Three- and Four-Dimensional Cardiovascular Ultrasound Imaging

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Among the clinical applications of ultrasound in medicine, echocardiography has evolved to become the most commonly used diagnostic method in cardiology. Multiple two-dimensional (2D) slices of the heart are obtained in order to fully assess the cardiac structures. This method however requires that the examiner performs a mental three-dimensional (3D) reconstruction of the heart to integrate 2D images recorded in various planes. Real 3D reconstruction should allow for direct visualization of the complex anatomy of the heart, thereby helping to assess various cardiac abnormalities, even for non-specialists.

Until recently attempts to obtain 3D images of the heart were hampered by the difficulty to record good quality images throughout several cardiac cycles with accurate spatial location and to account for respiration. In addition such methods were extremely labor-intensive, and display of 3D "images" were unsatisfactory.

We have used a recently developed program for 3D reconstruction of the heart (TomTec, Münich, Germany) based on images sequences acquired by transesophageal echocardiography with a commercially available ultrasound system (Hewlett-Packard, Andover, U.S.A.). Images of the heart were acquired from a fixed point using a transesophageal probe with a 5MHz phased-array rotating transducer at the tip, under ECG- and respiration-gating. Data of a complete cardiac cycle were recorded every 2° during a 180° computer-controlled rotational scan. They were transferred on-line to the computer and digitized. The procedure added only 3 to 5 min to the normal duration of a diagnostic transesophageal study.

3D reconstruction was then performed off-line. In the spatial region scanned by the ultrasound beam, backscatter intensity from each volume element (voxel) was determined to compute a gray scale volume. Within this volume, structures of interest could be displayed from any point. Image processing also allowed for four-dimensional echocardiography, i.e. dynamic display of the structures throughout the cardiac cycle, thereby providing a better sense of perspective and an assessment of the motion of cardiac structures.

Thus far, this approach has proven useful particularly for the localization of atrial and ventricular masses, as well as the assessment of valvular morphology and of ventricular function. Validation of measurement of cardiac cavity volumes, without the need for geometric assumptions as required for 2D echocardiography, is presently in progress.

In conclusion, 3D echocardiography now offers realistic display of cardiac anatomy and function, and has the potential for highly accurate quantitation of volume.