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HOW TO

A comprehensive view on real-time magnetic resonance-guided flutter ablation image planes from an electrophysiological perspective

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Several centres have embarked on performing right atrial (RA) flutter ablations in the magnetic resonance imaging (MRI) scanner to pioneer real-time MRI-guided cardiac interventions [interventional cardiac MRI (iCMR)].[1] MRI offers not only a radiation-free environment, which is safer for patient and operator, but also provides excellent anatomical soft tissue contrast ideal for precise catheter navigation to the target ablation site.[2] Moreover, the unique ability for substrate imaging, direct ablation lesion assessment, and immediate imaging of complications offers the prospect to increase efficacy and safety of more complex electrophysiology (EP) procedures (i.e. ventricular tachycardia ablations) while potentially reducing the need for re-do procedures.[3]

Performing real-time MRI-guided flutter ablations requires a well-trained multidisciplinary iCMR team and a dedicated iCMR suite. The multidisciplinary iCMR staff includes an imaging cardiologist, cardiac interventionalist (i.e electrophysiologist), anaesthesiologist and safety officer. In addition, a dedicated CMR technician, EP technician, and the support of nurses are required. Importantly, the complete team involved in iCMR is much larger and includes also the cooperation of radiologists, MRI physicists, biomedical engineers, and medical instrumentation technologists.

A pre-existing standard diagnostic MRI scanner room can be transformed into an iCMR suite, though practical and technical challenges have to be overcome to ensure a safe setting for both patient and staff.[3] Dedicated MR compatible equipment including an EP recording system, EP catheters, haemodynamic monitoring system, displays for real-time viewing, wireless communication system, and anaesthetic instruments is mandatory to perform MRI-guided cardiac interventions safely. Performing MRI-guided cardiac interventions also requires adjustments in the control room. For instance, a non-MR compatible radiofrequency (RF) generator and additional monitors are positioned in the control room. A dedicated 3D navigation and electro-anatomical mapping system is required for active catheter tracking and integration of electrophysiological and spatial information with the real-time MR images. Finally, the complete iCMR infrastructure requires approval of hospital safety boards (i.e. infection prevention and electrical safety).

Prior to the ablation procedure, careful preparation of the patient outside the scanner room is necessary. After intubation and femoral vein cannulation, the patient is moved into the MRI scanner for the actual intervention procedure. CMR image planning, catheter positioning, and ablation typically takes 40–60 min. Thereafter, additional imaging can be performed to visualize and characterize the acute ablation lesions.[1]

During a MRI-guided RA flutter ablation, real-time-acquired anatomical (biplane) images are displayed in the MR-room, allowing the electrophysiologist to navigate the catheters.[2] In general, however, the electrophysiologist is not (yet) familiar with the standard orientations of CMR image planes. In contrast, the CMR technician mainly responsible for scanner setup and image planning, is not familiar with the standard fluoroscopy image orientations, as preferred by the electrophysiologist. This introduces a risk of miscommunication and hazardous disturbance during the iCMR procedure. Therefore, we provide a comprehensive overview on cardiac image planes as used in MRI catheter guidance for RA flutter ablations.

X-ray guided typical atrial flutter ablation procedures traditionally use a 45° to 60° left anterior oblique (LAO) and a 30° to 45° right anterior oblique (RAO) projection to visualize and navigate the coronary sinus (CS) catheter and RF ablation catheter. The target area for a typical RA flutter ablation is the cavotricuspid isthmus (CTI), situated between the electrically inert tricuspid valve and vena cava inferior (VCI).

X-ray visualized anatomy is limited to the heart contours (left and right in LAO-view, anterior and posterior in RAO view), the spine, and the diaphragm, which appear as shadows in the acquired image. The catheters may serve as additional landmarks for orientation on the VCI, RA and CS. The LAO projection generally shows the CS catheter situated inside the CS pointing in a 2 o'clock direction. The ablation catheter originating from the VCI is laying over the CTI, pointing at the viewer as illustrated in the *Figure 1* (*Panels A and B*).[4] The RAO projection best demonstrates the position of the ablation catheter in relation to the ablation trajectory on the CTI (*Panels D and E*).[4] These views correspond to the CMR planes as illustrated in panels C and F, respectively.

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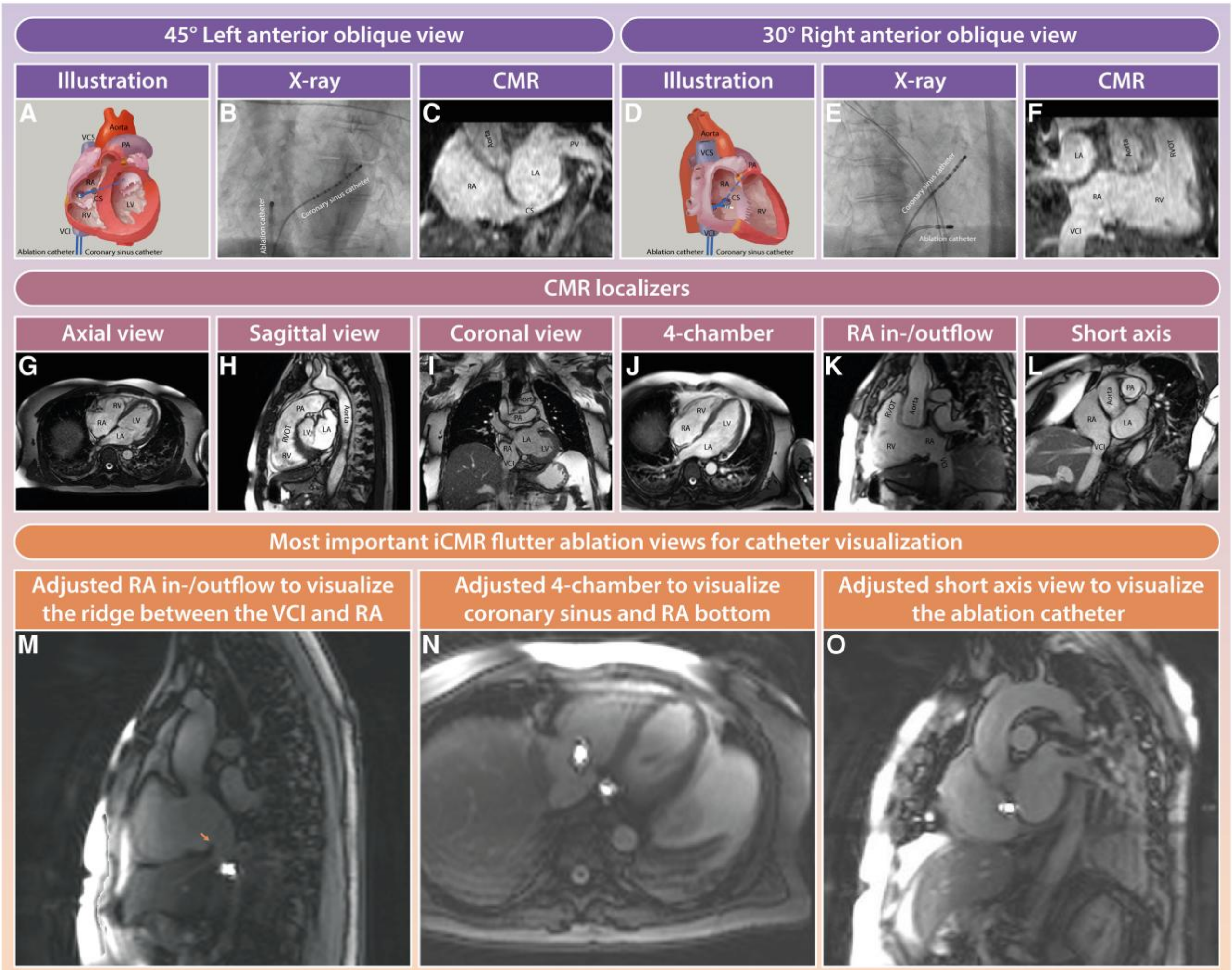

Figure 1 MRI-guided flutter ablation image planes. The top row illustrates the left anterior oblique view and RAO view (*A* and *D*) (*illustrations adopted and adjusted from Mayo Clinic Foundation; with permission*[5]), X-ray projections visualizing the catheters in the right atrium and CS (*B* and *E*), and matching cardiac magnetic resonance imaging (MRI) (*C* and *F*). In the middle row, MRI-guided flutter ablation localizer images can be appreciated. Essential iCMR right atrial flutter ablation views with catheters (the catheter tip has a high signal intensity) *in situ* are demonstrated in the bottom row. *M* shows an adjusted RA in-/outflow view with the catheter in the VCI. *N* shows an adjusted four-chamber view with the ablation catheter on the CTI and the CS catheter in the CS ostium. *O* shows an adjusted short axis view with the catheter positioned against the atrial septum.

Compared with X-ray, in which structures appear as translucent shadows in the image, CMR visualizes structures in a 2D opaque slice. Moreover, CMR is known to image planes adjusted to the patient-specific long axis and short axis of the heart. To visualize the gross cardiac anatomy in the thorax, so called localizers are acquired at the beginning of each CMR exam. These scans consist of multiple (a stack) low resolution still images acquired in standard axial (*Panel G*), sagittal (*Panel H*), and coronal (*Panel I*) orientations. These standard CMR localizers are used to plan procedure-specific views by perpendicular or orthogonal positioning of planes guided by distinct landmarks such as the tricuspid valve, the right ventricular apex, and the pulmonary valve.

Specific localizers for MRI-guided RA flutter ablations consist of a 4-chamber view (*Panel J*), RA in-/outflow view (*Panel K*), and a short axis view (*Panel L*). These views enable proper real-time catheter navigation during the flutter ablation procedure. As MR receiver coils are integrated into the tip of the catheters, the end of the catheter 'lightens up' on the MR images (illustrated in panels M, N and O).

The adjusted RA in-/outflow view (*Panel M*) is essential to visualize the ridge between the VCI and RA (see arrow). This ridge may hinder advancing catheters from the VCI towards the RA and hence, visualization of the height of this ridge can help the operator. Additionally, the steepness of the CTI trajectory and possible bulges and pouches can be observed. These CTI variations, in particular pouch depth, can result in difficult and prolonged ablation procedures. MRI-guided CTI ablation offers a tailor-made ablation approach adjusted to the patient-specific CTI trajectory.

After advancing the catheters into the RA, the CS catheter can be positioned in the CS ostium. Particularly useful for this manoeuver is the adjusted 4-chamber view (*Panel N*) visualizing the CS ostium and bottom of the RA. In addition, during the actual ablation procedure, the 4-chamber view can assist in visualizing the position of the ablation catheter on the CTI. Visualization of the atrial septum in the 4-chamber view and short axis view can help to avoid conduction system injury, which may occur when the CTI ablation is performed too close to the atrial septum.

The short axis view (*Panel O*) can visualize the transition of the RA to the tricuspid valve annulus, a region which is known to be a predilection area for reconnection after CTI ablation. In this view, the operator can also appreciate whether the ablation catheter is correctly positioned at the bottom of the RA. Moreover, the CS, coursing within the left atrioventricular groove, is observable in the short axis view and can show how far the CS catheter is positioned in the vein.

The acquired images, including the ablation-specific image planes, provide the electrophysiologist with a detailed roadmap prior to inserting the catheters and during the ablation procedure. Additionally, routinely performing real-time MRI-guided flutter ablation procedures with a multidisciplinary dedicated team will add to a safe and efficient iCMR workflow. MRI-guided flutter ablations are considered to be a first step towards more challenging MRI-guided ablation procedures. The lessons to be learned from these rather straightforward procedures are necessary for flawless clinical implementation of more complex MRI-guided procedures in future.

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Data availability

No new data were generated or analyzed in support of this research.

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