Magnetic Resonance Perfusion Tracks $^{133}$Xe Cerebral Blood Flow Changes After Carotid Stenting

Nerissa U. Ko, MD; Achal S. Achrol, BSc; Alastair J. Martin, PhD; Manju Chopra, MD; David A. Saloner, PhD; Randall T. Higashida, MD; William L. Young, MD

Background and Purpose—To compare magnetic resonance (MR) perfusion to gold-standard cerebral blood flow (CBF) determined by intra-arterial $^{133}$Xe washout method.

Methods—Eight patients with high-grade carotid stenoses underwent bolus-tracking MR perfusion and intra-arterial $^{133}$Xe washout before and after carotid stenting. MR perfusion was compared with $^{133}$Xe-CBF values using Pearson linear correlation analysis.

Results—We observed a mean 37±38% increase in $^{133}$Xe-CBF and a mean 19±27% increase in relative CBF (rCBF) by MR perfusion immediately after stent placement. Relative (percent) changes in MR-rCBF showed a close and linear correlation to those seen in $^{133}$Xe-CBF ($r=0.91$; $R^2=0.84$; $P=0.002$). There was a trend for MR perfusion to underestimate change in CBF at higher relative changes in flow.

Conclusion—Bolus-tracking MR perfusion correlates with $^{133}$Xe-CBF in estimating postprocedural increases in blood flow but may underestimate the magnitude of the change with higher relative changes. (Stroke. 2005;36:676-678.)

Key Words: cerebral blood flow ■ magnetic resonance imaging ■ xenon

Hemodynamic changes associated with interventional procedures such as stenting are poorly understood. MRI perfusion techniques have the ability to show acute changes in cerebral blood flow (CBF) within 3 hours after carotid stenting, but more studies are needed to validate these data.

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Data Analysis

Descriptive statistics are expressed as mean ± SD. Results were analyzed by Pearson linear correlation, linear regression, and ANOVA. In addition, we subjected the data for relative changes in CBF to analysis described by Bland and Altman and previously reported when comparing perfusion indices against the 133Xe gold standard.

Results

Of 8 patients studied, 1 had visual loss from stroke and 1 had transient ischemic deficits. The 6 asymptomatic patients underwent elective stenting for restenosis after carotid endarterectomy, surgical risk, or patient preference. Average age was 74 ± 4 years, with average stenosis of 72 ± 8%. Hematocrit was 41 ± 3%. Physiological parameters were obtained concurrent with each blood flow measurement (Table).

133Xe-CBF measured immediately before and after stent placement (mean 48 ± 17 minutes) showed a mean 37 ± 38% increase. Bolus tracking MR perfusion measured within 1 hour demonstrated a mean 19 ± 27% increase in rCBF (Table). Changes observed by the 2 modalities showed close and linear correlations (Figure 2A through 2F).

We calculated the “limits of agreement” between the relative changes determined by MR measurements and by 133Xe-CBF method (Figure 2G through 2I). There was a trend for MRI to underestimate the extent of perfusion increase at higher degrees of change.

Observed correlations were not significantly affected by adjusting for physiological parameters, type of anesthesia, time between measurements, and patient characteristics. There were no differences between symptomatic and asymptomatic patients.

Discussion

We report the first demonstration of acute changes in CBF after carotid stenting measured by bolus-tracking MR perfusion and 133Xe washout methods. Our results show a strong linear correlation between qualitative changes in MR perfusion and quantitative 133Xe-CBF. Relative changes in rCBF had the strongest correlation. However, rCBV did not show a strong correlation and may reflect different states of autoregulation that are not necessarily correlated with perfusion rates.

Because of the spatial limitation of the radioactive tracer technique, we only examined ipsilateral CBF correlations. MRI has the ability to assess perfusion changes in the contralateral hemisphere. Further studies will be necessary to compare CBF changes in other brain regions. Use of bolus-tracking MR perfusion data may improve selection of patients who may benefit from procedures such as stenting. These methods can accurately demonstrate acute hemodynamic effects of interventional revascularization techniques.

Acknowledgments

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<td>Mean arterial pressure (mm Hg)</td>
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<td>7.3 ± 1.2</td>
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Mean ± SD.

*Expressed in relative units.
Huberty for assistance in preparation of the radiopharmaceuticals; Carroll Schreibman and Broderick Belenson for preparation of this manuscript; and the other members of the UCSF Brain Arteriovenous Malformation Study Project.

**References**


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**Figure 2.** Comparison of changes in perfusion before and after carotid stenting. A through C, Relative (%) changes vs 133Xe-CBF: A, MR–bulk flow internal carotid artery (bfICA; \( r=0.26; R^2=0.07; P=0.528 \)). B, MR-rCBV \( (r=0.62; R^2=0.39; P=0.099) \). C, MR-rCBF \( (r=0.91; R^2=0.84; P=0.002) \). D through F, Absolute changes versus 133Xe-CBF: D, MR bfICA \( (r=0.66; R^2=0.74; P=0.006) \). E, MR-rCBV \( (r=0.33; R^2=0.11; P=0.424) \). F, MR-rCBF \( (r=0.75; R^2=0.56; P=0.033) \). G through I, Limits of agreement. G, MR-bfICA (mean 54; SD 109%). H, MR-rCBV (mean 33; SD 30%). I, MR-rCBF (mean 18; SD 17%).
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