MR Safety and Compatibility of Cardiac and Peripheral Stents at 7T

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INTRODUCTION: Coronary and peripheral stents are increasingly being used for creating and maintaining flow in otherwise blocked blood vessels. Patients with stents are routinely imaged at 1.5T and 3T where the safety and MRI compatibility of some of these devices have been previously investigated [1]. With the availability of ultra high field scanners, there is now necessity to perform MRI safety and compatibility studies at these higher fields. We have investigated the magnetic interactions (translational attraction and torque), heating, and levels of artifacts for some widely used coronary and peripheral stents at 7T.

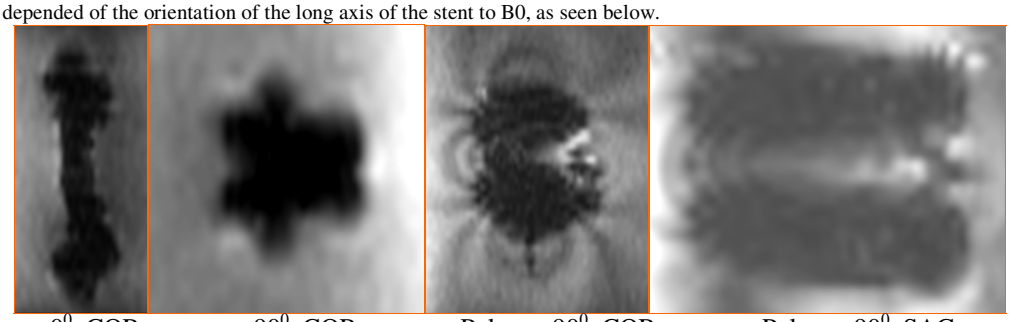
METHODS: Five coronary and four peripheral stents were examined. The Express, Cypher, Ultra, and Palmaz were made of stainless steel, the Vision and Driver were made of cobalt chromium, and the Sentinol and Precise were made of nitinol. Each stent was weighted and its translational attraction was measured by hanging it on a 30-cm long suture thread (size 8-0) and measuring its angle of deflection with a protractor at the point of highest B_0 gradient, about 160 cm from the magnet isocenter of a 7T Philips Achieva scanner. Torque on the stents was measured by positioning the stent, at the magnet isocenter, on the surface of a horizontally-leveled Petri dish and noting any movement of the stent on a millimeter scale that was attached on the bottom outside of the Petri dish. The level of torque was qualitatively assessed using a previously published scale of 0 – no torque to 4-very strong torque [1]. For each stent the torque was measured at 0, 45, 90, 135, and 180 degrees angle with respect to B0. RF heating was performed by submerging the stent in a human-torso phantom consisting of 16 L saline solution poured in a 43 x 22-cm rectangular plastic container. The phantom was then placed in a quadradure transmit-receive volume coil. A Fluoroptic probe was placed at the geometric center of each stent and temperature was recorded before, during, and after a 30-min application of the highest level of SAR available for the coil (1.9W/kg = 58% of the FDA limit for the head). RF heating was assessed with the stent being at 0 or 90 degrees with respect to B0. RF artefacts were noted by imaging the stent with a 3D T1W TFE, TFE factor 64, matrix 256x128, TR/TE = 4.0/1.83 ms. This sequence was used because it is one of the most widely used 7T sequences that generates low levels of artifacts.

RESULTS: The Table below summarizes the findings of the study.

Stent	Size, mm	Weight, mg	Deflection, degrees	Torque, degrees (0/45/90/135/180)	Temperature change, 0C, 0 / 90*	Artifacts, length ratio#, 0 / 90*	Artifacts, diam ratio#, 0 / 90*
Coronary							
EXPRESS (Boston Scientific)	3.0 x 28	33	42	0/0/0/0/0	0.2 / 0.1	1.9 / 1.8	4.7 / 6.0
EXPRESS (Boston Scientific)	2.5 x 16	19	39	0/0/0/0/0	0.2 / 0.0	1.8 / 1.9	6.0 / 9.6
VISION (Abbott)	3.0 x 15	13	17	0/0/0/0/0	0.2 / 0.1	2.7 / 1.5	2.7 / 5.3
VISION (Abbott)	4.0 x 28	33	19	0/0/0/0/0	0.2 / 0.1	1.4 / 1.2	2.8 / 4.5
CYPHER (Cordis)	3.5 x 33	65	41	0/0/0/0/0	0.3 / 0.2	1.5 / 1.3	4.0 / 6.3
DRIVER (Medtronic)	4 x 12	-	6	0/0/0/0/0	0.1 / 0.1	2.5 / 1.6	2.8 / 4.8
ULTRA (Abbott)	5.0 x 18	45	40	0/0/0/0/0	0.1 / 0.1	1.5 / 1.7	2.0 / 4.3
Peripheral							
PALMAZ (Cordis)	24 x 40	914	45	0/0/0/1/0	0.1 / 0.2	1.5 / 1.5	1.9 / 1.9
GENESIS (Cordis)	6 x 59	212	40	0/0/0/0/0	0.0 / 0.1	-- / 1.1	-- / 2.3
SENTINOL (Boston Scientific)	8 x 42	149	5	0/0/0/0/0	0.1 / 0.2	1.1 / 1.1	1.4 / 1.6
PRECISE (Cordis)	8 x 42	213	4	0/0/0/0/0	0.2 / 0.1	1.2 / 1.0	1.5 / 1.6

* Denotes the respective measurement with the long axis of the stent either along B0 or at 90 degrees to it.
# Length (diameter) ratio is the ratio of the artifact size (length, diameter) to the geometrical size of the stent.

The shape of the artifact depended of the orientation of the long axis of the stent to B0, as seen below.



0^0, COR 90^0, COR Palmaz, 90^0, COR Palmaz, 90^0, SAG

DISCUSSION: With the exception of the large Palmaz, all other stents showed deflection less than the critical 45 degrees. All stents exhibited no torque, and the RF heating for all was insignificant, in the order of 0.1 – 0.2 0C. The level of artifact was different for the different stents, all of them creating a void artifact in the order of few times their geometrical sizes. Palmaz generated spectacular dipole-like artifacts as seen in the figure above.

CONCLUSIONS: All of the listed stents, with the exception of the large stainless steel Palmaz, are MR safe. MR compatibility should be judged on an individual imaging case, taking into account the size of the artifacts and the proximity of the region of interest to the position of the respective stent.

REFERENCES: **1**. Shellock, F., Shellock V. AJR v.173, 543-47, 1999; Hug J., et al. Radiology 216: 781-787 (2000); Shellock, F., Forder, J. J. Cardiovasc. MR 7, 415-19 (2005).