Which factors influence MRI in-stent lumenvisibility of coronary in-stent stenosis? An in-vitro model investigation

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Purpose: Coronary stents generally hamper lumen visibility (LVis) in coronary MR angiography (cMRA); yet, there is considerable scientific interest, clinical need and economic implication in early detection of restenosis. Therefore we sought to develop a standardized approach to evaluate which factors need to be optimized for quantification of in-stent restenosis by analysis of LVis in a static MRI in-vitro model of artificial restenosis.

Subjects and Methods: Stentloaded silicon tubes were prepared to accurately reflect 50% and 75% in-stent diameter stenosis by standardized filling with a material which displays magnetiszation properties similar to neointima. The prepared stents were placed in a static saline /saline+gadolinium perfused phantom parallel and perpendicular to B_0 in a 1.5T and 3T MRI System (Achieva, PMS). Measurements were carried out using different sequences (T1wTSE, T2wTSE, 3D-FFE; FOV 530 mm, matrix 1024, pixel size 0.5 x 0.5 mm). LVis was analysed with respect to: stent susceptibility, stent design and strut thickness (6 different stents 3.5/30 mm; steel, cobalt-chromium, DES, tantalum), used MRI system, sequence applied, stent position relative to B_0, Gd application.

Results:

Stent characteristics

LVis and restenosis quantification was generally poor in stents with a high susceptibility ($p<0.001$, n=384), with closed stent cells ($p<0.001$) and with thick stent struts ($p<0.003$) (Tab.1). The stent lumen was completely covered by artifacts within steel stents. In cobalt-chromium stents strut design had more effect on LVis. On the other hand, LVis was much better in the tantalum stent with a lower susceptibility and an open strut design (Fig.1).

MRI-system characteristics

It is obvious, that a good LV is significant higher in a lower MRI field strength ($p<0.005$). TSE sequence imaging reduce better stent artifact appearance than FFE sequences ($p<0.005$). Furthermore artifact extention was lower for a parallel position of the stent to B_0 than for perpendicular position ($p<0.005$). The results show, that Gd does not improve LVis ($p=0.85$) (Tab.2).

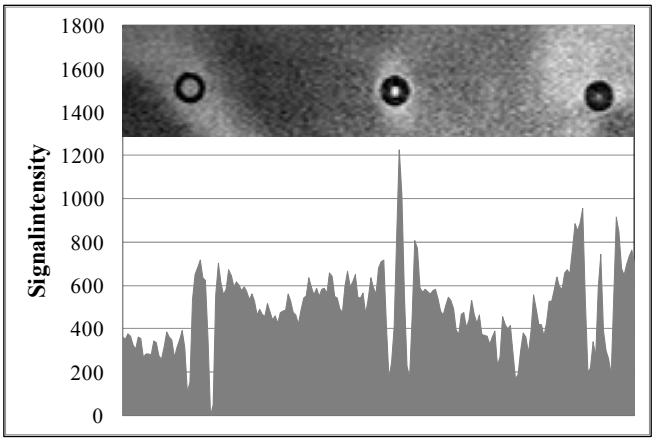

Fig. 1 Signal intensity profile of the Strecker Tantalum stent using TSE-T2 (left reference tube, middle 50% stenosis, right 75% stenosis)

Discussion: The purpose of this study was to evaluate the feasibility of measuring artificial in-stent stenosis in a static vascular phantom using magnetic resonance imaging. We showed that the feasibility to assess a degree of in-stent stenosis by MRI was highly significant depending on stent properties, like stent material ($p<0.001$), stent design ($p<0.001$), stent cells ($p<0.001$) and stent cell strut thickness ($p<0.003$, n=384). Stainless steel and cobalt-chromium stents were not assessable because of artifacts. Greatest image quality was seen in the tantalum stent. A difference was to be ascertained in the imaging with a 1.5 Tesla and a 3 Tesla MRI. Using a 3 Tesla MRI the stent artifacts were more frequent and dominant ($p<0.005$). Of another importance is the choice of the MR sequence. Good results were achieved with the TSE sequences ($p<0.005$). Especially, the T2-weighted turbo spin-echo sequence admitted a good view of the lumenvisibility. Additionally the stent orientation in the static field B_0 is a factor which influences LV. With the use of a parallel stent orientation ($p<0.005$) artifacts can be minimised. A significant improve of LV was not achieved with the use of Gadolinium ($p=0.85$).

Stent property significance to lumenvisibility					
Material susceptibility		Design		Strut thickness	
equal to human tissue	**positive**	oben cell structure	**positive**	thin	**positive**
different to human tissue	**negative**	closed cell structure	**negative**	thick	**negative**
p< 0.001, (n=384)		p<0.001, (n=384)		p<0.003, (n=384)	

TAB. 1 stent property significance to lumenvisibility

MR-system property significance to lumenvisibility							
field strength		sequence		stent orientation to B_0		Gd application	
1.5 Tesla	**positive**	TSE	**positive**	parallel	**positive**	yes	**positive**
3 Tesla	**negative**	GRE	**negative**	orthogonal	**negative**	no	**negative**
p<0.005, (n=384)		p<0.005, (n=384)		p<0.005, (n=384)		p=0.85, (n=384)	

TAB. 2 MR-system property significance to lumenvisibility

Conclusions: A static in-vitro model and a artificial restenosis material were developed in order to determine the factors which influence coronary MRI in-stent LVis. Using the artificial stenosis material and the static model LVis can be evaluated and compared. Stent material had the most significant influence on the visibility of in-stent stenosis. An additional important influencing factor is stent design and the stent strut thickness. Stents with closed stent cells performing worse than stents with open stent cells. Also the spatial position of the stents in relation to the static magnetic field B0, the used MRI field strength and sequence and have an influence on the extent of the stent artifacts. Furthermore Gd does not improve MRI imaging for evaluation of restenosis LVis.

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