3D and 4D Echo: Will It Replace 2D Echo Doppler?

Live 3D Echo Delivering Real-Time Benefits to Cardiologists

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INTRODUCTION

As cardiac ultrasound evolves from 2D to live 3D, the medical community is quickly realizing significant impacts on patient care and clinical management.

While the concept of 3D echocardiography is not new, its performance in a way that is clinically useful and on a fully-functional ultrasound system is new. Previously, dynamic cardiac 3D-rendered images were possible using an off-line process, by sequentially acquiring 2D images, outputting these images to disk or CD-ROM, and using a workstation to input the 2D images for Cartesian coordinate conversion. The result was a tedious, time-consuming process. Outside of a research setting, this cumbersome process proved costly in terms of productivity and the ability to provide quality patient care.

As clinicians sought methods to capture live 3D views of the heart to non-invasively view the complexities and inter-relationships of the heart, they discovered complex technological hurdles in achieving the extremely high frame rates required to capture the cardiac motion. Through extensive research and development of ways to capture these images in real-time, these challenges have now been addressed and Live 3D Echo, also referred to as real-time 3D echo, is a clinically viable option (Fig. 1 and 2). As a result, cardiologists are realizing improved pre- and post-surgical planning, improved measurement of heart function, decreased examination times, and enhanced patient communication.

CLINICAL IMPACTS

Cardiac imaging is highly beneficial in cardiac surgeons' pre- and post-surgical planning by giving clinicians a complete, accurate perspective of anatomical relationships and detecting abnormalities before surgery begins.

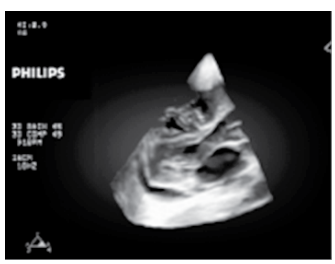

Fig. 1A

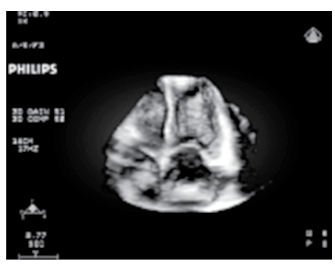

Fig. 1B

Fig. 1: Live 3D echo showing parasternal long axis (A) and apical 4-chamber views. The depth perception evident in these images cannot be provided by 2D echocardiography.

Ability to accurately locate cardiac abnormalities

One of the immediate impacts Live 3D Echo provides has been the ability of surgeons to get an accurate "surgical view" of the heart prior to surgery through the enhanced ability to identify and pinpoint the exact locations of abnormalities. Using 2D ultrasound, it was difficult to locate the exact area of abnormalities. Having this information in advance of surgery will save significant time since the surgeon will not find surprises during the operation and should not have to change course and make new decisions during surgery. This capability is a major advantage in accurately assessing valves, and detecting wall motion abnormalities and perfusion defects.

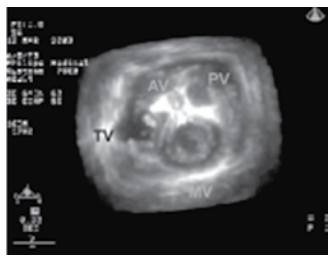

Fig. 2A

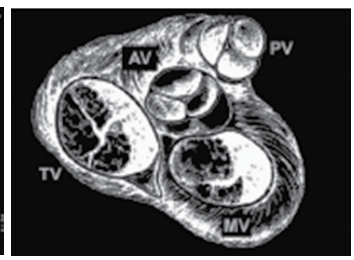

Fig. 2B

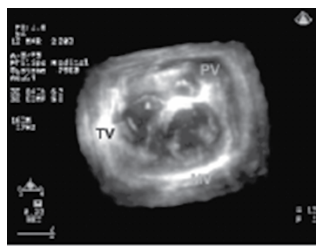

Fig. 2C

Fig. 2 : A. Live 3D echo simultaneously displaying all the four cardiac valves. This is not possible by 2D echocardiography. B. Anatomic schematic showing the relationship of the four cardiac valves. Note the striking resemblance of the live 3D echo image to actual anatomy. C. Another live 3D echo view showing the relationship of three cardiac valves. AV = aortic valve; MV = mitral valve; PV = pulmonary valve; TV = tricuspid valve. B is modified from Gray H: Anatomy of the Human Body (30th edition), Clemente CD (ed.) Baltimore: Williams & Wilkins 1985, p. 632 (illustration).

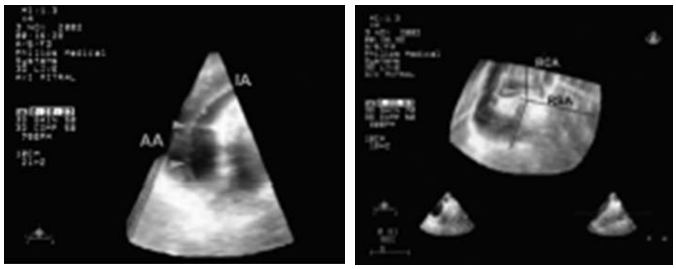

Fig. 3A Fig. 3B

Fig. 3 : Live 3D echo in aortic dissection. A. Arrowheads show the dissection flap involving the ascending aorta (AA) and the innominate artery (IA). Note the sheet-like appearance of the flap which differentiates it from an artifact and hence serves to make a definitive diagnosis of aortic dissection. Dissection flaps appear only as linear images on 2D echocardiography and hence are sometimes difficult to differentiate from an instrument artifact. B. The arrowhead points to the dissection flap in the same patient extending from the innominate artery into the right subclavian artery (RSA); both structures are viewed from top. RCA = right common carotid artery

An example of how Live 3D Echo aids in the pre-surgical process is in planning for mitral valve operations. Real-time 3D images show which portion of the mitral valve leaflet needs repairing. In our experience, Live 3D Echo has resulted in a very rapid diagnosis in patients with acute ascending aortic dissection and obviated the need for transesophageal echocardiography in some of them (Fig. 3). Safer and very rapid diagnosis is essential in this potentially fatal condition which needs immediate surgical attention and delays in making an accurate diagnosis result in poor patient outcome. Live 3D Echo has also helped in making the diagnosis of several congenital cardiac lesions which are difficult to detect by standard 2-D echocardiography (Fig. 4).

Improved cardiac quantification

Live 3D Echo improves spatial orientation and accesses critical views of the heart, aiding surgeons in the observation and quantification of size, shape, and volume of the heart. One of the most important methods in assessing heart function is measuring left ventricular volumes during the cardiac cycle. Since accuracy is critical in assessing and quantifying the condition of the heart, Live 3D Echo is a much better option than other imaging methods as it enables clinicians to measure without making geometric assumptions, which can prove costly.

In addition to pre-operative planning, Live 3D Echo is important in evaluating and monitoring surgical outcomes by performing real-time assessments of valves that have been repaired or replaced, helping to ensure a full patient recovery.

THERAPEUTIC APPLICATIONS

The broad-ranging uses of Live 3D Echo provide an exciting glimpse into the future of therapeutic applications – such as the ability to accurately deliver genes to re-grow myocardium and blood vessels. But, there are already a number of applications playing a key role in therapy.

Live 3D Echo is being used in the cardiac catheterization lab to provide real-time feedback as the procedure is being performed. For example, using the ultrasound, the interventionist is able to see exactly where a catheter needs to be placed for a right ventricular biopsy. Additionally, the technology can detect immediately whether any complications arise during the course of a procedure, which has been difficult to determine in the past using 2D technology.

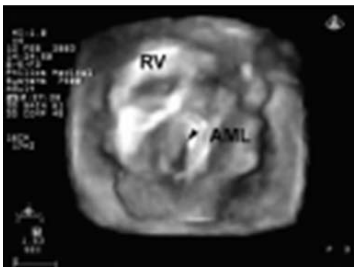

Fig. 4 : Live 3D echo in congenital cleft mitral valve. The arrowhead points to a cleft in the anterior mitral valve leaflet. RV = right ventricle.

Another area Live 3D Echo has proven effective is in monitoring the progress of a balloon mitral valvuloplasty procedure. The ability to monitor and carefully inspect the edges of the mitral valve for tearing is critical. Live 3D Echo provides immediate feedback should complications occur, which was considerably difficult using 2D echo because of the limited spatial orientation and lack of depth of the images.

Improvements in clinical management contributes to enhanced patient care

Live 3D Echo provides a significant impact on a clinic's operations. By speeding procedural time and implementing technology that both staff and patients understand will help improve patient throughput, training, patient communication and marketing.

Live 3D Echo contributes to improved clinical efficiencies by speeding up diagnostic and interventional procedural time. The ability to obtain more complete diagnostic information decreases time spent studying clinical information and provides a higher degree of confidence in those results.

The mobility of the ultrasound equipment also provides advantages. Ultrasound is simple and easily performed at the patient's bedside to help scan patients quicker and provide real-time results, thereby enhancing patient throughput and reducing wait times.

Training is another area of operations that will realize significant improvement and cost savings. Two-dimensional cardiac ultrasound required a steep learning curve, which made training time-consuming and expensive since it required visualizing the heart three-dimensionally in 2D pieces in order to understand the results. Live 3D Echo provides the ability to quickly view the heart as it really appears, instantaneously in 3D, which sharply reduces this learning curve, reduces training costs and time spent getting clinicians up to speed.

Live 3D Echo gives cardiac facilities an edge in today's competitive healthcare market. As patients become better educated and more interested in their own healthcare, they are becoming more selective about choosing a healthcare provider. While offering cutting-edge technology certainly isn't the deciding factor in a patient's decision-making, it certainly adds to a clinic's credentials when offering this technology. Patients seek knowledge, and the ability to deliver information that consumers understand

is becoming increasingly in demand as patients decide on a healthcare provider.

Two-dimensional ultrasound makes little sense to patients wanting to know and understand their own healthcare. The ability to show patients easily understandable 3D images of their hearts will make it easier for clinicians to explain these images to patients. This not only speeds time clinicians spend with patients but gives patients a higher level of comfort in what they are being told, as they will understand exactly what their healthcare provider is showing them.

CONCLUSION

New technology occasionally elicits skepticism as clinicians view anything that features bells and whistles as extras that are nice to have but not essential. Live 3D Echo is a significant new advancement in ultrasound that is changing the way cardiology is practiced from the clinic all the way to the operating room. As a result, Live 3D Echo is advancing the level of care provided to patients, which will ultimately have a positive impact on an institution's bottom line.