3D/4D Imaging: Technical Overview and Basic Methodology
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Technical Overview

Two main engineering solutions have been developed to allow integration of two-dimensional (2D) sectional images into 3D volume data: motorized acquisition and external electromagnetic position sensors. A simplified technique is the freehand acquisition of volumes without any reference to transducer position. In essence, this means that a cineloop of images is collated to form a volume dataset; because the system has no information on transducer position relative to the insonated tissues, measurements on volume data are impossible. Nevertheless, qualitative information may be obtained, and such systems have been used for clinical research in urogynecology.¹

However, quantitative evaluation of volumes requires information on transducer position at the time of acquisition. If probe movement is achieved with the help of a motor, its characteristics will determine imaging data coordinates. Motorized acquisition may take the shape of automatic withdrawal of an endocavitary probe or motor action within the transducer itself. The first such motorized probe was developed in 1974, and by 1987 transducers for clinical use were developed that allowed motorized acquisition of imaging data.² The first commercially available system platform, the Kretz Voluson, was developed around such a “fan scan” probe. Endocavitary probes make a freehand acquisition technique impractical, which is why the company did not develop this alternative approach further² and instead concentrated on a technology reminiscent of (otherwise obsolete) mechanical sector transducers. The results have been the abdominal and endovaginal probes used in systems such as the GE Kretz Voluson 730 series. The widespread acceptance of 3D ultrasound in obstetrics and gynecology was helped considerably by this development because these transducers do not require any movement relative to the investigated tissue during acquisition. Most of the major suppliers of ultrasound equipment have now developed their own transducers along such lines, although it is widely recognized that this technology will probably be replaced by matrix array transducers within the next five years. Such transducers are already available for echocardiography and small parts ultrasound.³
With current mechanical 3D transducers, automatic image acquisition is achieved by rapid oscillation of a group of elements within the transducer. This allows the registration of multiple sectional planes that can be integrated into a volume as the location of a given pixel (or, to use the correct term for a pixel that has a defined location in space, a “voxel”) is determined by transducer and insonation characteristics. Orientation within the volume is achieved by providing 2D image data in the three main axes of the volume, the “orthogonal planes” A (for our purposes, midsagittal), B (coronal), and C (axial or transverse) (see Figure 3.1).

Fortuitously, transducer characteristics on currently available systems for transabdominal use have been highly suitable for pelvic floor imaging. Acquisition is most conveniently performed with the main axis of the transducer in the midsagittal plane, because the urethra and bladder neck provide points of reference, ensuring symmetry. Provided this plane shows both the inferoposterior margin of the symphysis pubis and the pubovisceral muscle posterior to the anorectal junction, a single volume obtained

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**Figure 3.1.** The three orthogonal planes used to represent volume data information on translabial ultrasound, illustrated by transection of a popular fruit. The A plane (top left) represents the midsagittal plane, B (top right) the coronal, and C (bottom left) the axial or transverse plane. By convention, the bottom right field is generally used to show semitransparent, “rendered” representations of volume data. (Banana split images courtesy of Dr Shawn Choong, Melbourne.)