# Performing Image Registration at Massachusetts General Hospital with the CartoMerge™ Image Integration Software Module

*As more electrophysiologists use the CartoMerge™ Image Integration Software Module, they are refining the registration process to suit their particular techniques. This is one in a series of White Papers that have been prepared to share the experts' methods.*

Dr. Vivek Reddy, Director of the Experimental Cardiac Electrophysiology Laboratory at Massachusetts General Hospital in Boston, has performed several hundred procedures using the CartoMerge™ Module. His experience has given him insights for efficient use of this powerful tool.

Effective registration begins with a good CT or MR image, Dr. Reddy said. He asks the radiologist for images that extend from just above the arch of the aorta to just below the diaphragm, ensuring that all the Carto™ XP System points he acquires will have corresponding locations on the CT/MR image. During a mapping procedure, a patient's intake of breath is associated with a characteristic inferior motion of the catheter tip; for that reason, Carto™ XP System points are typically taken at end-expiration. Dr. Reddy asks the radiologist to provide a CT or MR image that is also acquired at end-expiration, at the level of functional residual volume, rather than the end-inspiration state often used for CT/MRI images. This precaution prevents a characteristic superior-inferior displacement of the left atrium relative to the aorta when image registration is attempted.

Dr. Reddy's basic registration procedure begins in the aorta if an end-expiration CT image is available and if the patient does not have atherosclerotic plaque in the aorta. He acquires Carto™ XP System points in the descending aorta, the arch, and sometimes the ascending aorta. "Taking points in the arch is critical for fixing the registration," Dr. Reddy noted. "If you acquire points only in the descending aorta, you still have rotation about the long axis of the descending aorta." He recommended acquiring points along both the bottom and top of the arch to fix it vertically as well as contact points contacting the left and right walls of the arch of the aorta to properly account for the rotation. He cautioned against acquiring electroanatomical points outside the boundaries of the CT/MR image, because these points will reduce the accuracy of the registration. After acquiring points in the aorta, Dr. Reddy creates three landmark pairs. He then performs Landmark Registration followed by Surface Registration.

After registering the aorta, Dr. Reddy takes between 20 and 40 points in the left atrium, superiorly, inferiorly, and on the posterior wall. He also takes a few points on the anterior wall, but notes that too many points in the anterior of the left atrium may cause volume-related errors. Next, Carto™ XP System points are taken at approximately 10 contact points in each pulmonary vein, using the tube pullback function for rapid acquisition of points. In the pulmonary veins, Dr. Reddy noted, the catheter should be touching the vein wall, which may require some torque. For example, he said, in the left superior pulmonary vein, the catheter may be torqued superiorly so it touches the superior aspect of the vein; in the left inferior pulmonary vein, the catheter is torqued so it touches the posterior aspect of the vein. However, too much torque might deflect the thin walls of the vein, causing anatomic distortion.

After Carto™ XP System points are acquired in the aorta, left atrium, and pulmonary veins, the left atrium can be registered, using the points from all of these structures. After registration, Dr. Reddy removes the aorta from the screen and drops the fill threshold for the electroanatomical map to almost zero. Now the shell is hidden and only the CT/MR image as well as the very small points of the electroanatomical map are visible.

"I used to have one screen showing the registered CT or MR image and another screen showing only the electroanatomical map," Dr. Reddy said. "I did that

so I could use both the familiar electroanatomical map and the new-technology CT/MR image to develop an understanding of the relationship between the two. I think that's a good approach in the beginning," he continued, "but after some time I stopped looking at the electroanatomical map. I'd rather use the screen space to view two orthogonal views of the registered image." The posterior view helps him identify where the catheter tip is along the posterior wall, particularly in the superior-inferior direction. The superior view helps him determine where the catheter tip is in the anterior-posterior direction. Dr. Reddy also uses an endoluminal view, in which a chamber is electronically dissected, to view the movement of the catheter tip inside the chamber.

Dr. Reddy emphasized the importance of obtaining unique, disparate points in all areas of the structure being registered, to avoid an erroneous local minimal solution. "The error analysis function in the CARTOMERGE™ Module will provide data saying that the average tip-to-surface distance is only 2 mm," he said, "While that may be true for the points you have taken, you may still have a local minimal solution that does not reflect the actual anatomy of the entire structure." Acquiring points in the aorta as well as in the left atrium prevents that problem, Dr. Reddy said. To complement the data provided by registration, he added, he and his colleagues use the external information provided by electrograms and the movement of the catheter. "We were using intracardiac ultrasound as well," he said, "but after some time we noticed that it was slowing us down, and we didn't really need it to assess the quality of the registration." One advantage of the CARTOMERGE™ Module, Dr. Reddy said, is that it allows him to avoid the exposure to radiation that fluoroscopy requires, reducing the risk for both himself, the medical staff, and the patient.

Before settling on the use of the aorta as a standard starting point for registration, Dr. Reddy and his colleagues tried other approaches. "Using the aorta for registration requires an arterial puncture using an 8-French sheath in the femoral artery, which you might not otherwise need," he pointed out. To avoid arterial puncture, they tried registration using the superior vena cava, the coronary sinus, the right atrium, and the pulmonary artery. Each of these approaches had disadvantages. For example, the superior vena cava and coronary sinus are both relatively thin-walled structures that are easily deformed. In the pulmonary artery, it's difficult to acquire CARTO™ XP System points on all of the walls so that the location of the left atrium and aorta can be fixed. These limitations add more time to the procedure, Dr. Reddy said. "The aorta is typically situated in between the pulmonary veins, close to the left atrium. Using the aorta for registration helps you avoid left-right movement errors that might increase the risk of pulmonary vein stenosis." In addition, he noted, the aorta usually contains contrast medium, facilitating visualization. "If you do a good job," Dr. Reddy said, "any structure can be used for registration. But in our experience, the aorta provides the quickest and best registration for making a useful map of the left atrium."

The CARTOMERGE™ Module is an effective guide to help electrophysiologists perform therapeutic procedures, Dr. Reddy said. "One of the nice things about the CARTOMERGE™ Module is that it is a relatively simple software algorithm that is easy to understand," he noted. Although it is simple, Dr. Reddy concluded, "As long as one is cognizant of the limitations of the software, and one understands that its accuracy is limited by the quality of the data provided by the operator, the CARTOMERGE™ Module is a powerful tool that works well."

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