Magnetic Resonance Image-Guided Transseptal Puncture in a Swine Heart

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Introduction

There has been a growing interest in the use of transseptal catheterization due to the clinical developments of balloon mitral valvuloplasty and radiofrequency catheter ablation of the pulmonary veins. Since the introduction of this technique in 1960[3], the procedure has always relied upon conventional fluoroscopic techniques to guide the needle puncture. For example, the use of biplane fluoroscopy in combination with anatomical landmarks such as a pigtail catheter in the aorta (which requires arterial puncture), use of the His bundle or coronary sinus catheters are used to define a safe needle trajectory. More recently, the use of intracardiac echocardiography has been described[4]. However, all these techniques can be cumbersome and provide limited anatomical and functional information. In addition the presence of a enlarged atrium, septal calcification or kyphoscoliosis can limit the use of these conventional techniques[5]. In the present study, we evaluated the use of realtime MR guidance as the sole imaging modality to guide transseptal puncture and catheterization[6]. Using a novel MR intravascular needle and realtime MR guidance we were able to repeatedly perform a transseptal puncture into the left atrium from a transfemoral/jugular route with direct visualization of all cardiac chambers and surrounding vasculature in a swine model. Use of real time MR, allowed for direct, simultaneous visualization of the extruded needle, all four cardiac chambers and the surrounding vasculature.

Materials and Methods

All procedures were performed under MR guidance in a 1.5 T MR scanner. A novel active MR intravascular needle system was utilized for needle tracking and septal punctures. Nineteen transseptal punctures were performed in five swine (40-45 kg) using combination of ECG-gated high resolution and non-ECG gated real time MR imaging techniques. All imaging was performed solely under MR guidance in a 1.5 T MR scanner (CV/i, GE Medical Systems Waukesha, WI). Images were acquired using a combination of external phased array coils and the intravascular needle. The needle was introduced though a standard clinical 12 Fr sheath which had been placed in the common femoral vein (N=2) or a jugular vein (N=1). Using a real-time FIESTA sequence (3.4 ms TR, 1.2 ms TE, 45º flip angle, 125 kHz bandwidth, 10 mm slice thickness, 30 cm FOV, 128 x 128 image matrix, and 1 NEX) in combination with an interactive scan plane acquisition (i-Drive, GE), the needle was advanced into the right atrium. (Figure 1) It was then guided to the atrial septum using a axial fast SPGR sequence (6.0 ms TR, 1.5 ms TE, 60º flip angle, 125 kHz bandwith, 7 mm slice thickness, 35 cm FOV, 256x256, and 1 NEX) employing a four chamber view. Under realtime FIESTA sequence, the needle system was guided from the right atrium through the septum and into the left atrium. The location of the distal tip of the needle in the left atrium was then confirmed by a Fast Gradient Echo sequence (34 ms TR, 3.4 ms TE, 62.5 kHz BW, 7 mm slice thickness, 34 cm FOV, 256 x 256 image matrix, and 1 NEX), A ventriculogram, using Gd-DTPA with concentration of 25%, was performed using a FSPGR (6 ms TR, 1.3 ms TE, 90º flip angle, 31.2 kHz BW, no slice selection, 45 cm FOV, 256 x 256 image matrix, and 1 NEX)[7]) **(Figure 2)**; A post procedure necropsy was performed on all the animals. After the procedure, the explanted hearts from all animals were fixed with unpressurized formalin. Post mortem examination was performed to evaluate the septal punctures.

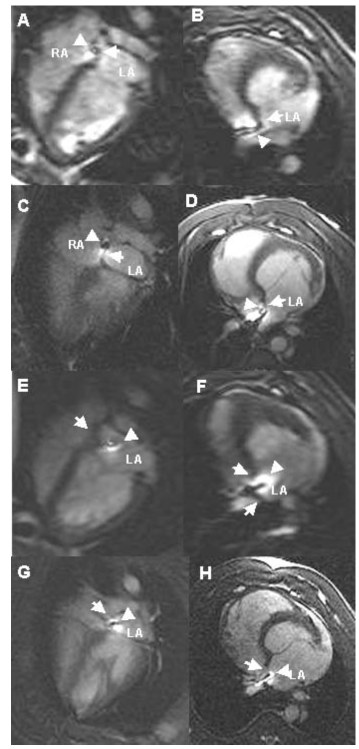

Figure 1: Monitoring the process of atrial septal puncture. (A-D) demonstrate visualization of tip of active needle within the right atrium adjacent to and pressing on the fossa ovalis. (E-H) views demonstrate the active needle tip now with in the left atrium having passed through the fossa ovalis. (A, C, E, G) are four chamber views and (B, D, F, H,) are axial views.

Results

The IVC was traversed from the femoral vein with the intravascular needle over a guide wire. Active tracking of the needle traversing through the septum was possible.(**Figure 1)** The location of the catheter tip was best confirmed using a segmented k-space MR imaging employing a steady state sequence (FIESTA). Confirmatory ventriculogram using gadolinium-DTPA was successfully performed with each puncture. **(Figure 2C)** An .014" guidewire was advanced into the left atrium and left ventricle **(Figure 2 A,B)**. *All punctures were made with out any change to cardiac rhythm or rate; post mortem analysis was performed on all animals and demonstrated that 18/19 (95%) punctures were directly through the fossa ovalis* **(Figure 2D)**.

Conclusion: Using MR-guidance only and a novel active intravascular needle system we were able to repeatedly puncture the fossa ovalis from a transfemoral approach with direct visualization of all components including the needle, the atria, fossa ovalis, and surrounding vasculature. Post mortem analysis demonstrated an accuracy of 95% for transseptal punctures under MR guidance in a swine model.

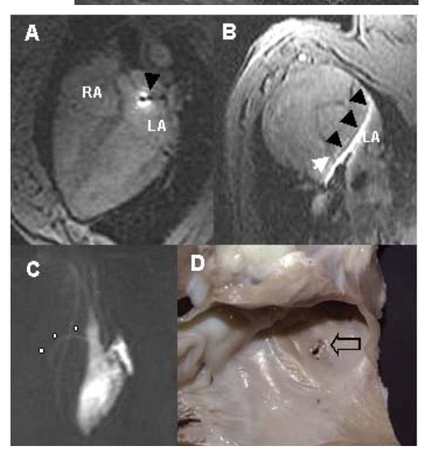

Figure 2: Images (A-four chamber view, B-short axis view) demonstrate a wire, which has been passed into the left atrium through the fossa ovalis. (C) Left ventriculogram captured after the injection of gadolinium through the septal puncture needle, which demonstrates the left atrium, left ventricle, aorta and coronary arteries. Note that there is no filling of the right atria or ventricle. (D) Gross pathologic photo of the fossa ovalis viewed from the left atrium. Block arrow indicates the atrial septal punctures. RA = Right atrium, LA = Left atrium, Small arrow = active needle tip, Large arrow = fossa ovalis, black arrows = inactive wire, circles = right coronary artery.

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