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Roadmaps Show the Way: Coregistration to Enhance Structural Heart Interventions

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X-ray fluoroscopy is versatile but produces only 2-dimensional (2D) projections with limited soft-tissue detail. Several groups have augmented conventional 2D fluoroscopy with overlaid three-dimensional (3D) roadmaps. The goals are to reduce procedure time, radiation and contrast exposure, and to improve procedural success. While it makes intuitive sense that 3D roadmaps are valuable, unequivocal clinical benefit has yet to be proven. It is conceivable that the preparation of such roadmaps could actually result in increased radiation or contrast dose, or in some cases they could even be misleading and misguide an operator to cause an undesirable outcome.

In this issue of *CCI*, Martin Glöckler and colleagues report a retrospective of 78 pediatric interventional procedures enhanced by 3D roadmap overlays to answer the question: are 3D roadmaps useful? The chief findings are reassuring. The roadmaps were not misleading in any case. “Value” was rated as useful or better in 90% of cases, as not useful in 5%, and as “essential” in 4%. “Soft” measurements like value rating may not be compelling to payors or to skeptics, but ultimately may confer the most important professional assessment.

One important feature is the ability to rotate the 3D roadmap volume to determine optimal working projection angles. This helps to offset the additional radiation and contrast used by Glöckler for the rotational angiogram used to coregister CT or MRI volumes. In the Glöckler report, greater value was evident in the most complex geometric structures.

Readers should be aware of important technical considerations:

1. Cone-beam CT based on rotational angiography (“flat-detector CT”) is inferior to conventional CT in terms of spatial detail, motion artifact, and often radiation exposure. That said, same-session CT is intrinsically registered, and some soft tissue and 3D detail may be more valuable than none.

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2. 3D roadmaps are usually collapsed into 2D for fluoroscopy overlay, but the position of the roadmap in the projection dimension “through-the-screen” can not be depicted easily and can be confusing.
3. Debate remains on what constitutes a desirable roadmap. Is it a complete contrast CT or MR angiographic volume? [1] Or is it a computer-synthesized mesh depicting specific regions of interest? [2] Representative images of these two approaches are shown in Figure 1.
4. How will images be processed to create the road-maps? Automatic computer segmentation of 3D images may not always be sufficiently accurate. Indeed usually a member of the clinical team needs to extract meaningful roadmaps, but this takes time, effort, and skill. How does this fit into the workflow of a busy interventional lab?
5. What happens when the patient moves, causing the roadmaps to become misregistered? Can the team reregister the roadmaps?
6. What happens when rigid guidewires or other devices distort the target anatomy, after the roadmap is created? Must such roadmaps be obtained with rigid guidewires already in place, in order to be useful?
7. Worse, what happens when the target structures change during the case? If an unrecognized hematoma displaces a cardiac chamber, or if loading conditions change and the chamber shrinks or grows? In other words, operators must be mindful that roadmaps can become stale, outdated, and irrelevant. How do we plan for and respond to this?
8. MRI and X-ray use different contrast mechanisms, making “feature-based” coregistration (e.g., of bones) difficult. This is less of a challenge in contrast-enhanced MR angiography, where pictures of a vessel or cavity can be registered to angiograms or ventriculograms. But for roadmaps of a ventricular epicardium and endocardium, this may be more difficult, since bony landmarks may not be apparent.
9. How useful is a static roadmap overlying a continuously moving patient? Is it enough to correct for cardiac motion? Do we sometimes need also to correct for respiratory motion, or can we control the patients’ respiration? We and others have shown millimeter precision, faster procedures, and radiation reduction with only static roadmaps, but perceive value from correction of cardiac [3] and respiratory [4] motion. Proving this value is difficult.

Other roadmaps also may prove quite valuable, such as feature-based registration of CT roadmaps using perivalvular calcification or other landmarks for real-time image-based coregistration, to display a target for transcatheter aortic valve replacement (TAVR) deployment [5]. In the meantime, Glöckler and colleagues show the appeal of commercial solutions being rolled out that promise to simplify image guidance, reduce overall contrast administration, and reduce radiation exposure for complex pediatric and structural heart interventional procedures.

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Fig. 1.

A comparison of MRI roadmap methods. Left: regions of interest are manually extracted from MRI, coregistered using multimodality beads, and targets overlaid on live X-ray. In this case a membranous VSD is depicted to allow antegrade crossing, from Ratnayaka et al [2]. Right: Contrast-enhanced MR angiography is surface-rendered and overlaid on live X-ray (Courtesy of Yoav Dori, Children's Hospital of Philadelphia). These roadmaps are easier to prepare and confer more imaging detail at the expense of more complex images. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]