# Live Three-Dimensional Echo — A Major Incremental Step in the Develpoment of Cardiac Ultrasound

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"Live 3D Echo" is the latest development in three-dimensional ultrasound and is providing clinicians a new, and arguably much improved, view of the complexities and inter-relationships of cardiac anatomy non-invasively. Three-dimensional ultrasound has been available for several years to scan an ever-increasing array of body parts. Acquiring real-time 3D ultrasonic views of the heart has until very recently proven technologically beyond reach due to the rapid and constant motion of the heart. After the better part of two decades of research and development, we are now seeing the significant engineering feats that it took to overcome the and technological hurdles.

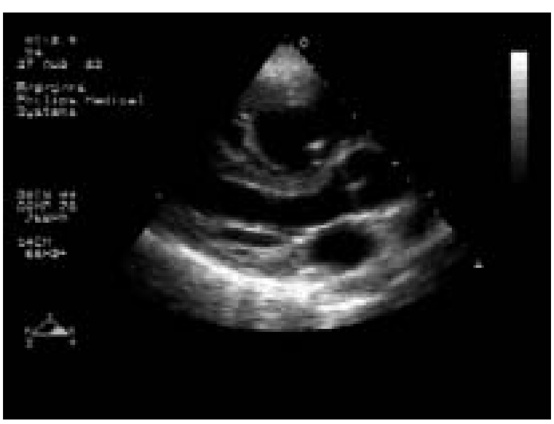
The recent unveiling of Live 3D cardiac echo by Philips Medical Systems is a significant technological breakthrough that is on the same level of change when cardiac ultrasound went from M-mode to 2D or when Color Doppler was first added to cardiac ultrasound. Live 3D cardiac echo has been made possible by the development of a transducer that can interpret the entire volume of the heart as opposed to one two-dimensional slice. This transducer has ~3000 elements as opposed to previous conventional transducers that had 128 (Figures 1-3). The significance of this advance is difficult for the casual observer to appreciate, but for those of us that have struggled with prior versions of non-Live 3D Echo for years, this is a major enlightenment. Live 3D Echo will have a profound impact in cardiac diagnosis in certain types of conditions.

It is a good bet that live 3D cardiac echo may move beyond the diagnostic realm and into the therapeutic. Administrators can expect these changes to impact clinical management, particularly by enhancing patient throughput, speeding training of sonographers, and even changing hiring practices.

### A Thirty Year Journey: Technological Hurdles

The idea of Live 3D Echo is not new, but performance of it in a manner that is clinically useful is. Three-dimensional echocardiography was first performed in the early 1970s, but the original equipment, as well as image quality, was rudimentary and certainly not real-time. The heart presents significant challenges to any type of three-dimensional imaging because of the combination of the cycles of the heart and the constant movement of the entire organ. One of the most

**Two-Dimensional Image**

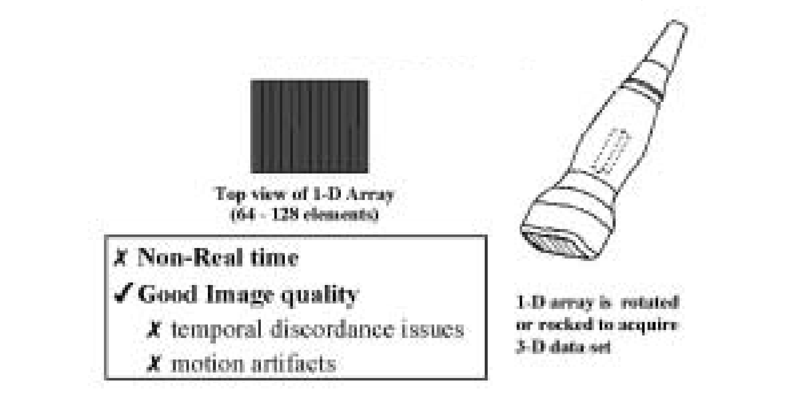


**Three-Dimensional Image**

significant challenges in developing Live 3D Echo has been the need to capture a large volume of data—inclusive of most or all of the heart—and be able to process the volume while it is moving. At the same time, the frame rate of the system, the number of pictures per second, must be adequate in order to resolve the definition of the heart as it moves.

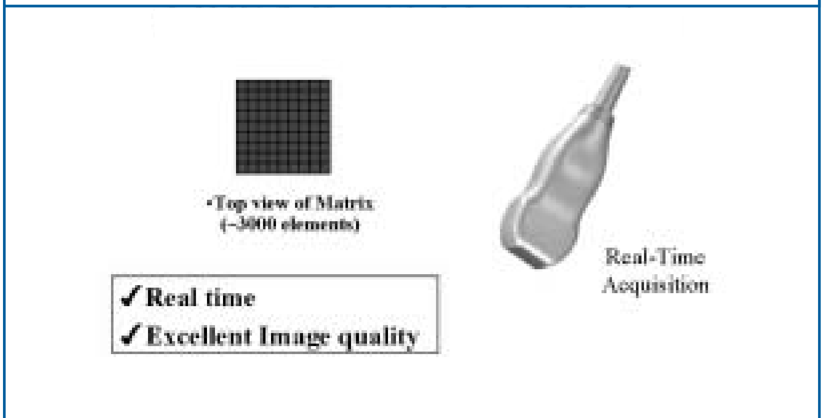
Before Live 3D Echo, clinicians did have the ability to view dynamic cardiac structures in three dimensions, but it was initially a very cumbersome process. The versions of 3D echo just prior to real-time 3D echo were more workable, but still were the compilation of multiple 2D images. For instance in the most recent version using transesophageal echo, developed jointly by Hewlett Packard and TomTec corporations, 61 2D images are obtained using the central axis of the TEE transducer as a point of reference. While the TEE probe is held fixed, the transducer internally rotates around this point of reference through 180 degrees, acquiring a 2D image every 3 degrees—hence 61 images. In order to synthesize all of these 2D images into one 3D image, the point of reference is used to synchronize all of the acquisition planes. All of the 61 2D images (each actually being one cardiac cycle, so actually each of the 61 cardiac cycles contains 10-18 images depending on the heart rate) are fed into a computer workstation. (Figures 4-6). Using an offline software program, the 2D images are rendered into a dynamic 3D image. The acquisition process takes a minimum of five minutes and the reconstruction or rendering process takes a minimum of 10-15 minutes. Hence, with “live” or real-time 3D, the ability to just turn a control on and see the heart in three-

**Figure 1. Gated Sequential Acquisition with 1-D Arrays**



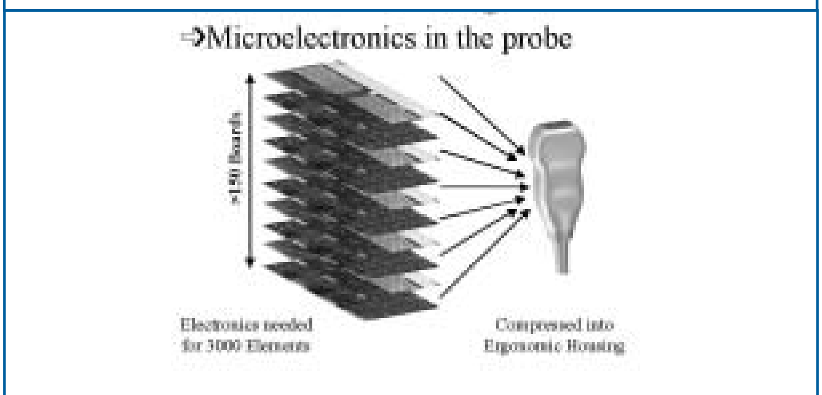

The rectangular box is a picture of the top view of a transducer - this is looking down at the elements (without a lens material on it), you would see a row of elements (slats). This is a 1D array - approx 64-128 elements. To gather the 3D data set - the probe is rocked or rotated and then the slices are put together (reconstructed) into the 3D volume set. It is not realtime and the IQ can be compromised due to motion artifacts and time alignment issues.

**Figure 2. Live 3-D with Matrix Probe**




With the Matrix - ALL elements are electically connected - We have access to full aperture giving us excellent IQ

**Figure 3. Matrix Array Advanced Technologies**




The 2nd biggest accomplishment and more significant is the Microelectronics in the probe. This slide shows how amazing this technology is. What the transducer team has successfully done is shrink the electronics from the system (over 150 front end boards) and packaged it into a transducer. See picture of multiple front end boards stacked up and then shrunk into probe housing - electrical and mechanical challenge.

dimensions, while it is moving, is a major step forward.

## Current, Essentially Immediate Impact

### Spatial location of abnormalities and Cardiac Surgery

Perhaps the most important contribution of Live 3D Echo is that it can identify and pinpoint cardiac abnormalities and show the depth of the abnormality. This is particularly important for surgeons since Live 3D Echo provides a "surgical view," that is the view that they will see when they open the heart. Surgeons have always been particularly fond of 3D technology. But Live 3D Echo allows the cardiac surgeon to plan the operation with potential complete knowledge of what will be seen. This should save significant time since the surgeon will not have any surprises at the time of the operation and therefore should not have to make new decisions about the course of the operation. This is particularly true for operations involving the mitral valve. The surgeon can see in a much more discrete way than ever before what the actual problem is with the valve leaflet can aid in determining whether the course of action should be valve replacement or repair. With regard to repair of the mitral valve, the surgeon can determine which division or "scallop" of the mitral valve is affected and tailor the operation accordingly. Live 3D is also very valuable in the post-operative and post-procedure follow-up.

### Improved Quantification

One of the most important measurements in cardiology today is measurement of the ejection fraction of the heart. A major criticism with two-dimensional echocardiography has always been the nature of left ventricular vol-

**Figure 4. Transeophageal 3D-Echo**

**Transeosophageal Multiplane Probe**

**Figure 5. 3D Acquisition**

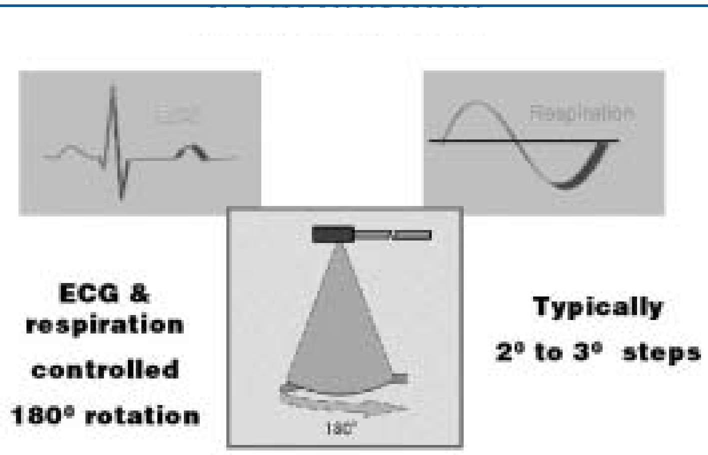
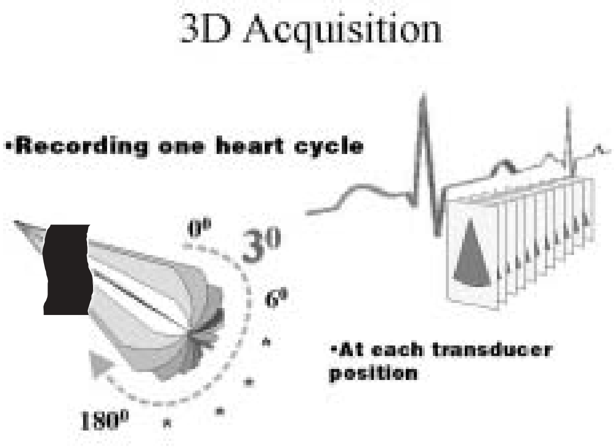



**Figure 6 3D Acquisition**



ume and ejection fraction calculations. These measurements require geometric assumptions of the left ventricle. These assumptions are most accurate in normal hearts and paradoxically are the least accurate in diseased hearts that are dilated and asymmetric, sometimes with aneurysm formation. For this type of heart, only true volume measurements made by a three-dimensional technique are accurate. While MRI was becoming the gold standard for such measurements, now similar accuracy will be attained by 3D echocardiography. Measurement of EF is now available with Live 3D Echo using offline TomTec software.

**Expansion to Therapeutic Applications**

Live 3D Echo is also moving from interventional to therapeutic applications. In the catheterization lab this technology provides the interventionalist feedback in real time as a procedure is being performed. For instance, this helps them to know exactly where a catheter needs to be placed during a right ventricular biopsy. Currently, right ventricular biopsies are performed under fluoroscopy and exact placement of the bioptome, the instrument used to pull out myocardial tissue, is not possible. Because of this, the bioptome often tracks naturally into a similar position. This is a problem for right ventricular biopsies performed on cardiac transplant patients for rejection monitoring because the area becomes scarred. Obtaining muscle tissue as opposed to just scar becomes difficult. With Live 3D Echo, the entire right ventricular cavity can be seen at once, a major advantage with regard to visualization of the discrete area where the biopsy will be taken. This allows an element of catheter location to the procedure never before experienced. That is, the operator can view all three planes simultaneously with regard to where the bioptome is. Although in the past, we have felt that echocardiography guided biopsy with 2D echo was safer than fluoroscopic guidance, the operator could only see where they were in terms of distance down the interventricular septum. With Live 3D Echo, the operator can see not only distance down the septum, but also how far anterior and posterior they are. Live 3D Echo can guide exact positioning into an area of the septum not previously biposied. This should make right ventricular biopsy safer and more likely to provide a diagnostic specimen.

This technology can also be used to monitor progress of a balloon mitral valvuloplasty procedure. In this procedure, careful inspection of the edges of the mitral valve for tearing is important. Hence, immediate feedback is available with live 3D if complications arise during a procedure. This was considerably more difficult with 2-D echo because of the limited spatial orientation and lack of depth with these images.

**Future Applications**

In the future, this technology may make possible other therapeutic procedures such as the accurate delivery of genes to regrow myocardium and blood vessels. For instance, in current animal trials, genes are packaged in contrast microbubbles and injected intravenously. When the bubbles arrive into the heart, the bubbles can be broken with ultrasound, releasing the gene product. Currently, the limitation of this technique is gene transfer into the cell. It is likely that as these problems are worked out by molecular biologists, live 3D will play a role in steering the genes into a precise area of the heart for local therapy. In a similar fashion, new cells with growth potential could be delivered to the heart by a tool similar to the bioptome used in right ventricular biopsy. The cells could be guided by Live 3D Echo to a scarred area caused by a heart attack (myocardial infarction) for the purpose of replenishing the scarred areas with functional cardiac muscle cells.

**Live 3D Echo: Impacting Hospital Operations**

The clinical efficiencies brought by Live 3D Echo will have a significant impact on operational efficiencies and practices. Enhancing throughput is perhaps the most notable, but there are other significant consequences such as more rapid training, changes in hiring practices, and efficiencies as a result of enhanced patient communication.

**Throughput and Mobility**

Beyond speeding up diagnostic and interventional procedures, the sheer mobility of ultrasound provides great advantages for enhancing patient throughput. While MRI and CT can create three-dimensional images, ultrasound is simple and can always be performed at the bedside to maintain patient flow. This is a tool that can be taken to the bedside and the heart can be rapidly imaged for catheter location or injection of contrast. While MRI scan time is measured in terms of the hours, ultrasound time is minutes. This is not only convenient for clinicians and patients but administrators will favor it as well since it takes a great deal of work out of transporting patients and waiting for these other modalities to become available.

Patients can be scanned more quickly since an entire volume of the heart is acquired in just a few beats and then viewed later. The clinician can then navigate through the volume of data containing the heart to find the structure(s) of interest.

## Training

Being able to see the whole heart simplifies the learning process for scanning because one is looking at the heart the way it really appears – rather than in slices. Clinicians will spend less time hunting for clinical information through slices of the heart than they had to with 2D echo, because the "hunt" will be shortened by the ability to locate a valve or vessel adjacent to the structure of interest. Echocardiographers who learned to view the heart the hard way will need to be retrained, but the learning curve should be rapid since they can now understand what they are seeing. Training inexperienced individuals should be even faster. This will bring the cost of training down as well as the time involved getting clinicians up to speed.

## Hiring Practices

There will be changes in hiring practices due to merging of diagnostic and interventional techniques. Although it is very difficult to have a crystal ball and see how this will actually unfold, it is very likely that cardiac sonographers will routinely be trained to interact in the cardiac catheterization laboratory to aid with therapeutic procedures. We are already seeing this change happen at the 2D echo level, specifically for helping the interventionalist perform percutaneous mitral valvuloplasty, right ventricular biopsy, and deploy atrial septal occluder devices. Live 3D Echo brings to the table significant advantages for aiding these procedures. In percuanteous mitral valvuloplasty, the balloon can be visualized as it is inflated across the mitral valve, helping guide the therapy and prevent complications.

## Patient Communication

Having images to show to patients is probably better than no images at all, but a regular 2D echo makes no sense to patients and that is disconcerting to those who are very concerned and interested in their own healthcare. In the past, I have spent an inordinate amount of time explaining 2D echo images to patients. With Live 3D Echo we will be able to show patients very understandable images of their hearts as we are scanning. This will save us a great deal of time and provide patients with a higher degree of comfort.

## Conclusion

Most new imaging technologies claim to provide very important improvements in the way a procedure or operation is performed. Live 3D Echo is the type of advance that comes along once a decade. The benefits are obvious from the very first viewing of the images. Real-time 3D echo is ultimately going to change the practice of cardiology from the clinic to the echo lab to the catheterization lab and the operating room. There is the potential for a new paradigm in how patients are managed. Most importantly, this is advancing the level of care we can provide to our patients, and this is the bottom line.