4)	+0.4s (1.2s)	-0.3s (1.9s)

Discussion

MR evaluation of carotid stent therapy demonstrated excellent angiographic correlation with x-ray techniques and permitted analysis of physiologic effects. Not surprisingly there is a significant increase in flow within the affected vessel and this was most pronounced in tightly stenotic vessels. Patients were asymptomatic prior to therapy and this likely contributed to the relatively subtle changes evident on perfusion data. Similarly, the null result on diffusion imaging was consistent with no known embolic complications during stent deployment. The implications of ipsilateral enhancement on post contrast turbo-FLAIR are currently under investigation.