X-ray Fused With Magnetic Resonance Imaging to Guide Endomyocardial Biopsy of a Right Ventricular Mass

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Background A patient with a history of cancer in remission and congestive heart failure with no acute symptoms presented for a follow-up echocardiogram. The scan revealed a new echodense mass filling his right ventricular apex. An endomyocardial biopsy guided by x-ray fused with magnetic resonance (MR) imaging (XFM) was performed. This case report outlines the steps of XFM image preparation involving MR image acquisition, processing, and coregistration with x-ray fluoroscopy.

Discussion In cases of focal pathology or cardiac masses, endomyocardial biopsy can be challenging because x-ray fluoroscopy guidance offers limited visualization of soft-tissue structures. XFM overcomes this issue by overlaying high-resolution MR images onto x-ray fluoroscopy images.

Conclusion This case report illustrates the clinical use of XFM for endomyocardial biopsy of an apical right ventricular mass and provides a practical, step-by-step description of MR image acquisition, processing, and coregistration with fluoroscopy, as performed by the MR technologist.

Keywords | x-ray fused with MRI, endomyocardial biopsy, cardiac mass, image coregistration

X-ray fused with magnetic resonance (MR) imaging (XFM) involves acquiring roadmap MR images and overlaying them onto x-ray fluoroscopy. Endomyocardial biopsy typically is guided by x-ray; however, fluoroscopy does not permit visualization of soft-tissue structures, which is important when the pathology is focal, as with an intracardiac mass. Although x-ray fluoroscopy can depict interventional biopsy devices clearly, it requires the use of radiographic contrast for transient display of cardiac chambers and associated vasculature.

Some physicians use echocardiography to guide endomyocardial biopsy procedures, but it has a limited field of view and is unable to demonstrate the biopsy device shaft and tip simultaneously, making navigation difficult. Documented risks of echocardiography-guided biopsy include tricuspid valve damage and subsequent regurgitation, as well as myocardial perforations if the device inadvertently moves out of plane. XFM overcomes those challenges by fusing previously collected MR images to x-ray fluoroscopy allowing simultaneous soft-tissue and device visualization. It also has been shown to increase physician confidence and accuracy, as well as reduce radiation exposure and iodinated contrast use in routine pediatric diagnostic cardiac catheterizations. In addition, MR imaging acquisition for the purpose of XFM does not require use of a gadolinium-based contrast agent.

This case report provides a clinical example of XFM-guided biopsy of a right ventricular intracardiac mass and details the 3 key steps for XFM image preparation as performed by the MR technologist:
1. MR image acquisition.
2. Image processing.
3. Coregistration of processed MR imaging data with fluoroscopic x-ray.

Case Description A 60-year-old man with no symptoms but with a history of chronic lymphocytic leukemia, Leydig cell
cancer with metastases to the lung, and congestive heart failure presented for a follow-up echocardiogram. Seven years earlier, he received radiation and chemotherapy and was pronounced to be in cancer remission. The echocardiogram revealed a new echodense mass filling his right ventricular apex. The patient was referred to the MR department for initial tissue characterization of the mass to differentiate between tumor and thrombus. The MR scan confirmed a heterogeneous mass filling the right ventricular apex, measuring $45\, \text{mm} \times 24\, \text{mm}$ that enhanced with administration of gadolinium-based contrast, suggesting vascularity consistent with malignancy (see Figure 1). A subsequent positron emission tomography-computed tomography (PET-CT) scan revealed focal hypermetabolic activity conforming to the shape of the right ventricular mass, further suggesting malignancy.

A right ventricular biopsy using XFM guidance was performed in a combined interventional cardiovascular MR imaging and x-ray fluoroscopy suite (Aera 1.5T and Axiom Artis; Siemens Healthcare).

**Image Acquisition**

Six dermal fiducial markers (PinPoint; Beekley Medical) were placed on the patient’s chest at mid-sternum above the mammillary line, bilaterally on the chest wall at the intersection of the midaxillary and intermammillary lines, along the lower rib margin in plane with the mammillary lines bilaterally, and on the xiphoid process (see Figure 2). The MR technologist then performed the MR image planning examination with the following imaging protocol: 3-plane localizer, standard cardiac localizers, true fast imaging with steady-state free precession (FISP) cine imaging (2-chamber views of the left and right heart, 4-chamber view, and short axis view), and a 3-D fiducial marker localizer (see Table 1). Total MR imaging scan time was approximately 30 minutes. The patient then was transferred to the adjacent fluoroscopy suite using an intermodality transport system consisting of a dockable interventional table and transfer board (Combi Table, Siemens Healthcare). The patient was prepared for biopsy, which included sterile draping, ultrasonography-guided venous access, and right ventricular angiography.

**Figure 1.** True fast imaging with steady-state free precession (FISP), 4-chamber view, shows a right ventricular mass (arrow). Image courtesy of the authors.

**Figure 2.** Placement of the 6 fiducial markers on the chest for x-ray fused magnetic resonance imaging (XFM) preparation. Image courtesy of the authors.

**Image Processing**

While the patient was being prepped in the x-ray room, the MR technologist manually segmented the mass and right ventricular blood pool from the MR short axis images using Osirix Imaging Software (Pixmeo), an advanced open-source PACS and DICOM viewer. The resulting surface renderings were
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Table 1

<table>
<thead>
<tr>
<th>Magnetic Resonance Imaging Acquisition Protocol</th>
<th>Standard Cardiac Localizers</th>
<th>TrueFISP Cine</th>
<th>3-D Fiducial Marker Localizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetition time</td>
<td>335.90 ms</td>
<td>34.20 ms</td>
<td>2.6 ms</td>
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<tr>
<td>Echo time</td>
<td>1.09 ms</td>
<td>1.19 ms</td>
<td>0.98 ms</td>
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<td>Matrix (readout × phase)</td>
<td>450 × 394</td>
<td>360 × 270</td>
<td>400 × 270</td>
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<tr>
<td>Slice thickness</td>
<td>8.0 mm</td>
<td>8.0 mm</td>
<td>1.6 mm</td>
</tr>
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<td>Flip angle</td>
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<td>35°</td>
<td>17°</td>
</tr>
<tr>
<td>Parallel imaging</td>
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<td>N/A</td>
</tr>
<tr>
<td>Cardiac gating</td>
<td>N/A</td>
<td>retrospective gating</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Abbreviation: FISP, fast imaging with steady-state free precession; N/A, not applicable; ms, millisecond.

Imported into MeshLab (Visual Computing Lab), an open-source system for editing 3-D triangular meshes involving automated removal of duplicated vertices and filling of holes (see Figure 3). This software-dependent step was required to finalize the surface renderings for seamless import into MR Overlay (Siemens Corporate Research), a prototype coregistration program.

Figure 3. XFM preparation. A. Segmentation of mass (white) and right ventricular blood pool (blue) from short axis. B. 3-D surface rendering of right ventricle. C. 3-D surface rendering of mass (blue) within right ventricle (white) after filling of holes and removal of duplicated vertices. Images courtesy of the authors.

Image Coregistration

The 3-D fiducial marker localizer scan was imported into MR Overlay, and the fiducial markers from the MR imaging data set were matched to those on live anteroposterior and lateral fluoroscopic images for initial coregistration. For this study, a contrast-enhanced right ventricular angiogram was performed using a 7F Berman catheter (Arrow International) to fine tune coregistration. The finalized 3-D surface renderings were imported into MR Overlay, augmented to display in contrasting colors, and superimposed on the fluoroscopy images, thus serving as a road map for the interventional cardiologist performing the biopsy (see Figure 4).

The biplane x-ray fluoroscopy unit then was used in tandem with the overlaid MR images to perform the endomyocardial biopsy. Eight tissue specimens were obtained using a 7F biotome (Cordis Corporation) through a 7F introducer sheath. Total fluoroscopy time was 7.6 minutes, with a dose area product of 4000 mGy•m², and 60 mL of Iopamidol (Bracco) for x-ray angiography was used. Histopathology revealed malignant epithelioid cells with melanin pigment consistent with a diagnosis of metastatic melanoma. The patient was started on...
This case study adds to the literature related to x-ray fused with MR imaging by providing reproducible steps of XFM image preparation, including MR image acquisition, processing, and coregistration with fluoroscopy, and highlights the role of the MR technologist in performing these tasks.

With regard to coregistration techniques, our laboratory uses 2 independent methods (fiducial markers and angiography) to ensure optimal matching of cardiac contours from the MR and x-ray imaging data sets. Dermal fiducial markers can shift relative to anatomic structures within the torso. We trace all fiducial markers with a pen on the skin so they can be reapplied in the same position should they become displaced. Contrast-enhanced angiography of internal anatomic landmarks, such as the right ventricle, innominate vein, or aortic root, can serve as confirmation of the fiducial marker–based coregistration technique.

MR images currently are segmented at a single phase in the cardiorespiratory cycle, resulting in static surface renderings that are not a perfect fit to fluoroscopy. Second-generation software is under development to incorporate cardiorespiratory motion into these surface renderings. No special requirements for the patient to remain still or for the use of sedation for patient comfort are needed beyond those used in a traditional MR imaging examination or cardiac catheterization procedure. XFM guidance does not necessarily require a combined interventional cardiovascular MR imaging and x-ray fluoroscopy suite and can be performed with stand-alone MR imaging and cardiac catheterization suites provided the appropriate software is in place.

XFM is an innovative technique that has the potential to increase the accuracy of fluoroscopy-guided procedures by providing physician operators with visualization of critical soft-tissue structures. The MR technologist can play a key role in acquiring and processing the MR images, as well as coregistering them to the fluoroscopic images.

**Conclusion**

XFM provides the physician with high-resolution surface renderings of soft-tissue structures superimposed chemotherapy (dabrafenib and trametinib), and a 5-month follow-up transthoracic echocardiogram showed a 30% reduction in right ventricular mass size.

**Discussion**

In 2005, Ector et al first demonstrated the merging of cardiac MR images with biplane fluoroscopy to assist in catheter ablation in human patients. In 2006, our team applied XFM to guide preclinical transcatheter interventions, including direct antegrade crossing and delivery of a ventricular septal defect closure device, and to guide endomyocardial injections. In 2015, Grant et al reported the use of XFM guidance for closure of a left-ventricle-to-right-atrium shunt. The mature XFM system has since been used in clinical procedures, including bypass graft angiography, right ventricular free-wall mass biopsy, and iliac and femoral artery recanalization and stenting. XFM technology is not used widely, but with the increased attention being given to fusion technology and with further research and continued clinical application, it will become a standard imaging tool for challenging cardiovascular interventional procedures.

![Figure 4. XFM image registration. A. Anteroposterior fluoroscopic view of the heart. B. Right ventricular angiogram. C. Coregistration of surface renderings to contours of the heart during angiogram. Right ventricle (blue outline), mass (light blue). D. Surface renderings overlaid on live fluoroscopy during biopsy, after contrast washout. Images courtesy of the authors.](image)
on fluoroscopy. This case report illustrates the clinical use of XFM for endomyocardial biopsy of an apical right ventricular mass and provides a practical step-by-step description of MR imaging acquisition, processing, and coregistration with fluoroscopy.

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References


