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EDITORIAL COMMENT

Display of 3D Multimodality Cardiac Images With 2D Polar Maps

Simplicity Can Be a Virtue*

Mark F. Smith, PhD, Vasken Dilsizian, MD

From painters to cartographers to medical imagers, humans have faced the challenge of depicting the 3-dimensional (3D) world using 2-dimensional (2D) displays. The transition from planar to tomographic imaging engendered various approaches to display the physiologic information contained in 3D single-photon emission computed tomography (SPECT) and positron emission tomography (PET) cardiac studies in 2D format. Recent developments of new display methods are because of conceptual advances, faster computer hardware, and improved software tools.

HISTORICAL PERSPECTIVE

The earliest display method for 3D tomographic nuclear medicine cardiac studies was transaxial slices in the scanner reference frame. Incremental steps forward were display of sagittal and coronal slices and interactive slice scrolling capability. The heart orientation is different for each patient and a major advance facilitating standardized clinical interpretation was routine reorientation to the short-axis reference frame (1), where short-axis slices have a doughnut appearance for perfusion studies and orthogonal slices are the vertical and horizontal long-axis slices.

The next important advance was the bull's eye or polar map display (2–5), which compactly shows radiotracer uptake. It is generated by tracing rays from the left ventricular axis through the myocardium and mapping the maximum amplitude along each ray. The apex is at the center and concentric rings contain amplitudes in short-axis slices from apex to base. The polar map has been widely adopted by clinicians and research scientists (6). Its usefulness was aided, oddly enough, by the relatively poor spatial resolution of nuclear cardiac images compared with the myocardial wall thickness: there is essentially just 1 independent amplitude value from each ray traced through the myocardium.

The polar map facilitated standardized quantitation and reporting of relative perfusion in the 3 main coronary artery vascular territories and in the 17 segments of the American Heart Association heart model (7). Its wide use was aided by development of easy to use software for cardiac reorientation and map generation. Polar maps became popular for display of cardiac attributes in addition to perfusion (8,9), including match/mismatch between rest and stress uptake or perfusion and metabolism (10), wall motion, myocardial blood flow, and flow reserve. Perhaps because of its simplicity and capability to display attributes of the entire heart, polar maps are used for other cardiac imaging modalities, including echocardiography and magnetic resonance imaging (7). The standard cardiac orientation in polar maps ensures regional co-registration for various modalities.

It was not inevitable that polar maps would become the predominant method for 2D display of cardiac attributes of the whole heart. In mapping a 3D curvilinear surface (e.g., endocardial/epicardial surface) to a flat 2D display, there are unavoidable distortions. With polar maps the basal parts of the heart have a relatively larger area (their ring diameter is greater) than mid-ventricular parts. If desired, "equal area" cardiac polar maps could be created as have equal area map projections of the earth (e.g., Mollweide, Lambert azimuthal equal-area). The area distortions of cardiac polar maps are not as severe as one might imagine because, at least through the mid-ventricular region, the diameter of the myocardium in short-axis slices increases with distance from the apex.

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From the Department of Diagnostic Radiology and Nuclear Medicine, University of Maryland School of Medicine, Baltimore, Maryland. Both authors have reported that they have no relationships relevant to the contents of this paper to disclose.

A significant advance in nuclear medicine cardiac display was 3D display using surface- and volume-rendering (11–14). The displays are not really 3D, but are 2D projections of a 3D image space with embedded 2D surfaces or semitranslucent 3D objects. The availability of fast 3D displays has been driven by advances in computer graphics (e.g., graphics processing units [GPUs]) for video gaming. Cardiac properties can be mapped to ventricular surfaces and can be examined by viewing the heart from different angles. Wall motion can be assessed from cine views of the surfaces from gated studies.

The next major display innovation was multimodality image fusion and 3D display of fused images. An example is fusion of SPECT amplitudes with cardiac vessel information from coronary computed tomography angiography (CTA). Color-coded SPECT intensities can be projected onto the myocardial surface derived from SPECT or computed tomography (CT) and the coronary vessels can be projected or overlaid onto this surface or otherwise transformed to the same reference frame to form a fused surface- or volume-rendered image (15,16). Overlay of vessels from coronary CTA enables ready assessment of the correlation between vessel anatomy and local cardiac function.

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A NEW APPROACH TO IMAGE FUSION OF PHYSIOLOGY AND ANATOMY IN NUCLEAR CARDIOLOGY

In this issue of *iJACC*, Nakahara et al. (17) present a new methodology for combining myocardial perfusion SPECT data with structural vessel anatomy derived from coronary CTA in a bull's eye (polar map) format. This is complementary to 3D display of fused perfusion and vessel anatomy. Viewing the entire heart using 3D visualization requires viewing rotated images or a rotating display, whereas a polar map permits inspection of the entire cardiac surface and the coronary anatomy in a single image. This comes at the expense of geometric distortions, although this has not hindered the use of polar maps in nuclear medicine. This new polar map method involves extracting a small strip from images generated by a commercial 3D fusion program as the heart is rotated, forming a rectangular panoramic image from these strips and applying a geometric transformation to bull's eye format. It is different from the approach of Kirişli et al. (18), where coronary vessels are projected onto a bull's eye plot of cardiac function. In both cases, however, cardiac function and anatomy are fused in a single image.

A LOOK TOWARD THE FUTURE

The desire to integrate and spatially correlate tissue attributes from multiple cardiac imaging modalities, such as echocardiography, SPECT/CT, PET/CT, and PET/magnetic resonance imaging will increase. Robust and simple to use tools for multimodality registration, correlation, and quantitative analysis are needed. One trend is display of multimodality cardiac information on the same 2D polar map (17,18). In our own laboratory we use polar maps for fused display of PET and SPECT perfusion and viability data with discrete voltage data from electroanatomic mapping (19–21). Advances in computer speed, graphics hardware, and software will enable faster and easier manipulations of pseudo-3D displays with multimodality image fusion. Devices for viewing 3D medical images with perception of depth, such as stereo viewers, varifocal mirrors, and head mounted displays (22), may eventually have a clinical role but will likely remain research tools for the near future.

CONCLUSIONS

The amount of data to consider in evaluating the heart is increasing. Simple 2D displays may be helpful for providing an overview of the whole heart and its regional features before viewing more complex displays. Simplicity can be a virtue and the polar map, with its capability to distill and display information in a compact manner, will remain an essential tool in the armamentarium of nuclear medicine physicians and scientists.

REPRINT REQUESTS AND CORRESPONDENCE: Dr. Mark F. Smith, Department of Diagnostic Radiology and Nuclear Medicine, University of Maryland School of Medicine, 22 South Greene Street, Baltimore, Maryland 21201. E-mail: msmith7@umm.edu.

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