Summary
The primary role of echocardiography in clinical practice is to provide minimally invasive, cost-effective answers to the clinical questions of structure, function and risk. QLAB Advanced Quantification software helps to provide these answers by extending and complementing the extensive on-cart tools provided by Philips ultrasound systems. By automating many complex analysis tasks and allowing them to be performed on saved image sequences either on-cart or off-cart, QLAB offers many workflow advantages while minimizing operator dependence and improving reproducibility of investigations.

A key requirement for making automatic quantification more accurate and robust is the use of optimized image data containing high-quality, undistorted acoustic information. The continuing optimization of image quality and data integrity is a major priority for Philips product engineers, providing a high degree of synergy between data acquisition technologies and quantification tools.

This is perfectly exemplified by Philips’ development of PureWave crystal technology, one of the most significant breakthroughs in ultrasound acoustic technology in 40 years. The S5-1 transducer established PureWave technology as an industry benchmark for adult echo image quality. With the introduction of the new X7-2 transducer, the availability of Live 3D imaging for adult and pediatric populations provides wide-ranging possibilities for analysis of new structural and functional parameters. Moreover, the X7-2 transducer is the first to combine PureWave Crystal technology with 3D xMATRIX array technology, bringing the image quality advantages of improved clarity and detail resolution associated with PureWave technology to 3D imaging. This offers considerable benefit in the area of automated quantification and QLAB analysis.

Philips and QLAB address the key questions of structure, function and risk across a full spectrum of analysis methods in echocardiography, providing the choice of fast, reproducible, fully quantitative 2D and 3D echocardiography either off-cart or on-cart across the entire echocardiography product family. The range and system compatibility of QLAB on-cart and off-cart quantitative tools is summarized in Figure 1.

QLAB Workflow Advantages
QLAB software allows investigators to perform on-cart analysis either at the time of the study or at a later time. This flexibility is further enhanced by the ability to save and export all or any selected portion of the QLAB analysis screen. The resultant images/loops may be stored as single or multi-frame DICOM sequences thereby making advanced analysis data available for later review as part of the patient electronic record. The investigator may also choose to hide patient details before export.
File compatibility is another QLAB advantage with support for DICOM wrapped 'native' and compressed 'native' data (a data-rich format akin to raw or pre scan-converted data) as well as ZLIB compressed 3D and 4D and lossless JPG still frame data. DICOM wrapped native data offers the “best of both worlds” by providing rich proprietary content in a format suited to open architecture environments; files may be stored on third party PACS systems or archives, retrieved and analyzed without loss of content. The software is also compatible with multiple PC operating systems with the recent addition of Windows 2003.

QLAB exists as either a stand-alone version or specific QLAB applications can be added as plug-ins on iE33, iU22 or HD11 XE ultrasound systems, or directly to an Xcelera image management and reporting solution. The Xcelera scenario provides particular workflow advantages as advanced analysis tools can be launched directly from the routine reporting environment. Even as a stand-alone solution, QLAB offers its own DICOM SCP and can be easily networked with echocardiography systems for direct transfer of relevant study data. Philips echocardiography systems support multiple, concurrent archive configurations allowing routine study data to be sent to a standard PACS server while native data is selectively transferred to QLAB.

**IMT Plug-in**

*Background*

Atherosclerosis represents a significant healthcare burden in developed countries and is the leading cause of mortality in the USA. Because atherosclerosis typically provides clinical symptoms only when advanced, a growing number of clinicians now recognize the necessity to detect and treat pre-clinical presentation.
Clinical application
Three clear conclusions can be drawn from IMT literature:
1. There is a strong association with various risk factors for atherosclerosis.
2. Arterial wall thickening has a strong prognostic value for cardiovascular events, in particular stroke and myocardial infarction.
3. IMT allows convenient stratification of patients at risk for cardiovascular disease and has proven to be a good marker of the efficacy of antiatherogenic drugs.¹²

Application guidelines
On launching the IMT plug-in, a window is shown which requires you to select the side (right or left), vessel and location for labeling purposes. A 10 mm (resizable) window is then displayed which should be positioned over the far wall of the named carotid segment. The ROI should be rotated to achieve near-parallel alignment. If the vessel wall appears normal (i.e. < 0.7 mm), “Optimization A” should be used. If the vessel wall appears grossly abnormal in thickness (i.e. > 0.8 mm), “Optimization B” should be used. Storing a measurement provides reference to the appropriate image and ROI/trace coordinates so that the full study result may be recalled for future reference. Labelled measurements may also be added to the iE33 patient study report.

IMT findings may now be fully labeled for vessel and location and added to the iE33 patient study report.

Technology
Reproducible IMT data requires a robust, automatic measurement system. The QLAB IMT plug-in uses an intelligent algorithm which detects intima-media pixel pairs along each scan-line based on multiple criteria rather than simple image brightness gradients. By evaluating “pixel-pairs” along each scan-line within the chosen region of interest, the QLAB IMT plug-in provides a true “spatially averaged” measurement, which is less likely to be corrupted by random irregularities of the vessel wall. A contention point amongst IMT analysis systems is the definition of consistent ultrasonic criteria for the media-adventitia interface. Thanks to exhaustive validation against histology specimens and amongst observers, the QLAB IMT plug-in provides a highly robust approach for tissue boundary selection.

IMT findings may now be fully labeled for vessel and location and added to the iE33 patient study report.

The ultrasound presentation of arterial walls shows two echogenic lines separated by a hypoechoic space. The inner line represents the lumen-intimal interface and the outer line represents the medial-adventitial interface. Anatomical studies show that the distance between the two parallel lines represents the IMT.
Benefits
The ease and accuracy of computer-assisted IMT measurement makes it a useful marker of cardiovascular involvement in atherosclerosis. The QLAB IMT plug-in sets a new benchmark for this technique by providing a new standard for measurement.

Strain Quantification Plug-in

Background
Tissue Doppler velocity data can provide a useful method for assessing intra-ventricular, systolic dyssynchrony by comparing the time to systolic peak velocity between basal and mid segments in multiple apical views. TDI data may also be used to calculate strain and strain rate data which respectively measure intrinsic local deformation (shortening or thickening) and the rate of deformation. Assessing myocardial ischemia with Tissue Doppler velocity data can be problematic due to overall heart motion and tethering. Because they are derived from relative motion between two local samples, strain and strain rate data avoid issues associated with cardiac translation and passive motion or tethering of non-contracting segments.

Technology
In echocardiography, strain is defined as relative deformation of tissue where negative strain is shortening and positive strain is elongation. Strain rate is a measure of the rate of deformation and is based on the myocardial velocity gradient. The longitudinal velocity component \( v \) of every point in the muscle is available from TDI data, so the gradient can be estimated from any two points along the ultrasound beam as:

\[
\text{MVG} = \frac{v(r) - v(r + \Delta r)}{\Delta r}
\]

where \( r \) is the distance along the beam, and \( \Delta r \) is the small offset between the two points. This estimate of velocity gradient (MVG) is equivalent to strain rate. By using a sufficiently small offset, \( \Delta r \), it is possible to map the strain rate in segments over the whole myocardium throughout the heart cycle. QLAB provides the possibility to select strain rate offsets ranging from 0.25 to 3.0 cm. The QLAB SQ plug-in uses a flexible curved M-line approach for sampling the myocardium. Each M-line may be divided into multiple sub-regions, the size of which may be set to provide automatic one to one correspondence with the chosen strain rate sample size. The curved M-line approach also ensures that motion is sampled along the path of contraction thereby minimizing bias in velocity estimation.

Potential clinical application
Potential applications for the QLAB Strain Quantification plug-in include assistance in the detection of ischemia, evaluation of myocardial viability, evaluation and differentiation of LV hypertrophies and cardiomyopathies, and evaluation of diastolic function.

Ischemia can be readily identified in strain m-modes and X-Y traces by any of the following criteria: reduced peak negative strain, PSS (postsystolic shortening) or inverted (positive) strain (Figure 2). To assist in the precise identification of valve closure and opening time-points (as used when assessing PSS, for example) QLAB software supports the addition and overlay of phonocardiographic data traces. It also provides a convenient

\[\text{MVG} = \frac{v(r) - v(r + \Delta r)}{\Delta r}\]
interface for entering timing offset values (such as R wave to Aortic Valve Closure) measured from Doppler or m-mode traces. Upon entry of such values, appropriately labeled time-bars are automatically added to the X-Y results trace in QLAB (see Figure 3). Values for isovolumic contraction time, isovolumic relaxation time, ejection time and filling time are also calculated and displayed.

Application guidelines
The curved M-line sampling method is ideally suited to regional comparisons, of timing and function. In synchronization studies, time to peak systolic velocity can be easily displayed for as many sub-regions as required. For example Yu et al. recommended a 12-segment comparison of time to peak systolic velocity. This can be easily achieved by setting M-lines consisting of 2 sub-regions (basal and mid) on each wall (for example, septum and lateral) in each of the 3 apical views. Using this data, a systolic dyssynchrony index can be calculated from the standard deviation in time to peak velocities between the 12 segments.

QLAB allows fast on-cart or off-cart measurement of time to peak velocity from the X-Y display window. Discrete comparisons between any selected segments may be achieved by using a special ‘toggle’ control. Specific time intervals may be marked using a ‘click and drag’ caliper tool and the delta time values may be labeled in the results display (see Figure 4). The X-Y result display may also be zoomed and panned to allow more precise measurements and data comparisons.
Qualitative evaluation of contraction timing between all points on the myocardium can be achieved using the intuitive color M-mode display window (see Figure 5). This M-mode display may be hidden at any time to maximize screen area available for display of X-Y data. Both the color M-mode and X-Y display data may be averaged across multiple heart cycles for a temporally smoother presentation. Adaptive curve processing for all cardiac cycles is also available allowing three user selectable options for temporal smoothing.

The ability to change the M-line width provides flexible options for precise sampling of any sub-mural tissue path or trans-mural averaging for additional data smoothing. The M-line width may be preset to suit different scanning requirements (e.g. a narrow width is better suited to pediatric investigations) but may be changed to any width at any time by simply clicking and dragging.

Benefits
QLAB offers a highly flexible solution for TDI velocity, strain rate and strain quantification. Intelligent sampling combined with an intuitive data interface provides rapid access to data of high integrity and reproducibility. It is also an ideal tool for comparing different segments for intra-ventricular dyssynchrony.

ROI Plug-in

Background
A key goal of quantitative ultrasound is to infer physiologic characteristics of different regions of tissue. To achieve this, it is necessary to define regions of interest (ROI) for detailed analysis. This technique is known as densitometry. Unlike video densitometry and early attempts at analyzing digitized offline data, the QLAB ROI quantification works on digital ‘native’ data containing high-integrity acoustic information. One of the major applications for ROI analysis is analysis of contrast echocardiography. The increased sensitivity of the iE33 system for contrast echo applications places even greater emphasis on accurate quantification.

Technology

The QLAB ROI plug-in provides time-intensity curves (data sets) from multiple ROIs applied to triggered or real-time image cine segments. In the case of real-time sequences, QLAB supports retrospective gating – automatic selection of frames at a single point in each heart cycle – for analysis.

Contrast destruction-replenishment methods are used to obtain wash-in curves, showing the refilling of microbubbles after their destruction by an ultrasound pulse. These curves are fitted to mathematical models so that quantitative parameters relating to peak intensity (A) and refilling rate (B) can be extracted. The QLAB ROI plug-in provides automatic curve-fitting tools which apply the appropriate models to these replenishment sequences and extract the relevant parameters. Up to 10 curves may be displayed and fitted simultaneously.
Clinical research application
The use of contrast echocardiography for left ventricular opacification (LVO) provides enhanced endocardial border detection for more accurate assessment of left ventricular function, particularly in stress echo applications. Acoustic Densitometry and ROI analysis offers the potential to extend the role of contrast echocardiography into more quantitative realms.

Application guidelines
The QLAB ROI plug-in provides the facility to define a background frame so that initial curve values may be normalized to a zero value, thereby correcting for non-uniformity in residual contrast intensity. The position of each ROI may also be corrected on a multi-frame basis to allow for dynamic tracking over time. Quality control and reproducibility of data is further enhanced by the interaction and synchronization between respective display panes and analysis components – moving the mouse cursor over any x-y display curve results in an update of the current displayed image and ROI to the corresponding spatial and temporal position. Comparison of different data points is achieved by simply clicking two successive values, producing a “delta” result window while also displaying side-by-side images corresponding to the comparison image frames/ROIs.

Triggered 2D Echo images appear with a time stamp for the low MI images and the number of beats between trigger events for the high MI/Triggered images.

Benefits
The QLAB ROI plug-in offers an intuitive and robust package for detailed analysis of image characteristics and for rapid calculation of key parameters. The ROI plug-in also provides the capability for image data content analysis in gray scale echo, color Doppler velocities and Power/Angio modes.

Parametric Plug-in
Background
The spatial resolution of ROI densitometry is limited by the need for multiple ROIs to achieve global evaluation with acceptable spatial resolution. Adjusting multiple regions to follow a specific area of interest in the presence of cardiac translation is difficult and impractical, as each ROI must be independently corrected. The QLAB Parametric Quantification plug-in addresses this issue by providing detailed global characterization of each of the key contrast replenishment curve parameters (A=velocity, ß=intensity, A×ß =flow, and Goodness of Fit).

Technology
The Parametric Quantification algorithm analyzes image data on a kernel by kernel basis – where each kernel is comprised of a relatively small number of pixels determined according to operator preference for display smoothing. This data is plotted and curve-fitted according to replenishment curve-fit model: 
\[ y(t) = A(1-exp(-\beta t)) + C, \]
and a distribution of values is derived for each of the replenishment curve parameters. A relative color scale for each parameter is derived from this distribution and assigned to the image as an overlay. The replenishment curves for any image kernel are available for display and provide spatially precise quantitative data including A, ß, A×ß and normalized A expressed as a ratio to contrast intensity in the LV cavity.

Both triggered and real-time image sequences are supported. In the case of real-time sequences, the plug-in automatically locates the post-flash frame and groups the subsequent replenishment frames according to their position in the heart cycle. The resulting groups of frames each contain the replenishment sequence for a specific point in the cardiac cycle. Parametric images may be generated for each group and reconstituted into a parametric movie combining motion and replenishment data.
Application guidelines
Parametric Quantification provides a familiar global, scintigraphy-like display based on contrast replenishment curve data. The quality of this display is largely dependent on the correct definition of the myocardial boundaries. This can be achieved with relative ease using either the software-assisted myocardial template or the freehand spline method. Multi-frame correction for cardiac translation is also available. Even if the boundary is imperfectly defined and, for example, signals from the brighter LV cavity encroach on the region for interrogation, it is possible to discriminate meaningful data by referring to the “Goodness of Fit” image. The presence of a blue band around the area of possible encroachment clearly indicates that the background intensity levels are too high and that data in this zone should be regarded with caution.

When high MI/triggered images are analyzed, the number of beats between trigger events is displayed. This is a useful quality assurance aid to help ensure reproducibility and valid follow comparisons.

Benefits
Parametric Quantification offers superb levels of spatial discrimination as well as faster global interrogation compared with ROI methods for contrast analysis.

2DQ (2D Quantification) Plug-in
Background
With the introduction of QLAB, Philips extended the power of echocardiography by providing a dedicated “engine” for advanced quantification tasks such as ROI analysis, IMT analysis, Parametric Quantification and Strain Quantification. 2DQ adds another dimension to quantitative echocardiography, improving the speed and reproducibility of everyday analysis tasks while still providing the opportunity for retrospective analysis of stored image data. It achieves this via enhanced versions of existing Philips “benchmark” technologies such as Acoustic Quantification, Color Kinesis, xPlane and xPlane Stress Echo. The availability of both on-cart and off-cart versions provides a flexible workflow solution for all analysis tasks.

Technology
At the heart of 2DQ is a new algorithm for Semi-Automated Border Detection – the next generation of technology which combines the best of AQ (Acoustic Quantification) and ABD (Automatic Border Detection), providing new border tracking technology and significant performance enhancements over the original version. The new system classifies each pixel in the image as either blood or tissue, thereby identifying and tracking endocardial borders. It has two key advantages over the traditional AQ method:

• It does not have to be used at the time of scanning but can be applied to stored loops
• It offers a choice of two highly robust and reliable border tracking algorithms:
  – Complex Border – offering the familiar, highly detailed AQ boundary definition, or
  – Simple Border – which generates a more uniform border and Color Kinesis display, providing easier definition and detection of regional wall motion abnormalities.
In addition, the superb 2D image quality provided by PureWave crystal technology allows more precise tracking of blood/tissue interfaces, further enhancing the reliability of quantification. Enhanced Color Kinesis based on either Complex or Simple Border detection is also available. In addition to standard display of LV wall displacement, CK offers the possibility to view Mitral Annulus or A-V plane motion either selectively or combined with full LV analysis. A variable “transparency mode” is also available – providing visibility of underlying 2D data for quality assurance.

Clinical application
The key application for 2DQ is fast, reproducible analysis of LV volumes and ejection fractions. It is therefore a vital tool in the quest for truly objective assessment of global function. 2DQ provides a “waveform” presentation of data, showing changes in volume or area during ventricular or atrial contraction and relaxation. Other advanced parameters for LV systolic and diastolic function, including Fractional Area Change (FAC), Peak Ejection Change and Peak Rapid Filling Rate may also be displayed.

Enhanced Color Kinesis provides additional information relating to global and regional wall motion, showing unique color-coded time bands representing sequential stages of contraction. It is of particular value in stress echocardiography analysis and may be readily combined with LVO contrast studies. In addition there may be value in detecting late contracting segments in patients with conduction abnormalities that are undergoing CRT.

Application guidelines
Although highly robust, 2DQ semi-automated border detection also offers the possibility for operator override via an intuitive “force field” border editing system. Positioning the cursor close to the border allows selection of specific edit points while moving it farther away makes it possible to “pick-up” larger segments for re-positioning. 2DQ also supports Live xPlane quantification, allowing fast generation of LV ejection fraction and timevolume graphs based on Simpson’s bi-plane method of discs.
The intuitive 2DQ user interface offers numerous workflow advantages. Of particular value in routine and stress echo is the guided control system, which highlights appropriate task buttons according to a logical checklist beginning with 2D view selection. Having selected the required view, the appropriate steps are sequentially highlighted from left to right, thereby prompting the user to perform such tasks as positioning the ROI, adjusting TGC and LGC, selecting AQ or CK, and launching study waveforms or the full data report.

Benefits
2DQ extends the established 2D quantification engine of QLAB, providing the choice of an integrated or offline system for intuitive, robust, automated and rapid assessment of global and regional LV function.

3D Viewing and Manipulation
Philips has revolutionized echocardiography with Live 3D and Live xPlane imaging. Cardiologists can now interrogate the entire heart using a single volume containing any 2D plane as well as achieving the surgeon’s viewpoint to obtain unique real-time 3D views of anatomy and function. To extend the power of these capabilities, QLAB offers a convenient on-cart or off-cart environment for viewing, manipulation and cropping of 3D datasets. Its user interface is highly intuitive, closely matching the controls on the iE33 system to minimize additional user training needs. As well as the familiar controls for 3D visualization, QLAB offers unique 3DQ capabilities such as MPR (multiplanar reconstruction) for viewing, cropping and rotation of volumes. Support has also been added for new vision settings as well as a high-resolution native data format to allow better appreciation of depth and enhanced visualization of anatomic structures. These settings allow exceptional detail particularly when viewing studies acquired with the new X7-2 xMATRIX transducer.

3DQ (3D Quantification) Plug-in
Background
One of the greatest advantages of 3D data is the potential to derive new and more accurate quantitative parameters. The growing number of chronic heart failure (CHF) and valve disease patients demands objective data that can be tied to prognostic outcomes. 3DQ allows users to fully exploit the extra clinical information provided by xMATRIX technology, providing faster and more accurate measurement of 2D volumes, areas and distances. Moreover, 3DQ helps fulfill one of the key promises of 3D ultrasound by reducing the need for time spent at the ultrasound scanner analyzing and measuring acquired study data. By allowing the acquisition of all required measurement planes in a single volume, the “one view” echo concept is now a reality, providing advantages in both workflow and clinical accuracy.

Technology
One of the major drawbacks in the use of 2D data for analysis of LV size and function is the limited access to correctly aligned planes for single or bi-plane methods of analysis. Philips Live 3D Echo allows rapid acquisition of all relevant data in a single volume data set, which can be exported directly to an Xcelera server or to a stand-alone PC running QLAB. This data may then be viewed as orthogonal slices using MPR mode. These MPR views can be used for distance and area measurements as well as analysis of volume and LV mass.
Clinical application

The determination of ejection fraction is more accurate with 3D methods because it allows access to any plane within a 3D data set thereby avoiding some of the geometric problems commonly associated with conventional 2D ejection fractions, such as apical foreshortening. 3DQ’s MPR view provides a perfect solution for such issues, offering an intuitive interface for performing LV volume studies using either a multi-format display or selected full-screen views of any plane for enhanced measurement accuracy. It also offers a unique approach for regional comparisons of wall motion in the form of parallel MPR, which produces an MRI-like display giving new views that are not available with conventional ultrasound. The heart is presented as a set of moving serial slices allowing the user to “scroll” or “scan” through chambers for an intuitive “3D bull’s eye” impression of function.

Application guidelines

MPR mode provides the opportunity to toggle between a multi-format view and a full-screen view of each orthogonal plane. Adjusting each plane helps ensure finding non-foreshortened dimensions for each apical LV view used in volume measurements. An intuitive “3 click” LV border template is then available with the option to define an additional epicardial border for LV mass calculations. Manual correction is available by selecting single or multiple border points and repositioning them using an intuitive “force-field” click and drag editing system. A simple multi-click polygon border tool is also available if preferred for unusually shaped ventricles.

Benefits

3DQ extends the established 2D quantification engine of QLAB, providing a powerful and flexible solution for achieving the full promise of quantitative echo – the choice of fast, reproducible, fully quantitative 3D data either on-cart or off-cart. LV measurements based on a full 3D data set ensure much better reproducibility of data and, in particular, increased likelihood of locating optimal intersecting planes for LV mass, volume and ejection fraction studies. 3D cardiac analysis methods based on MRI, CT and nuclear imaging have been used in numerous studies to examine the relationship between 3D shape deformation and heart malfunction. There is particular interest in such techniques for the investigation of post-MI LV remodeling. 3DQ offers a fast, non-invasive alternative to these methods, which has been validated against MRI in published peer review journals.
3DQ Advanced Quantification Plug-in

Background
The 3DQ Advanced plug-in has revolutionized echo quantification and extended the diagnostic power of Live 3D echocardiography by providing the first fast, semi-automated, on-cart or off-cart analysis of true LV volumes — using all of the voxels to generate a dynamic 3D surface mesh. This is a true 3D shell with higher accuracy and less dependency on LV shape assumptions than conventional methods, which rely on interpolation and analysis of sparsely acquired 2D views. 3D True Volume Quantification provides more accurate LV volume and ejection fraction assessment by significantly reducing the problem of apical foreshortening and removing many of the geometric assumptions associated with volume assessment. 6,7

By providing tools for accurate LV segmentation and analysis of regional time-volume curves, 3DQ Advanced has helped establish Live 3D Echo as an important adjunctive technique for selection and monitoring of heart failure patients for cardiac resynchronization therapy (CRT). 3DQ Advanced analysis offers the unique advantage of combining mechanical dyssynchrony data with global and regional function and excursion data for comprehensive heart failure assessment. 1,2,8

Technology
3D volume analysis is typically performed by reconstructing volumes from “sparse” views or multiple 2D slices. Now, thanks to advanced parallel processing technology and sophisticated, proprietary algorithms from Philips, 3DQ Advanced allows rapid generation of a full 3D wire-mesh endocardial volume with minimal operator intervention. A full, moving endocardial border can now be achieved either on-cart or off-cart in less than one minute. Advanced physics-based modeling plus 3D pattern matching which tracks the mitral annulus and apex over time provides an “active object” motion presentation of the dynamic 3D shape. This allows 3D borders for the endocardial space in each frame to be combined into a smooth, beating volume, providing excellent spatial and temporal detail.

One of the main drawbacks of motion detection analysis techniques is the problem of overall cardiac translational motion by subtracting the velocity of each floating centroid from the estimated overall velocity. Left ventricular segmentation is performed in accordance with the standards defined by the American Heart Association Writing Group on Myocardial Segmentation and Registration for Cardiac Imaging and the ASE 17-segment model. This allows valid regional comparisons with other 3D imaging modalities. 11

Clinical application
It is possible with 3DQ Advanced to display global or regional volume waveforms, color coded against a segmented LV shell. An interactive bull’s eye segmental display and 3D orientation markers including septum, lateral, anterior, inferior (SALI) anatomic reference labels on the mitral ring, allow easy identification and selection of segments for analysis. The global and segmental waveforms provide highly accurate data for assessing function based on LV volume, ejection fraction, regional volumes and timing.

Segmental time-volume waveforms provide a technique for evaluating the synchronization of mechanical contraction. This approach has been evaluated as a new method for selecting heart failure patients who will respond favorably to CRT. 1,2,6,7 CRT involves atrial-synchronized, bi-ventricular or LV pacing as a therapeutic option for patients with advanced chronic heart failure and prolonged QRS complexes. It provides improved hemodynamics and increased exercise tolerance and quality of life. However, not all heart failure patients will benefit from CRT and the use of traditional criteria such as QRS width for patient selection has been shown to have relatively poor predictive value.
New evidence is emerging that mechanical intraventricular dyssynchrony provides a potential independent predictor of patient response. This mechanical evidence can be readily obtained by determining the time to minimum systolic volume (TMSV) for each segmental waveform and analyzing the dispersion in these values. The wider the dispersion or standard deviation of TMSV values, the greater the degree of mechanical dyssynchrony. The standard deviation of TMSV values has been referred to in research literature as the SD Index.

3DQ Advanced analysis offers numerous tools to assist in analysis of mechanical dyssynchrony. For qualitative assessment quick reference arrows are automatically displayed on each time-volume curve to indicate the minimum systolic volume. For quantitative assessment the SD index is calculated automatically based on a 16, 12 or 6 segment model. The user may also select a specific collection of segments for analysis. The software also calculates the maximum difference between any two segments.

Qualitative assessment of 3D wall motion is further enhanced by the availability of special viewing modes such as iSlice, which presents the moving LV walls as 9 serial slices or short axis views. This provides an accurate and intuitive approach for global assessment of comparative wall motion. Other viewing options include the Slice Plane view which shows a beating LV surface mesh within the 3 orthogonal axis planes and ‘Show Reference Mesh’ which retains an end-diastolic surface mesh against which subsequent wall motion may be compared.

Segmental time-volume waveforms may be displayed as absolute value curves or as relative volumes normalized for end-diastole. This allows easier direct comparison of relative motion. SD index and MaxDiff results may be expressed either as absolute (time) values or as relative values (% or R-R interval) to correct for heart rate. This allows more accurate serial comparisons when patients present with different heart rates.

The key benefits of real-time 3D echo in quantifying mechanical dyssynchrony are as follows:

- It takes all myocardial segments into account, by examining the composite mechanical effect of radial, circumferential and longitudinal contraction.
- The standard deviation of times to peak segmental contraction based on 3D regional volumetric analysis is reproducible with a variability of less than 10%.
- This methodology is effective in patients with both normal LV systolic function and those with varying degrees of systolic dysfunction while sensitive to changes associated with differences in LV systolic function.
Studies are currently underway to define normal ranges in 3DQ Advanced. 3D evaluation of segmental timing and function can therefore offer a valuable tool in the potential selection, optimization and monitoring of patients undergoing bi-ventricular pacing.

3DQ Advanced also offers new parametric displays for enhanced quantitative and qualitative assessment of ischemia (excursion display) and dyssynchrony (timing display). The excursion map provides a color coded presentation of excursion amplitudes as well as quantitative values for maximum, minimum, mean and standard deviation excursion. Darker areas provide rapid confirmation of reduced contractile function. Red areas may also reveal dyskinesia.

The timing display allows assessment of both early and delayed contraction. Areas which represent early outliers in the distribution of TMSV values are coded in progressively lighter shades of blue and areas which are late are coded in red – orange – yellow.

Application guidelines
With 3DQ Advanced, it is possible to get an assumption-free 3D volume over time with the same number of clicks as a conventional analysis for biplane volumes. Thanks to an intuitive interface requiring minimal operator intervention and very fast processing speed, an entire moving 3D endocardial border can be generated online in less than one minute. Although highly robust, it is possible to use an editing mode to ensure optimal border definition on end-diastolic and end-systolic frames before launching the sequence analysis for temporal analysis and deformation throughout the remainder of the heart cycle.

For investigations of unusually-shaped ventricles or of chambers other than the left ventricle, a manual editing mode is now available which allows highly flexible definition/adjustment of borders for surface rendering. This may be selected in the plug-in preferences menu.

On the parametric reporting page, a slider control may be set against any point in the range of excursion values for timing comparisons. For example, it is possible to set the threshold so that only areas exceeding a minimum excursion value will be included in the display. This is a convenient way to disallow non-contributing or ischemic regions from the analysis.

Benefits
3DQ Advanced redefines quantitative echocardiography and fulfills the promise of Live 3D Echo – offering fast, robust online analysis and waveform display of true 3D volumes for global and regional function and timing studies, either on-cart or off-cart.
References


2. Hong TE, Lang RM, Sugeng L, Weinert L, Mor-Avi V, Desai AD, Burke MC, Kim S, Salem Y, Knight BP. The use of real-time three dimensional echocardiography to quantify ventricular dyssynchrony and the response to cardiac resynchronization pacing therapy. Submitted to JACC.


Philips Medical Systems is part of
Royal Philips Electronics

Interested?
Would you like to know more about our imaginative products? Please do not hesitate to contact us.
We would be glad to hear from you.

On the web
www.medical.philips.com

Via email
medical@philips.com

By fax
+31 40 27 64 887

By mail
Philips Medical Systems
Global Information Center
P.O. Box 1168
5602 BD Eindhoven
The Netherlands

By phone
Asia
Tel: +852 2821 5888

Europe, Middle East, Africa
Tel: +49 7031 463 2254

Latin America
Tel: +1 954 628 1000

North America
Tel: +800 285 5585

© 2006 Koninklijke Philips Electronics N.V.
All rights are reserved.

Philips Medical Systems Nederland B.V. reserves the right to make changes in specifications and/or to discontinue any product at any time without notice or obligation and will not be liable for any consequences resulting from the use of this publication.