

# In-stent lumen visualization using intravascular MRI and a bSSFP sequence

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## Introduction

Performing magnetic resonance imaging inside metallic vascular stents still represents a major challenge in many cases. Metallic stents are known to hinder visualization of the inner lumen as a result of both susceptibility artefacts and radiofrequency shielding effects [1]. Proposed solutions to the radiofrequency shielding effects include the use of sequences with an increased flip angle [2] or imaging using inductively coupled stent antennas [3]. In this study, we investigate the use of an intravascular loopless antenna [4], which can be inserted inside the stent lumen, to reduce the radiofrequency shielding effects and provide a clear depiction of the vessel lumen inside the metallic vascular implant.

## Methods

A phantom including a flexible plastic tube (inner diameter: 8 mm) was constructed. A nitinol stent (S.M.A.R.T. 10 mm x 60 mm, Cordis Corporation, Miami, USA) was inserted over the tube in order to cover part of its total length. This particular stent is known to produce minimal susceptibility artefacts but leads to an important radiofrequency shielding effect [1]. The whole phantom was filled with a gadolinium solution of concentration 1.8 mmol/L. All imaging was performed with the stent parallel to the main magnetic field in a 1.5T clinical scanner. A custom-made loopless antenna was used for intravascular imaging, while surface MRI was performed using a combination of a spine array and body array coils.

All imaging was performed using a balanced Steady-State Free-Precession (bSSFP) acquisition, as this sequence was shown to provide the highest vessel depiction in an interventional context [5]. Sequence parameters were: FoV : 64 mm x 64 mm, matrix: 256 x 256 (250  $\mu$ m in-plane resolution), slice thickness: 3 mm, NEX: 5, TR: 8.8 ms, TE: 4.4 ms, acq. time: 12.5 s/slice. In order to study the achievable signal-to-noise ratio (SNR) as a function of the excitation angle, the flip angle was varied between 10° and 90°, using a 10° increment.

## Results and Discussion

Fig 1. illustrates typical images inside the stent using the loopless antenna and the surface array coils. While a good depiction of the inner vessel wall is possible with the loopless antenna, the signal attenuation observed when using the surface coils greatly reduces the contrast between the wall and the lumen.

As the use of a sequence with an increased flip angle has been proposed as a way to increase SNR inside a stent [2], Fig 2. presents the mean vessel SNR as a function of the flip angle for a bSSFP sequence, both inside the stent and without the presence of the stent. It can be observed that an increase in flip angle effectively leads to an increase in SNR over the clinically relevant flip angle range investigated. It is important to note that the actual behaviour of the signal depends on the T<sub>1</sub> and T<sub>2</sub> relaxation times of the medium, and consequently on the contrast agent concentration used [6].

It can be assessed that the achievable SNR inside the stent with an intravascular coil is much higher than the SNR obtained with surface coils, even with the highest flip angle tried (90°). Two main reasons explain the higher SNR achieved with the intravascular coil. First, the loopless antenna is intrinsically more sensitive than most surface coils. This effect occurs both inside the stent and without the stent and is the rationale behind the use of intravascular coils in general. However, it is also observed that the degree of radiofrequency shielding is significantly reduced by the use of the intravascular coil, as expressed by the comparison of the signal inside the stent and without the stent. Globally, the presence of the stent is found to lead to a mean SNR decrease of 31  $\pm$  4 % with the loopless antenna in comparison to 70  $\pm$  4 % when using the surface coils. Over the investigated range, this level of signal attenuation is found to be mostly independent of the flip angle used.

Since the loopless antenna was used in reception mode only and barring some coupling effects, its use can not decrease the radiofrequency shielding of the stent during excitation, which explains a certain level of signal attenuation. Therefore, the gain observed indicates that the use of an intravascular receive coil, which can be inserted inside the stent, appears as an effective way to reduce the radiofrequency shielding of the MR signal during reception.

## Conclusion

The results presented illustrate that the use of an intravascular loopless antenna appears as a valuable help for imaging inside a stent, in an interventional MRI context. Not only the intravascular coil provides intrinsically a higher SNR, but its use also helps to prevent the shielding effect of the stent during signal reception.

## References

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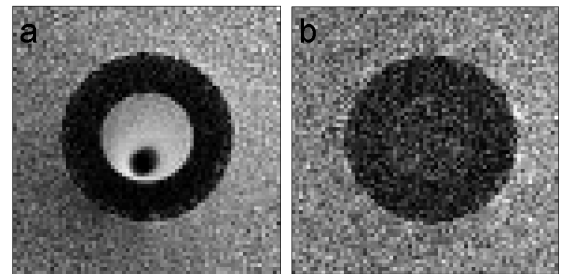


Figure 1 : Axial images in the presence of the metallic stent, for a flip angle of 50°. a: Loopless antenna b: Spine and body surface arrays. An inhomogeneity correction is applied to the loopless antenna image for better visualization.

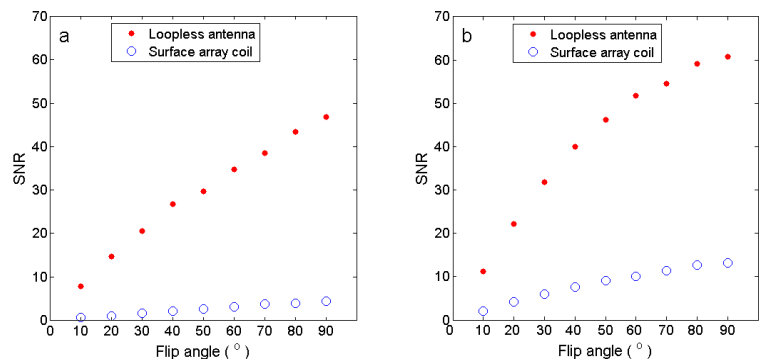


Figure 2 : Mean vessel SNR as a function of the flip angle for the loopless antenna and the surface array coils. a: Inside the stent b: Without the stent.