Optimizing 3D MR angiography parameters in imaging platinum alloy stents

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Synopsis: Non-ferromagnetic, platinum-iridium alloy stents produce minimal artifact on MR and can be assessed by 3D MRA. *In vitro* phantom study demonstrates lumen visualization was maximized by aligning the long axis of the stent with the magnetic field, decreasing the slice thickness, and increasing the flip angle. Maximum signal-to-noise ratio within the stent was observed at a flip angle of 60º. Compared to digital subtraction angiography, 3D MRA with optimized parameters successfully depicted 22 stents in 18 patients. The greatest accuracy was acquired using a 75º flip angle. On average, the difference between stenosis severity on MRA and DSA was 21% (0-75%).

Introduction: Patients undergoing angioplasty and stent placement need follow-up studies to reassess the treated vessels whenever the clinical question of restenosis arises. Although MR is safe for imaging commercially available stents, metallic artifact can severely degrade image quality in the region of the stent. OmniFlex, a non-ferromagnetic, platinum-iridium alloy stent, has been developed to treat renal artery stenosis. The purpose of this study was to develop an optimized 3D Gd:MRA imaging sequence for this platinum stent in an in vitro phantom and use this optimized MRA sequence to evaluate patients who have undergone stent placement.

Materials and Methods: Platinum stents were embedded in Gadolinium impregnated gelatin and imaged at 1.5 T using a 3D spoiled gradient echo pulse sequence with a range of flip angles from 45º to 150º, different slice thickness and orientations. Images were evaluated for the accuracy of lumina depiction, degree of artifacts, and the percentage of non-obscured in-stent luminal diameter. Gd-enhanced 3D MRA was performed on 18 patients with 22 stents and compared to digital subtraction angiography (DSA). The diameter of vessels within and adjacent to the stents was measured to calculate the percent stenosis within the stent lumen (0% = no stenosis, 100% = occluded). This was compared to blinded readings of percent stenosis on the corresponding DSA.

Results: Stent lumen visualization with MRA was maximized by aligning the long axis of the stent with the magnetic field, decreasing the slice thickness, and increasing the flip angle. Maximum signal-to-noise ratio within the stent was observed at a flip angle of 60º (Figure 1). Luminal signal was successfully visualized in all 22 stents with the greatest accuracy using a 75º flip angle. Differences between stenosis severity on MRA and DSA are shown in Table 1.

Discussion: All metallic stents produce artifacts to a greater or lesser degree. The severity of artifacts produced by a stent for a given MRA sequence is related to many factors. Stents built from ferromagnetic alloys produce severe susceptibility artifact due to local magnetic field changes and thus, are unsuitable for imaging with MR. Non-ferromagnetic alloys such as Nitinol (nickel – titanium) and platinum produce substantially less artifact. The design of the stent meshwork affects MR signal inside the stent. Stent orientation with respect to the magnetic fields B_0 and B_1, field strength, TE, flip angle and post-processing of 3D data also influence stent lumen imaging.

Phantom and animal experiments have shown that patency of several non-ferromagnetic, tantalum or Nitinol stents can be assessed using 3D contrast enhanced MRA with only minimal artifacts. In vitro data of this study demonstrate visualization of the lumen of platinum stents by optimizing 3D Gd:MRA imaging parameters. Higher flip angle, thiner slices and orienting the stent parallel to B_0 improved visualization within the stent lumen. The highest in-stent signal intensity occurred at a 60º flip angle which is consistent with prior studies. The background signal intensity and the in-stent signal intensity were equalized at a flip angle of approximately 80º-90º. However, the increased SAR at higher flip angles require a longer TR and a corresponding lengthening of the scan and breath hold. Accordingly flip angles of 60º-75º are recommended to strike a reasonable balance between attaining adequate intra-stent of spin excitation and avoiding excessively lengthening the scan due to SAR constraints. In this study most of the patients were imaged at 75º to equalize vascular signal inside and outside the stent. The iliac artery is oriented with magnetic field and gives nearly perfect correlation between MRA and DSA at a 75º flip angle (Figure 2). Renal, superior mesenteric and celiac arteries on the other hand are perpendicular or oblique to the magnetic field and show less reliable grading of stenosis on MRA (Figure 3). This is further evidence of the importance of stent orientation.

Data from patients using optimized 3D Gd:MRA techniques show MRA is a safe and reasonably accurate alternative to DSA for stent follow-up. Signal inside the stents could be visualized in all patients although grading of luminal narrowing is imperfect.

Table 1. MRA accuracy compared to DSA

Category	# of stents	Difference between MRA & DSA % (min-max)
All stents	22	21 (0-75)
Iliac (// to B_0)	2	10 (3.3-16.7)
Flip angle = 45º	6	18 (0-47)
60º	3	39 (10-75)
75º	10	16 (0-48)
90º	1	62
150º	2	15 (12-18)

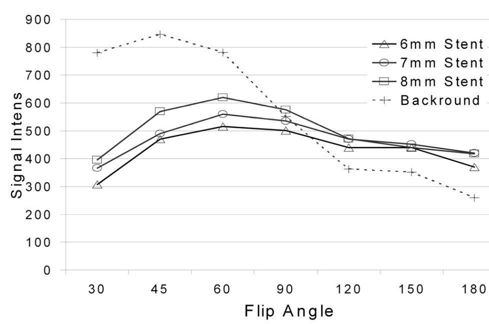

Figure 1. Graph of signal intensity vs. flip angle within the lumen of a platinum stent dilated to 6mm (triangles), 7 mm (oval), 8 mm (square) and in the gelatin outside the stents (dashed line). Note that at lower flip angles the signal within the stent lumen is much lower than the background but it increases directly with increasing the flip angle to 60º – 75º.

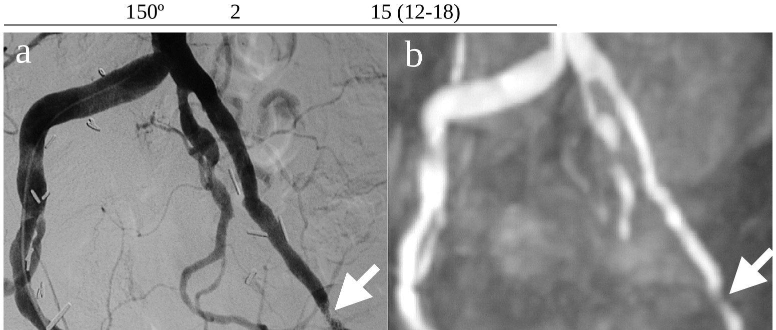

Figure 2. DSA (a) and 3D Gd:MRA (b) in a patient with left external iliac artery stenosis treated with Omniflex stent. An 80% stenosis at the site of stent (arrow) is noted on MRA with 45º flip angle which is consistent with DSA showing 83% stenosis.

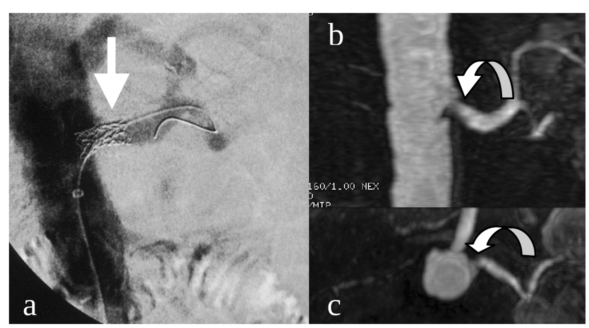

Figure 3. DSA (a) and 3D Gd:MRA coronal (b) and axial (c) MIPs in a patient with left renal artery stenosis treated with platinum stent (arrow). Mild stenosis (40%) is identified with MRA (curved arrows) using a 60º flip angle and obtained 14 days following DSA which shows 23% stenosis.