Stent-retriever mechanical thrombectomy has emerged as a valuable armamentarium for acute ischemic stroke treatment. However, concerns over possible vessel wall injury during withdrawal of an unfolded stent, inherently causing considerable vasospasm, have been raised. To date, black-blood vessel wall MRI was used to investigate intracranial atherosclerosis, dissection, aneurysmal wall, and vasculitis. The objective of this study was to assess the vessel walls after thrombectomy noninvasively with 3-Tesla high-resolution multimodal vessel wall MRI.

Methods

Patient Selection
From August 2012 to November 2013, 1268 acute ischemic stroke patients were referred to our stroke center, and 144 of them were treated with thrombectomy. As part of an ongoing quality control study, 3-Tesla MRI was performed in 23 of them within 1 week after successful recanalization. In 11 patients, thrombectomy was performed after intravenous thrombolysis and in 3 after additional stent angioplasty of a proximal stenosis in the access site. A neurologist assessed National Institutes of Health Stroke Scale (NIHSS) score. The study was performed in accordance with the ethical guidelines and permission of our university hospital.

Thrombectomy and Digital Subtraction Angiography Assessment

Treatment was performed under general anesthesia (n=17) or conscious sedation (n=6). The Solitaire 4/20 mm and 6/30 mm stent-retrievers were used in 17 and 6 patients, respectively, with previously described retrieval maneuvers. Recanalization was classified according to the thrombolysis in cerebral infarction grading system criteria.

MRI Assessment

Patients were examined in a 3-Tesla Scanner within 1 week after thrombectomy. Our post-thrombectomy MRI quality control protocol includes routinely 3-dimensional time-of-flight MR angiography, susceptibility-weighted imaging, fluid-attenuated inversion recovery, and fat-suppressed T1-weighted imaging.

High-Resolution Vessel Wall MRI

Black-blood, double inversion recovery, 2-dimensional turbo spin echo sequences were acquired in axial planes with peripheral pulse gating. Acquisition window of 859 ms was set during systole; slice thickness, 2 mm; gap, 0.2 mm; number of slices, 5; field of view, 140×140 mm; matrix size, 205×256; flip angle, 180°; number of excitations, 2; and fat saturation was done with SPAIR. For T1-weighting, TR/TE is 700/13 ms and echo train length is 28; and for T2-weighting, TR/TE is 775/82 ms and echo train length is 14.

Statistical Analysis

Binary logistic regression was used to calculate odds ratios (OR), 95% confidence intervals (CI), and P values with a commercial software (IBM SPSS Version 20, Armonk, NY). Statistical significance was assumed with P≤0.05.

Results

Presumed stroke pathogenesis was large vessel disease (n=7), cardio-embolic (n=8), and undetermined (n=8) according to Trial of ORG 10172 in Acute Stroke Treatment (TOAST)
criteria.9 The NIHSS score at admission was 14.4±5.2. Time from symptom onset to intervention lasted 234.4±150.2 minutes, and time needed for recanalization took 49.3±30.6 minutes. The modified Rankin score at the 3-months follow-up was 1.1±1.3 (mean±SD). The vessel occlusions, categorized as previously described, were as follows10: 15 middle cerebral artery, 4 terminal internal carotid artery, 1 basilar artery, and 3 middle cerebral artery and internal carotid artery termed as tandem occlusion. Passes of stent-retriever maneuvers (median, 1; 1, n=12; 2, n=7; 4, n=4) required to achieve TICI 2b (n=8) and TICI 3 (n=15) recanalization were comparable to the whole collective of 227 patients treated with this technique, as reported earlier.7

In 10 patients, vasospasms were detected angiographically after thrombectomy, necessitating intra-arterial nimodipine in 2 of them. Presence and severity of vasospasms were not related to number of passes (OR, 1.3; 95% CI, 0.6–2.78; P=0.51), usage of Solitaire 4/20 mm versus 6/30 mm (OR, 1.43; 95% CI, 0.22–9.26; P=0.71), usage of intermediate catheter (OR, 0.67; 95% CI, 0.12–3.76; P=0.65), or type of anesthesia (OR, 0.56; 95% CI 0.08–3.94; P=0.56). Contrast extravasation or iatrogenic dissection was not noted angiographically.

Two patients suffered symptomatic intracranial hemorrhage. One patient with an initial NIHSS 18 bled into the infarcted basal ganglia and had an unfavorable outcome (modified Rankin score 4) after 3 months. The other patient with an initial NIHSS 7 suffered a symptomatic isolated subarachnoid hemorrhage but had a good clinical outcome (modified Rankin score 0). Contrast extravasation during digital subtraction angiography was not seen, and vessel wall MRI was unremarkable in both patients.

Follow-up MRI revealed asymptomatic high-grade stenosis of the target vessel segment in the middle cerebral artery with thickening of the vessel wall in 2 other patients, proven to be preexisting in 1. De novo occlusions or intramural hemorrhage were not be detected.

**Discussion**

This study provides high-resolution vessel wall 3-Tesla MRI assessing potential disruption of vascular integrity in 23 patients after successful stent-retriever thrombectomy. We investigated 2D black-blood, double inversion recovery sequences and fat-suppressed T1-weighted images to assess for intramural hematoma. Fluid-attenuated inversion recovery and susceptibility-weighted imaging were applied to detect intracranial blood with high sensitivity.11

Little histopathological data are available from small preclinical trials of mechanical thrombectomy showing endothelial denudation and elastic lamina fractures as most frequent findings.12 Even less data are available in humans. In a post-mortem study, subintimal dissection with resultant occlusion

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**Figure 1.** A 79-year-old patient presented 4.5 h after symptom onset with National Institutes of Health Stroke Scale 18 and terminal internal carotid artery occlusion. Immediate flow restoration of the M1 segment after the deployment of Solitaire 6/30 mm (A). Because of the extension of the thrombus in the A1 segment, an additional Solitaire 4/20 mm was placed (B). Successful Y-double stent-retrieval maneuver through an intermediate catheter with complete recanalization (C).

**Figure 2.** Same patient as in Figure 1. The dedicated MRI technique reveals no evidence of vessel wall injury: 2 successive sections are depicted covering the terminal internal carotid artery, the M1 and A1 segment on the right side, which were targeted by the mechanical thrombectomy. The MRI sequences include thin noncontrast T1 black-blood double inversion recovery (A), T2 black-blood double inversion recovery (B), and fat-suppressed T1-weighted images (C).
of the middle cerebral artery was found in 1/5 patient.\textsuperscript{13} Immunohistochemical examinations found endothelial cells in 28/48 thrombi, retrieved by thrombectomy, suggestive for minor intimal damage.\textsuperscript{14}

In our cohort, 2/23 patients suffered symptomatic intracranial hemorrhage. During digital subtraction angiography, no vessel perforation was noted and MRI did not show any signal changes in the vessel wall, suggestive of intramural hematoma. Also in the 1 patient with simultaneous Y-double stent-retrievement of 2 Solitaire devices for treatment of a terminal internal carotid artery occlusion with thrombus protruding into the M1 and A1 segments (Figures 1 and 2), vessel wall MRI was unremarkable.

We found 2 asymptomatic high-grade stenoses of the target vessel segments, of which 1 was preexisting. Whether the second stenosis was truly de novo remains unclear. Our results are in line with an angiographic long-term follow-up study, which revealed de novo vessel occlusion in 1/116 and de novo stenosis in 4/116 vessel segments without clinical sequelae.\textsuperscript{15}

Although mechanical forces of withdrawing an unfolded stent were sufficient to induce angiographically detectable vasospasm in 10/23 patients, we did not detect any morphological changes of the target vessel segments using dedicated multimodal vessel wall MRI technique as part of our ongoing quality control after thrombectomy.

**Conclusions**

Vessel wall MRI is a sensitive noninvasive quality control tool. Our preliminary results confirm that clinically significant disruption of vessel integrity after stent-retriever thrombectomy is rare.

**Disclosures**

Dr Mattle reports honoraria from Covidien and is Staff of the SWIFT PRIME Steering Committee. Dr Gralla was PI of the STAR Study and therefore consultant for Covidien. The other authors report no conflicts.

**References**

Multimodal 3 Tesla MRI Confirms Intact Arterial Wall in Acute Stroke Patients After Stent-Retriever Thrombectomy


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