Direct MRI-Guided Needle Access to the Heart and Blood Vessels

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INTRODUCTION

Arterial or venous access must be achieved prior to any catheter-based cardiovascular procedure. Adjunct imaging is used in difficult cases to assist the operator and avoid significant complications. Alternate or non-traditional cardiovascular access such as perventricular direct cardiac puncture may further enable more unique procedures where peripheral vessel access is insufficient due to the target location and orientation, a patient's aortic or other vascular disease, and device size. MRI guidance in these procedures can permit percutaneous interventional cardiovascular procedures to be performed wholly under MRI, allow precise targeting of the proper entry site to avoid critical structures in the entry path, and enable close monitoring of potential complications and cardiac function.

METHODS

Animal protocols were approved by the institutional Animal Care and Use Committee. All imaging was performed on a short, wide bore Siemens Espree 1.5T MRI scanner (Siemens Medical Solutions, Erlangen, Germany) with spine and body matrix coils as receivers in addition to the independent active device channels. Real-time balanced steady-state free precession (SSFP) imaging (TR/TE 3.23/1.62ms, ST 6mm, Flip Angle 45°, FOV 340x340mm, Matrix 192x144) using a separate real-time reconstruction and display system was used during *in vivo* animal experiments. Static roadmaps from segmented imaging and 3D MRAs were also implemented to display additional anatomic information to guide the operator.

Peripheral vascular access of jugular veins in swine was performed by both an experienced interventional cardiologist and a medical student to vary the experience level of the operator. Vessel images in three orthogonal views determined the optimal location to enter the vessel relative to bends and bifurcations and guided the real-time slice positioning. Two constantly updating (4-5 frames per second) perpendicular long-axis slices along the needle trajectory were used in the coronal and sagittal directions to provide right-left and anterior-posterior positioning, respectively, of the needle relative to the target vessel. A third short axis slice through the vessel could also be used to confirm vessel entry by the needle. An actively visualized needle with distinct tip markers (1) was used on one side. A similar approach with a passive needle targeted the contralateral jugular vein where a Gd-filled syringe on the surface was used to direct the appropriate trajectory. Insertion of an active guidewire down to the right heart and gadolinium injection through the needle lumen confirmed correct vessel entry. Finally, the needle was exchanged for a standard introducer sheath using a nitinol guidewire, securing access to the jugular vein.

Transthoracic closed-chest direct cardiac access to the right ventricle was attempted. The right ventricle free wall was accessed via an intercostal space parasternally. Imaging planes were selected to achieve a trajectory that would allow a direct and safe needle passage from the skin entry site to the target structure while avoiding structures such as the internal thoracic arteries and papillary muscles. The active needle was also used externally to plan and follow the proper trajectory. Two long-axis slices along the needle provided positioning during entry while short-axis imaging was used to monitor cardiac function and entry of the needle into the proper chamber. Cardiac access was confirmed visually on MR by needle locations in the appropriate ventricle, with aspiration of blood and gadolinium injection through the needle, and sheath placement.

RESULTS

MRI guidance enabled vascular access to the jugular veins, providing the operator with an appropriate trajectory and information on needle positioning relative to the target structure in all three directions. Jugular access was successful with both passive and active needle approaches by novice and experienced operators. Use of an active needle facilitated trajectory planning prior to puncture and simplified monitoring of device positioning, particularly in direct ventricular access where motion is a considerable factor and missed targets can have adverse consequences.

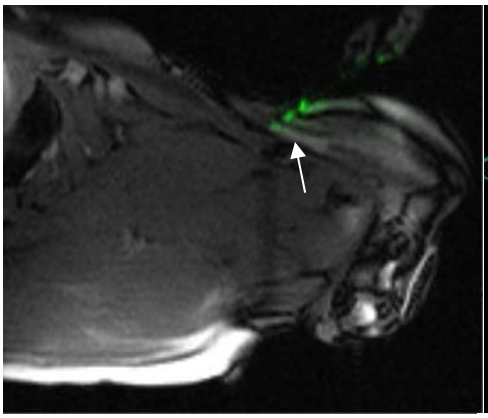
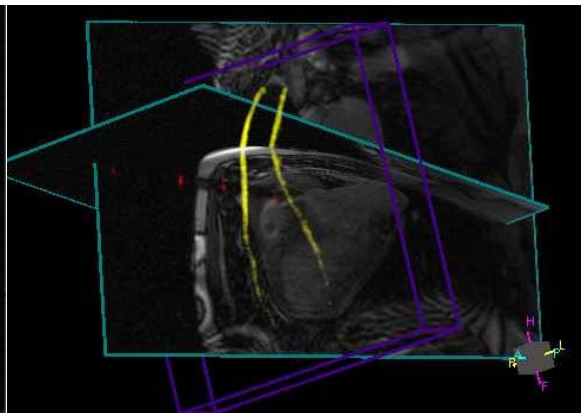


Figure 1: Active needle (green) in the jugular vein (arrow) during peripheral access.



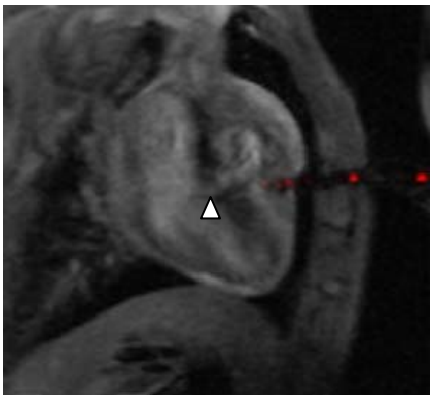


Figure 2: Right ventricular access. (A) Needle trajectory to avoid internal thoracic arteries displayed as 3D MRA renderings (yellow). (B) Active needle (red) in the RV targeting a muscular VSD (arrowhead).

DISCUSSION

Real-time MRI combined with additional MR roadmaps provides the operator with vessel or chamber visualization prior to access and superior anatomic context to guide conventional and novel cardiovascular access. Small vessels may be approachable with increased imaging resolution and smaller device imaging profiles. Vascular access represents an important critical step to enable traditional and more complex interventional procedures to be performed entirely in the MRI suite under superior imaging guidance.

References

1. Saikus CE, Ratnayaka K, Faranesh, AZ, Lederman, RJ, Kocaturk, O. *Active Needle for Real-Time MRI-Guided Percutaneous Procedures.* ISMRM 2009.