MR Assessment of Vasospasm Severity and the Impact of Endovascular Therapy

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Introduction

Cerebral vasospasm is a condition that is characterized by narrowing of the vessel lumen and increased rigidity of the vessel wall. Vasospasm is most commonly associated with prior subarachnoid hemorrhage, which in turn may originate from a ruptured aneurysm or head trauma. It typically appears ~3 days post-ictus and peaks approximately 6-8 days after the original bleed. The condition usually resolves of its own accord within 2 weeks. If not adequately managed, however, vasospasm can lead to delayed infarction of brain tissue and 15-20% of patients who develop the condition will suffer disability or die from progressive ischemia. Endovascular therapy for cerebral vasospasm is considered when medical management is insufficient and involves vessel dilatation via either pharmacological or mechanical means. The objective of these therapies is to selectively alleviate ischemia in tissue fed by arteries with spasm. Controversy exists as to the most effective agent for the treatment of vasospasm and all existing pharmacologic therapies tend to produce transient benefits. Thus, several endovascular procedures may be necessary during the 2-week window of vasospasm.

Presently, a combination of neurological assessments and trans-cranial Doppler ultrasound (TCD) is used to predict whether endovascular therapy may be warranted. TCD reveals only flow patterns in larger cerebral vessels and is insensitive to diffuse spasm in more distal vessels. The objective of this study was to assess the degree to which MR methods could characterize the regional severity of vasospasm and reveal the impact of endovascular therapies.

Methods

A total of seven patients undergoing endovascular therapy for vasospasm were studied in a hybrid XMR suite (Philips Medical Systems). The study protocol was approved by the local IRB and patients or their surrogate provided informed consent. All patients previously had ruptured aneurysms either clipped (n=5) or coiled (n=2) and were 3-12 days post-ictal. MR studies were performed immediately prior to and following endovascular therapy. MR acquisitions included quantitative flow assessment, diffusion-weighted imaging, DSC perfusion, and post-contrast T1-weighted acquisitions. Qflow measurements were performed in an axial scan plane at approximately the mid-basilar level, where flow in the basilar and carotid arteries could be assessed. Physiologic parameters, including heart rate, blood pressure, oxygen saturation and end tidal CO_2 (when possible), where noted at the time of MR evaluations. An x-ray angiographic evaluation of all major cerebrovascular arteries was performed after the baseline MR study and intra-arterial pharmacologic therapy (verapamil) was administered into vascular territories exhibiting spasm. Balloon angioplasty was performed in arterial segments with focal spasm if it was felt that it could be safely performed. The follow-up MR study was performed immediately following the angiographic procedure.

Results

All patients exhibited angiographically evident vasospasm and received intra-arterial delivery of verapamil into at least one vessel. One patient exhibited focal spasm in an accessible arterial segment and underwent balloon angioplasty (Figure 1). Cumulative volumetric flow through the basilar and carotid arteries increased by an average of 22±45% following therapy. This effect tended to be systemic and flow changes did not correlate significantly with dose or distribution of verapamil delivered. In the one instance where balloon angioplasty was performed a greater increase in arterial flow was evident in the angioplastied vessel (Figure 1). Global rCBF also increased by an average of 20±15% in these patients. Patients demonstrating appreciable hemispheric asymmetry in MTT prior to therapy were found to resolve to balanced values following therapy. There was considerable variability in response across patients and this appeared to be partially related to variations in mean arterial pressure (MAP). MAP was found to have fallen by an average of 16±20 mm Hg between the time of the pre and post-catheterization MR studies, and this could substantially affect the flow and perfusion properties detected by MR. Other physiologic parameters, including heart rate, oxygen saturation and end-tidal CO2, were not found to change as substantially following therapy.

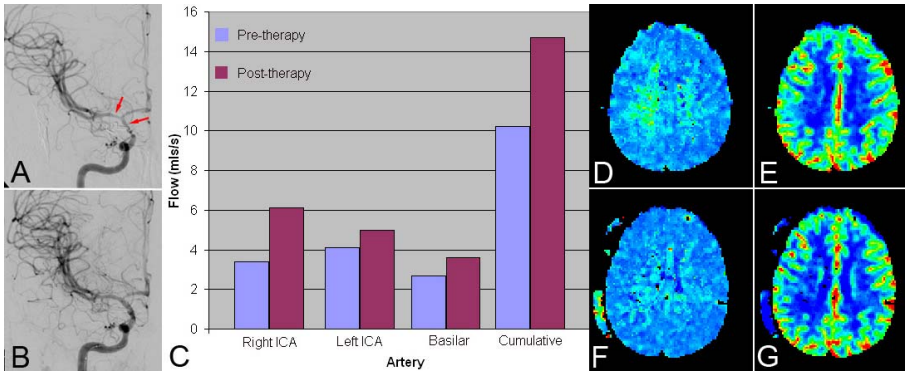

Figure 1: XMR evaluation of a patient with moderate vasospasm, including focal narrowing of the right ICA and MCA (A-arrows). Angioplasty was performed in both the ICA and MCA and verapamil was administered into all major vessels). Post-therapy x-ray angiography of the right ICA (B) demonstrates substantial improvement of angiographic caliber. Flow changes were most pronounced in the right ICA (C), although flow increased in all vessels. DSC perfusion revealed prolongation of the MTT in the ipsilateral watershed territory (D), which resolved after treatment (F). rCBF measures taken prior to (E) and following (F) therapy were comparable.

Conclusions

MR provides useful insight into the severity of vasospasm prior to therapy and provides reliable indices for evaluating the impact of therapeutic interventions. On average, a post-therapeutic increase in bulk flow and rCBF was demonstrated, even in the presence of a substantial drop in systemic blood pressure following verapamil administration.