Visualization of CO_2 filled balloon catheters in a flow phantom and in patients using SSFP imaging

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Synopsis

Passive catheter tracking involves direct interaction between the device and its surroundings creating a signal loss or enhancement on the image. In this abstract we used standard balloon catheters filled with CO_2 and imaged them using Steady State Free Precession (SSFP). Using this technique it was possible to visualize and track the catheters both in a flow phantom and in patients. Frame rates greater than 7 frames/s were achieved giving enough temporal resolution for interventions in patients.

Introduction

Catheter tracking methods can be divided into three groups: active, semi-active and passive. Active devices use direct electrical connection to the MR system or an external power source and are usually grouped into four categories: devices which change the signal locally by affecting the field homogeneity [1], devices which localize the tip of the catheter [2-5] typically small resonant coils, devices which allow visualization of the length of the catheter like the Surgivison guide-wire antenna [6-7] and finally devices that can be used to track the position of the catheter and image locally [8]. Semi-active devices utilize wireless inductive coupling to track the catheter [9-10]. Passive devices interact directly with the imaging system or surrounding tissues to allow visualization of the catheter. In the work from Utrecht, dyprosium rings were placed on conventional catheters to create an area of signal loss [11]. It is also possible to use Gd-DTPA solutions to obtain positive enhancement of the catheter [12]. At present, there is a lack of CE approved catheters and guide wires designed specifically for active or passive MRI guided cardiac catheterization in patients. In this study, we used cardiac balloon catheters routinely used for X-ray guided cardiac catheterization. To enhance the visualization of the signal void created by the CO_2 filled balloons SSFP imaging was used because blood has a bright signal in this sequence. This abstract includes the results of work on a flow phantom and the first few patients who have undergone cardiac catheterization in our combined MRI and X-ray (XMR) suite.

Methods

A Schematic of the flow phantom is given in **figure 1**. Pump heart rate was set to 60 bpm and stroke volume 60 ml. Patients details are shown in **table 1**.

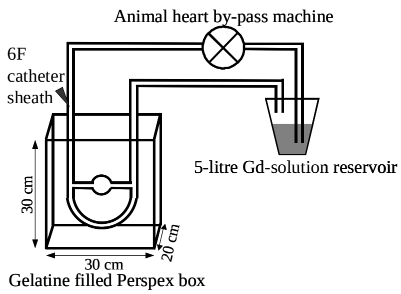

Figure 1: Schematic of the flow phantom

	Age	Diagnosis	Imaging	Structures entered
1	5.8	VSD, Pulmonary hypertension (PHt)	RT	IVC, RA, LPA
2	7.5	aortic arch hypoplasia, VSD (r)	RT	descending aorta, aortic arch
3	7.4	secundum ASD	I	IVC, RA, LA
4	38	mitral atresia, single ventricle, PHt	I	IVC, RA, LA,RV, LV
5	4.3	hypoplastic left heart, Norwood (I and II)	RT	SVC, LPA, RPA
6	2.3	AVSD (r), RVOT obstruction (r), VSD	I	IVC, SVC, RA, RV, PA, RPA
7	35.2	AVSD (r), residual VSD	I	IVC, RA, LA, LV
8	20.4	single ventricle, Waterston shunt	I	IVC, RA, LA, LV, aorta, PA
9	0.8	pulmonary atresia, single ventricle	I	SVC, RPA, LPA

Table 1: Patients details ((r)=repaired, RT=real time, I=interactive).

Imaging: Scanning was carried out on a 1.5T Philips Intera in the XMR suite. B-FFE and B-TFE were used. In order to choose the ideal sequence for patient studies the following parameters were tested on the phantom. For cartesian acquisition: scan % (100, 90, 80, 70, 60, 50, 40), matrix (256, 240, 224, 208, 192, 176, 144, 128, 112, 96, 64), phase encoding direction, echo time (1.6, 1.8, 2, 2.5, 3, 4, 5 ms). All images were acquired using half-scan technique and were reconstructed to 256×256. For radial trajectories only the radial density was altered (100, 90, 80, 70, 60, 50, 40 ,30 ,20, 10). To image patients, two sequences were chosen on the basis of the optimization experiments (**table 1**): a real time sequence (B-FFE, TE 1.05 ms, TR 2.1 ms, scan % 100, matrix 96×96 reconstructed to 128×128, α 50°, > 9frames/s) and an interactive mode sequence (B-TFE, TE 1.45 ms, TR 2.9 ms, matrix 128, scan % 75, > 7 frames/s). In patients planes of interest were first acquired and stored in interactive mode.

Results and Discussion

Phantom: B-FFE and B-TFE lead to identical results. It was possible to visualize the catheter in all experiments (**figure 2**). It was found that using lower spatial resolution and higher temporal resolution greatly improved the manipulation and tracking of the catheter. With a high resolution image (256×256) a frame rate of only 1-2 frames/s can be achieved whereas rates >10 frames/s can be achieved with lower resolution (less than 128×128). For the highest frame rates it was possible to visualize the small lateral motion caused by flow for static catheters. A frame rate of 5 frames/s was deemed necessary for clinical use. Increasing TE to increase susceptibility artefacts and balloon visualization was ruled out as it reduces greatly the frame rate (<1 frame/s).

Patients: In patients the technique was successfully used to track the catheter in a range of anatomical structures (**table 1**). Although, it was possible to guide the catheter by just visualizing its tip the lack of torque of these catheters sometimes made it challenging to enter some anatomical structures.

Conclusion

Using only standard balloon catheters filled with CO_2 and imaged with SSFP it was possible to visualize and track catheters in a flow phantom and in patients. The phantom work demonstrated that it was advantageous to lose spatial resolution in order to increase temporal resolution. Although only the tip of the catheter was visualized this technique proved to be effective in patients.

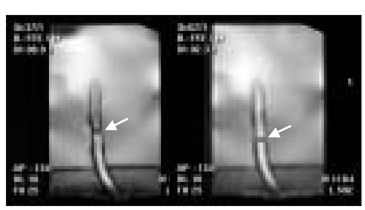

Figure 2: High (256×256) and low (64×64) resolution images of the phantom showing the catheter.

Figure 3: Four frames from patient 2 showing the catheter in different parts of the aorta (real time sequence)

References

[1] Glowinsky A et al (1997) *Mag Reson Med* **38**:253-258.
[2] Leund DA et al (1995) *Radiology* **197**:485-488.
[3] Wildermuth S. et al. (1997) *Radiology* **202**:578-583.
[4] Ladd ME et al. (1998) *J Mag Reson Imag* **8**:220-225.
[5] Ladd ME et al. (2000) *J Mag Reson Imag* **12**:534-546.
[6] Ocali O and Atalar E (1997) *Mag Reson Med* **37**:112-118.
[7] Lardo AC et al. (2000) *Circulation* **102**: 698-705.
[8] Zhang Q et al. (2000) *Mag Reson Med* **44**:56-65.
[9] Wong Ey et al. (2001) *J Mag Reson Imag* **12**:632-638.
[10] Weiss S et al (2001) *Proc Int Soc Mag Reson Med* **9**:554.
[11] Bakker CJ et al. (1996) *Mag Reson Med* **36**:816-820.
[12] Unal O et al. (1998) *Mag Reson Med* **40**:356-362