Reduction of the RF shielding caused by a vascular stent using a pseudo-adiabatic excitation

G. Gilbert[1], and G. Beaudoin[1]
[1]Department of Radiology, Centre Hospitalier de l'Université de Montréal, Montreal, Quebec, Canada

Introduction

Metallic vascular stents are widely used during revascularization procedures to improve the success rate of the intervention. However, metallic stents are also known to produce susceptibility and radiofrequency (RF) artifacts that can hinder the depiction of the stent lumen during subsequent magnetic resonance angiography (MRA) investigations [1]. Proposed solutions to the RF shielding effect include the use of specially designed stents [2, 3] and the employment of MRA sequences with an increased flip angle [1].

In this study, we alternatively investigate the reduction in RF shielding that can be achieved by using a pseudo-adiabatic excitation pulse [4] in an angiography sequence. Since the standard proportionality relation between the time integral of the B_1 field amplitude and the resulting flip angle no longer holds for adiabatic and pseudo-adiabatic pulses [5], a significant and beneficial alteration of the RF shielding behavior of the stent during excitation can be expected.

Methods

A 3D T_1-weighted MRA spoiled gradient-echo sequence (T_R = 28 ms, T_E = 5 ms) was implemented with a BIR-4-like pseudo-adiabatic excitation pulse (pulse length = 2.1 ms, maximum B_1 = 22.5 μT), following the approach proposed in [4]. This specific pulse was chosen over other adiabatic pulses because of its relatively short application time and reasonable power deposition. Imaging was performed in a vascular phantom in which a flexible plastic tube (inner diameter = 6 mm) was partially covered with a nitinol stent (S.M.A.R.T. 10 mm x 60 mm, Cordis Corporation, Miami, USA). The whole phantom was filled with a blood-mimicking solution with a gadopentate dimeglumine concentration of 1.8 mmol/L. Flip angle maps were also computed for a region encompassing the lumen of the stent, using the method proposed in [6] with a gradient-echo sequence. All experiments were performed with the stent parallel to the main magnetic field of a clinical 1.5T scanner, with RF excitation being performed by the birdcage bodycoil.

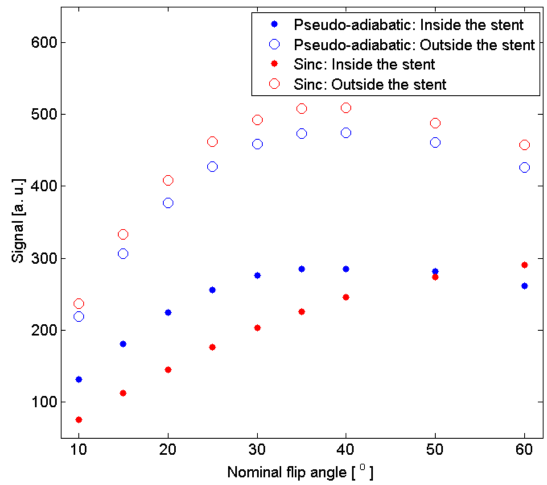

Figure 1 : Signal as a function of the nominal flip angle. Error bars are included in the size of the data points.

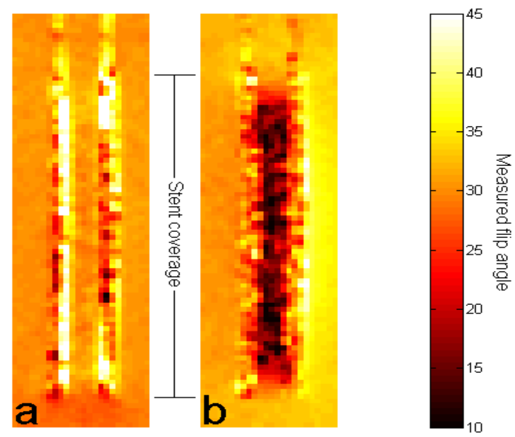

Figure 2 : Flip angle maps for a region covering the stent lumen. Nominal flip angle of 30°. a) Pseudo-adiabatic BIR-4 pulse. b) Standard sinc pulse.

Results and Discussion

Fig. 1 presents the mean signal as a function of the nominal flip angle for a region-of-interest (ROI) located inside the stent lumen and a reference ROI located outside the stent, for imaging performed with the pseudo-adiabatic pulse and a standard sinc pulse. First, it can be observed that the signal behavior is very similar for the two excitation pulses for the ROI located outside the stent, with only a small signal decrease (~ 7 % for a nominal flip angle of 35°) for the pseudo-adiabatic pulse. This effect is likely caused by relaxation effects during the pulse. Nevertheless, it is also possible to assess that the use of the pseudo-adiabatic pulse leads to a modification of the signal response for the ROI located inside the stent lumen. When the pseudo-adiabatic pulse is used, the nominal flip angles needed to reach a maximum signal become nearly identical for both ROIs, indicating that a similar effective flip angle is achieved inside and outside the stent lumen. This conclusion is also supported by the flip angle maps presented in Fig. 2. It can be observed that the important flip angle decrease observed inside the stent with the standard sinc pulse is almost completely eliminated when the pseudo-adiabatic pulse is used. With the sequence parameters used, the choice of the pseudo-adiabatic pulse leads to a signal increase of ~ 25 % for an optimal flip angle of 35°. Finally, it is important to mention that the remaining decrease in signal for the ROI located inside the stent lumen comes from the reciprocal shielding effect during signal reception, which is independent f of the excitation pulse used.

Conclusion

The results presented in this abstract illustrate that the use of an adiabatic or pseudo-adiabatic excitation pulse is an effective way to decrease the shielding effect of a vascular stent. The observed increase in signal for the ROI located inside the stent lumen could also be achieved by using a standard pulse with an increased flip angle, as proposed in [1]. However, the current approach presents the benefit that an optimal signal is obtained inside and outside the stent for the same nominal flip angle. Furthermore, for a reasonable range of RF shielding levels, no prior knowledge of the amount of RF shielding caused by the stent is needed to obtain optimal results. With the current implementation, the most important limitation comes from the relatively important RF power deposition, which forbids the use of a very short T_R because of specific absorption rate (SAR) limitations. Approaches to further limit the SAR will be investigated.

References

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