Clinical MR guided cardiac catheterization

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Synopsis
We describe clinical experience of XMR guided cardiac catheterisation of 13 patients. We were able to guide catheters to all the chambers of the heart and great vessels from either venous or arterial access. There was a substantial reduction in x-ray dose compared to traditional procedures. The availability of anatomical and functional information from MR was found of great benefit.

Introduction
We have installed an XMR facility which we are using to perform cardiac catheterization of children and adults with congenital heart disease. We describe our facility and report on our first 13 clinical cases.

Purpose
We aim to reduce or eliminate X-ray dose, improve visualisation of relevant structures during the procedure, provide 3D imaging and flow quantification, and integrate invasive electrophysiology with MR derived motion.

Methods

Description of Facility: Our interventional suite, comprises a 1.5T Philips Intera I/T MRI scanner and Philips Pulsera cardiac x-ray unit in the same RF and x-ray screened room. A movable table top allows patients to be easily moved between modalities in less than 60 seconds. MR compatible anaesthesia and monitoring is incorporated. The Philips flexible coil arrays are sufficiently radio-translucent to be left in place during x-ray imaging without any image quality degradation. MR-compatible catheters (ie: non braided, and without guidewires) can be manipulated in the heart and great vessels using direct MRI visualization with the real-time and interactive imaging capabilities of the Intera system, which provide between 10 and 20 frames per second. Swan-Ganz Catheters, which have a carbon-dioxide-filled balloon at their tip can be clearly seen using these fast imaging protocols by means of passive contrast mechanisms.

Description of procedures: Patients are anaesthetised in the patient preparation area, and transferred to the MR table in the XMR suite, where the ECG electrodes, anaesthetic tubing and RF coils are connected. The patient is then transferred to the x-ray end of the room to gain access by means of femoral artery, femoral vein or jugular vein as appropriate. The patient is then transferred to the MR scanner for pre-intervention imaging. This comprises a 3D volume heart examination (100 slices in 8 chunks at 3 phases of the cardiac cycle), then the required ventricular function and flow studies. The interactive mode of the scanner is used at this point to identify the required image planes for subsequent catheter tracking. Catheters can then be inserted and manipulated within the magnet as required, using real time or interactive imaging. Where braided catheters with more torque or guidewires are needed for catheter manipulation, the patient can be transferred back to the x-ray table. Invasive pressure waveforms and ECG are recorded continuously under both MR and x-ray guidance, and blood gases (for saturation measurements) can be collected under MR as well as x-ray. Device implantation and RF ablation is invariably done at the x-ray end of the room due to lack of device MR compatibility. Suitable devices can be imaged in MRI immediately post implantation to ensure correct placement.

Results
Thirteen patient studies have been performed: eight diagnostic cardiac catheterizations, one device closure of atrial septal defect (ASD), one intracardiac coil occlusion, and two radiofrequency ablation of tachycardia. Catheters were placed in all chambers of the heart and great vessels using MR guidance. Phase-contrast MR derived pulmonary artery flow measurements were used along with invasive pressure measurements to calculate pulmonary vascular resistance in 7 cases. In the two cases where devices were implanted, 3D MRI was used to plan the procedure. In the RF ablation cases, tagged MRI was used to assess ventricular motion. Mean x-ray dose in the XMR procedures was 13 mSv compared to 55 mSv for matched subjects in a conventional x-ray cath-lab. The figure shows catheter being manipulated through the right heart from IVC to LPA. The catheter tip appears as a dark circle, marked with an arrow in the first image. The catheter was guided using the interactive capability of the MR scanner.

Conclusions
We have used an XMR facility to carry out cardiac catheterization on thirteen children and adults with congenital heart disease, using a mixture of left heart and right heart procedures. Catheters were manipulated under MR guidance, with the tip of the catheter visualized by means of passive contrast from a carbon dioxide balloon. As we have gained experience, we have found less need for x-ray imaging during the procedure. We have found x-ray dose substantially lower in XMR. For one diagnostic procedure, no x-ray imaging at all was required. Three dimensional imaging, flow quantification and myocardial motion assessment have all provided clinically useful extra information in these procedures that would not otherwise have been available.

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