THREE-DIMMENSIONAL (3D) SCANNING

TRIDEMENZIONALNI (3D) ULTRAZVOK

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A fairly recently developed scanning method is the 3D scanning. In this mode the scanner automatically or semiautomatically collects ultrasound reflectivity data from a volume in the body (1). For simplicity this can be meant as a series of adjacent 2D scans stored in the computer memory. The thus collected 3D data can be displayed in various ways including very flexible section display at angles that are originally not visible as well as different rendering methods to convey the spatial impression.

It should be born in mind that the only thing that is really three-dimensional is the data on reflectivity, while, as long as we watch the images on a flat screen monitor, the images may be quasi-3D at best. However, there are extremely useful ways of using the 3D data without attempting to render the image quasi-three-dimensional.

Scanning in the third dimension in a rotational, sectorial or translational manner can collect a series of tomographic planes that incorporate a volume of interest. This can be done manually or automatically, depending on the type of the scanner. The density of the data, that can be thought of as the number of collected planes, depends on the scanner setting and the more planes are collected the better is the 3D reconstruction but the longer is the collection time. The basic limitation of the density of the collected 3D data is the ultrasound beam width and the quality of reception focussing, thus it is impossible to increase this density above the physical limit irrespective of the computation power of the built-in processors.

Available types of machines

The methods to collect the three dimensional data on reflectivity for B mode images or Doppler shift data for 3D study of blood vessels vary in hardware and software realisation as well as in price and simplicity of application.

Two main types of equipment for 3D display of vascular structures and reflectivity (B-mode morphological) data are currently available; i.e. add-on programs and scanners with dedicated hardware.

The first kind is a computer program without additional hardware. This kind of machine does not need to upgrade the hardware and does not relate to a complicated calculation of spatial information for each acquired 2D set of data. The data acquisition is free hand; i.e. the operator makes a sweep and thus collects the data in the third dimension. In this type of acquisition, the XY plane is fixed (and equal to the width of each single 2D view). However, the moving path and speed of the transducer in Z-axis is not defined. Therefore an accurate and reliable surface rendering of, say foetal face is almost impossible. It doesn't contain accurate positional information in Z-axis. Varying the manual movement of the probe over the same area will produce a different image.

The second kind of 3D machines operates with fully digitised processing of reflectivity for B-mode imaging or Doppler data for 3D blood vessel study, all that with full storage of the 3D data. In this type of acquisition one can think that each originally acquired 2D view contains its own positional information. Therefore the 3D reconstruction is more accurate. The data is acquired with mechanical 3D probes, matrix probes or a remote-positioning sensor linked to 2D probes. The mechanical 3D probe contains a normal 2D probe that is driven in the third dimension with a motor. During the 3D data acquisition, the mechanical 3D probe must be kept still. The relationships between acquired 2D planes are constant. The matrix probe can contain over a thousand independent transducers on its face so that it can steer the beam electronically in all directions as well as collect and focus reflection data from a three-dimensional block of tissue. On the other hand, the remote magnetic positioning sensor attaches to the conventional transducer, and provides spatial information for each of the captured 2D images. Here the moving of the transducer is free and accurate remote sensing of the conventional 2D-transducer movements fills in the third dimensional data. The result of such data collection can be processed in an offline graphic workstation.

The properties of these types of instruments are summarised in table 1.

Table 1. *The properties of instruments.*

Type	Advantage	Disadvantage
Free hand with add-on computer program	Low price, available for many scanners	Not for intracavitary applications, geometrically inaccurate, no real-time 3D
Free hand with remote position sensing	Light probe, needs little adaptation of routine practice	Experimental, presently not fit for intracavitary, no real-time 3D
Mechanical (motorised) third dimension movement	Accurate geometry, available transabdominal and intracavitary, broad choice of probes, possibility of real time 3D scanning	Mechanical parts require maintenance
2D matrix probe	Accurate geometry, no moving parts, possibility of real time 3D scanning	Still in development, only few probes available commercially

Most recently some machines collect these 3D data sets fast enough as to operate practically in real time. This real time 3D operation is sometimes, in commercial language, called 4D scanning (2).

Such operation can be achieved only with automatic mechanical or matrix probes that operate fast enough in the third dimension. At the present, the data collected with real time 3D have no advantage over static 3D in medical terms, but the 3D learning curve may be faster and new parameters like evaluation of foetal movements may herewith become possible as well as puncture or biopsy procedure guiding may become easier (2).

Differences of the types of displays for three-dimensional vascular images

With the simplest built-in program 3D vascular images are viewed as multi-sided objects with vascular or anatomic architecture mapped on multiple planes. The 3D multi-sided objects can be rotated horizontally.

On the other hand, with the fully digitised data with spatial information such rotation is possible around any axis.

There exist a number of ways to bring forward specific features of the scanned structure.

A minimum-intensity projection of vascular images is used for creation of translucent images, and a maximum-intensity projection is for surface-rendered vascular images. With free hand 3D compounding the operator must take care to move the transducer at a constant rate. The resulting image is quite good for visualisation of the 3D architecture (topology) of the vascularity, but not for distance or volume measurement or shape (e. g. face) study and evaluation. Fully digitised processing with spatial information allows more accurate 3D display. The operator needs to acquire technical knowledge and a sense for spatial orientation.

Safety

3D scanning has the potential to reduce exposition to ultrasound energy as well as to increase it depending on the operator education and attitude.

Knowledgeable operator can reduce the total energy deposition to the tissues by an order of magnitude. This mainly due to the fact that the stored 3D reflectivity data can be inspected off-line in any desired section of projection. This can seriously reduce the total insonation time both in echographic B mode and in Doppler studies. Particular care must be exercised in Doppler applications in pregnancy (3).

Conclusions

Humans are three-dimensional beings and it is a reasonable proposition to expect that 3D collection of ultrasound data will bring some real medical advantages. At the present real medical usefulness has been proven in obstetrics in detection of signs of early malformations (4), in neonatal scanning, (particularly brain) where the duration of actual insonation can be seriously reduced as well as in some of the vascular work where information on the distribution and form of blood vessels already yields useful diagnostic data. On the other hand there has been a growth of frivolous applications of 3D ultrasound, particularly in obstetrics, which should be discouraged.

The only way to prove or disprove medical usefulness of a method is using it in clinical practice when there is a theoretical hint of diagnostic profit. We can only encourage the application of the method as research tool in all fields (5) so that after serious studies the method will find its right place among other diagnostic tools and modalities.

References

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