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Stent lumen quantification of 21 endovascular stents with MPI

F. Wegner[1,+,*] · A. von Gladiss[2,+] · J. Haegele[1,3] · U. Grzyska[1] · M. M. Sieren[1] · K. Lüdtke-Buzug[2] · J. Barkhausen[1] · T. M. Buzug[2] · T. Friedrich[2]

[1]Department of Radiology and Nuclear Medicine, University Hospital Schleswig-Holstein, Lübeck, Germany
[2]Institute of Medical Engineering, University of Lübeck, Lübeck, Germany
[3]Zentrum für Radiologie und Nuklearmedizin Rheinland, Dormagen, Germany
[+]equally contributing
[*]Corresponding author, email: franz.wegner@uksh.de

Abstract

Restenoses are a common problem after stent implantations and may cause new ischemic events, e.g. heart attacks and strokes. Thus, early diagnosis and treatment of in stent stenoses has tremendous clinical impact. Visualization and quantification of the stent lumen with the established noninvasive imaging modalities MRI and CT is severely limited by stent induced artifacts. The aim of this study was to investigate whether MPI can quantify the stent lumen accurately.

I Introduction

In recent years the huge potential of MPI for cardiovascular imaging/interventions was proven in numerous studies: e.g. first MPI compatible instrument designs were introduced [1], the quantification of simple stenosis was shown [2], [3] and the potential of MPI-guided vascular interventions was investigated [4]–[6]. Most recently, studies evaluating the safety and the potential of MPI guided endovascular stent implantations and artifact-free visualization became available [7]–[9]. The aim of this study was to investigate whether MPI can reliably quantify the lumen of metallic endovascular stents without artifacts.

II Material and methods

II.I Stents and phantoms

Twenty-one commercially available endovascular stents of different diameters (3-10 mm) and materials (stainless steel, nitinol, cobalt-chromium, platinum-chromium) were investigated [7]. The stents were implanted in silicone phantoms and filled with diluted tracer (1:100, Resovist, I'rom Pharmaceuticals, Tokio, Japan). As references we used phantoms with corresponding diameters without stents, solely filled with tracer. All phantoms were aligned along the x-axis of the scanner.

II.II Image acquisition and reconstruction

Imaging was performed with a preclinical MPI system (MPI 25/20FF, Bruker Biospin, Ettlingen, Germany). The excitation frequencies were 24.5 kHz, 26.0 kHz, and 25.3 kHz in x-, y-, and z-direction, respectively. The excitation field strengths were 12 mT in each direction. Gradient strength was 2 T/m in z-direction and 1 T/m in x- and y-direction, resulting in a FOV of 24 x 24 x 12 mm. The measurements were performed with 1000 repetitions, resulting in a scan duration of 21.54 s. Images were reconstructed with a hybrid system matrix based on a Kaczmarz algorithm [10], [11]. Reconstruction parameters were: SNR threshold: 250, regularization factor: 8, number of iterations: 1.

II.III Data analysis and statistics

In this work the eleven central slices of the xz-planes of the reconstructed maximum intensity projection images were analyzed. To estimate the diameter of the stent lumen, a threshold value (FWXM) was calculated from the signal intensity curves of each phantom based on the known nominal phantom diameter. The average of all FWXM's was applied on the signal intensity measurements of each phantom.

In order to describe the correlation between the diameters of the stented and reference phantoms Pearson's correlation coefficient was computed. Furthermore, the relative measurement error was calculated for each phantom (Table 1).

III Results and discussion

The calculated average FWXM of 39.2 % was used as threshold between lumen and adjacent structures. The diameters of the 3 mm phantoms were slightly overestimated. The calculated diameter of all other phantoms (> 3 mm) was in the range of the resolution inaccuracy or slightly underestimated. Pearson's correlation coefficient showed a strong correlation between nominal and calculated diameters for both, the stented phantoms and the reference phantoms (r=0.98).

Our study demonstrates that MPI can accurately quantify the lumen of all tested endovascular stents. *Vaalma et al.* and *Herz et al.* showed the possibility of stenosis quantification with MPI/TWMPI in the absence of metallic objects like stents [2], [3]. Interventional catheters and guidewires, which are made of ferromagnetic material like stainless steel or nitinol can generate an MPI signal [12]. In an additional study it was shown, that stents do not generate enough MPI-signal to induce any visible artifacts [9]. In this study we show, that the quantification of the stent lumen is not biased by metallic stents. Thus, MPI seems to have the potential to visualize and to quantify the stent in-vivo.

However, as stents are "invisible" in MPI the use of MPI visible stent markers is necessary to identify stents and their position in MPI [8]. To distinguish between stent markers and intraluminal particle signal, the use of multicolor MPI might be a useful approach [13]. Especially the influence of multicolor MPI on the accuracy of stent lumen quantification should be part of future analysis. Furthermore, our results should be proven under flow conditions and in an in-vivo situation.

Table 1: Details of the investigated stents and results of the lumen quantification.

Stent Type	Material	Ø/Length (mm)	Relative measurement error (%)
Biosensors, Biomatrix Neoflex	316L	3/28	-3
Biosensors, Bio Freedom	316L	3.5/11	23
Boston Scientific, Taxus Liberté	316L	4/38	-3
Boston Scientific, Taxus Liberté	316L	5/32	-13
Boston Scientific, Express LD Vascular	316L	7/57	-10
Boston Scientific, Express LD Vascular	316L	10/37	-7
IDEV, Supera	Nitinol	4/40	-5
Gore, Tigris	Nitinol	5/40	-13
IDEV, Supera	Nitinol	5/60	-5
IDEV, Supera	Nitinol	6/40	0
Gore, Tigris	Nitinol	6/40	-9
Gore, Tigris	Nitinol	7/40	-10
Boston Scientific, Epic	Nitinol	7/99	-3
Gore, Tigris	Nitinol	8/40	-3
Boston Scientific, Promus Premier	PtCr	3/28	13
Boston Scientific, Promus Element Plus	PtCr	3/32	16
Boston Scientific, Synergy	PtCr	3/38	28
Boston Scientific, Promus Element Plus	PtCr	4/28	-3
Boston Scientific, Promus Premier	PtCr	4/28	-13
Boston Scientific, Rebel	PtCr	4/28	-3
Boston Scientific, Carotid Wallstent	CoCr	7/30	-4

IV Conclusions

MPI enables the visualization of the stent lumen without any artifacts and may allow for the quantification of in-stent stenoses.

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Author's Statement

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