Passive Tracking In Vivo Cardiovascular Catheterization Under Real-Time MRI Guidance Using Conventional X-ray Angiographic Catheters

S. Zhang[1], S. Rafie[1], Y. Chen[1], C. Hillenbrand[1], J. L. Duerk[1], J. S. Lewin[1]

[1]University Hospitals of Cleveland, Case Western Reserve University, Cleveland, OH, United States

Introduction

According to the American Heart Association, more than 1.3 million cardiovascular catheterizations are performed annually in the USA for diagnostic or interventional therapeutic purpose. To date, x-ray fluoroscopy remains the primary modality for the guidance of cardiovascular intervention. However, MRI has advantages over x-ray since MRI can demonstrate not only the vessel lumen, but also the vessel wall, and does not rely upon ionizing radiation. Rapid image acquisitions have facilitated the exploration of MRI guided cardiovascular catheterization [1,2]. Successful MRI guided cardiovascular intervention can be achieved in many ways, including the use of passive tracking methods.

Different passive tracking strategies have been employed to visualize the tip of the catheter. These include filling the catheter with contrast medium [2]. To date, however, there has been no report on the feasibility of cardiac and coronary catheterization under real-time MR guidance using only the native susceptibility of a standard X-ray angiographic catheter. The purpose of this study was to test the hypothesis that cardiac and coronary catheterization can be successfully performed under real-time MR guidance with a conventional x-ray angiographic catheter through application of the appropriate MR imaging technique.

Material and Methods

Eight farm pigs, 70-100 lbs, were used in this study. All experiments were conducted on a 1.5 T MR system (Magnetom Sonata, Siemens Medical Solutions, Erlangen, Germany), and were performed under a protocol approved by our institutional animal care and use committee. The animals were anesthetized with an intramuscular injection of 6-10mg/kg tiletamine hydrochloride and zolazepam hydrochloride. For maintenance, a solution of ketamine and xylazine was infused through an ear vein. The animals were placed in the MR scanner in a supine position. After acquisition of a localizer, one set of axial and oblique two-dimensional true-FISP images (TR/TE/Tip/Thickness: 3.03ms/1.52ms/40°/5mm) was obtained to localize the aortic arch and root, the coronary artery for the left heart. A second set of axial and oblique two-dimensional true-FISP images were acquired to localize the inferior vena cava, the right atrium and the right ventricle. The images were displayed on an in-room monitor adjacent to the magnet. Then, a near-real-time True-FISP sequence (TR/TE/Tip/Thickness: 2.33ms/1.17ms/40°/10mm; 3 frames/sec) was used to track the tip of the catheters. A pigtail catheter was used on all animals for both left heart and right heart catheterizations. An Amplatz catheter was used for right coronary artery catheterizations; right heart catheterizations were attempted in 5 animals. All catheters used were manufactured by Cordis, (Miami Lakes, FL). A steerable hydrophilic-coated guidewire was coaxially inserted to advance the catheter. The intravascular devices were visualized by means of their native susceptibility artifacts. Approximately 5-10ml of 25% diluted Gadolinium-DTPA contrast material was injected to confirm engagement of the right coronary artery during right coronary artery catheterizations.

Results

Cardiac catheterization of both the right and left heart were successfully performed in all 8 pigs. The catheter tip as well as the longitudinal profile of the catheter were readily visible as signal void on the real-time True FISP images (Figure 1). In addition, right coronary catheterization was successfully completed in 4 of 5 pigs attempted (Figure 2). The average time for either left heart catheterization (including ascending aorta and left ventricle), or right heart catheterization (including right atrium and ventricle), was one minute, while the time range required for coronary artery catheterization was 30-90 minutes.

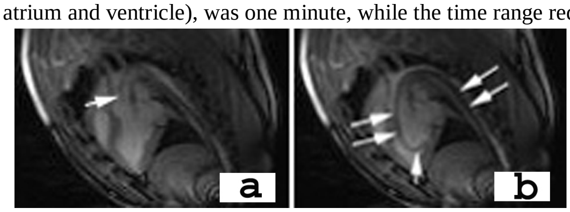

Figure 1 Real-time True FISP sagittal images. a: tip of catheter in ascending aorta; b: tip of catheter in left ventricle (short arrow). Long arrows indicate the longitudinal profile of the catheter.

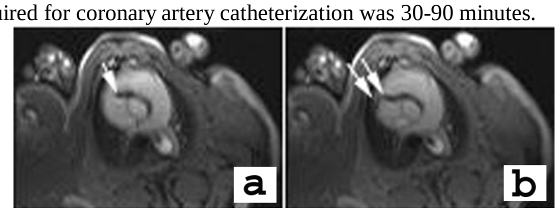

Figure 2 a: arrow indicates catheter engaged in right coronary artery without contrast injection; b: With injection of 25% diluted Gadolinium, the right coronary artery can be visualized as a dark curvilinear structure (dual long arrows).

Discussion and Conclusion:

While many conventional angiographic catheters cannot be used for interventional MRI because of unacceptable artifacts, certain catheters (including the Cordis catheters used in this study) are sufficiently MRI compatible with rapid acquisitions at 1.5T to facilitate image guided procedures. Cardiac catheterization was feasible with passive visualization using only the native susceptibility effect of selected conventional X-ray angiographic catheters under real-time MR guidance. Coronary catheterization was also achievable under real-time MR guidance. Specifically, it is possible to track a catheter during interventional procedures as long as enough native contrast exists between the catheter and the vascular lumen, thereby confirming that passive tracking cardiac and coronary catheterization under real-time MR guidance are feasible with conventional cardiac catheters. However, the procedure time for these experiments was unacceptably long for clinical application. More robust MR sequences for real-time demonstration of the coronary arteries and better device visualization, as can be achieved with active tracking utilizing catheter-based coils, will be necessary if coronary artery catheterization under MR guidance is to become a clinical reality.

References

1. Serfaty JM, Yang X, Foo TK, etal. Magn Reson Med. 2003; 49:258-263.
2. Omary1 RA, Green1 JD, Schirf1 B, et al. Proc ISMRM 2003, 317.