Contrast echocardiography has been specifically used for image definition and perfusion studies. Efforts were subsequently made to quantitatively analyse regional myocardial performance. In late 1992, the first software and prototype of colour Doppler velocity display of the myocardial wall dynamics was developed. To date, tissue Doppler imaging is available in routine echo-lab for assessing regional systolic and diastolic function. To overcome the limitations of tissue Doppler derived myocardial velocities, companies have introduced many breakthrough quantitative ultrasound tools based on leading-edge technologies, such as speckle tracking of myocardial deformation. Advances in microprocessor technology and computational power and the development of new matrix transducers using dense arrays have recently provided the potential for real-time, 3/4 D imaging. The concept of miniaturisation has made possible to provide echocardiography anywhere or to perform echocardiograms for imaging the heart of small animals as mice and rats.

**Tissue Doppler imaging and 2D speckle tracking**

Evaluation of left ventricular function is an essential part of all echocardiographic examinations [2]. Tissue Doppler imaging (velocity, strain) was introduced to provide precise quantitative measurement of regional wall motion and function.

Tissue Doppler uses the same principles as blood flow Doppler imaging, applying standard auto-correlation processing but reversing high velocity and low amplitude filters such that the high amplitude/low velocity motion of tissue is displayed in preference to blood flow (Figure 1). Applications include studies of regional systolic and diastolic function as well the timing of regional contraction. However, Doppler-only-based techniques are limited due to angle dependence of the signal [3]. As a result, certain myocardial areas are excluded. To overcome such a limitation, companies have created new software that allows the analysis of myocardial deformation through tracking of “natural acoustic markers” for frame-to-frame within the cardiac cycle.
This approach uses common gray scale images and provides information regarding the three components of myocardial deformation (radial, longitudinal, circumferential). It is angle independent. The main limitation relates to image quality. As with MRI tagging, this technique could display bull’s-eye parametric images of the peak systolic deformation. 2D-speckle tracking is probably the most exciting development in cardiac ultrasound for the evaluation of ventricular function in years (Figure 2).

It has now gained growing acceptance as a clinical tool particularly in the setting of ischaemic heart disease, stress echocardiography, diastolic function analysis, cardiomyopathy, and cardiac resynchronisation imaging [6-7]. It provides the unique opportunity to deeply examine the cardiac torsion and the twisting heart movement. 2D strain may thus be used as an alternative to MRI in the measurement of LV torsion. Efforts of engineers to miniaturise the probes has made possible to imaging small animals' heart. New technologies can also be applied in those which have opened the door of examining the effects of stem-cells therapy on regional function.

Contrast echocardiography

Ultrasound contrast agents have been used in clinical echocardiography since mid 1970s. Second generation of contrast agents usually consist of very small gas microspheres [8,9]. As they resonate when exposed to an ultrasound field with the appropriate acoustic pressure, they generate harmonics not shown in tissue allowing separating contrast from surrounding tissue. This makes it easier to detect and image the contrast agent within tissues and the cardiac chambers.

When administered from a peripheral vein, they pass the pulmonary vascular bed relatively unimpeded and appear in the left ventricular cavity resulting in enhanced visualisation of the left ventricular border. Finally, the distribution of contrast agent in the myocardium provides an estimate of myocardial blood flow. It can thus be used as a marker of normal and abnormal perfusion. Currently, contrast echocardiography is used primarily for improved border delineation, shunt detection and Doppler enhancement, and in a research setting, for perfusion imaging of the myocardium (Figure 3).

Furthermore, new therapeutic applications using microbubbles and ultrasound are expected. Thus, new ultrasound technologies in combination with pharmaceutical and molecular agents will create new opportunities for therapeutic ultrasound. Indeed, contrast agents could serve as vehicles for the delivery of therapeutic agents, including gene therapy or drugs, to patients. The ability of ultrasound to burst contrast “bubbles” will allow localised drug delivery, without significant systemic effects.

Figure 1: Top, color tissue Doppler imaging. Bottom, assessment of myocardial velocities.

Figure 2: 2D speckle tracking analysis of regional myocardial deformation. Arrows display the time delay between the peak strain of the septal and lateral walls.
Figure 3: Left, Left ventricular (LV) opacification by contrast administration. Right, defect of myocardial perfusion (arrows) in the lateral wall.

Real time 3-dimensional imaging

3D echocardiography has been introduced more than 15 years ago. Over the past 2–3 years, 3D echocardiography has evolved from cumbersome reconstruction of multiple cross sectional 2D images to real-time volumetric imaging. Indeed, the newer generations of matrix-array transducers are able to capture pyramidal volumetric datasets (30° x 60°) that can be rendered immediately to provide viewing and rapid interpretation.

This approach is classically used to visualise cardiac and valve morphology. To obtain an entire volume dataset (90° x 90°), four sequential cardiac cycles are typically captured and added to create a complete volume of information. By sectioning or cropping away parts of the dataset, it is possible to see inside the heart and the anatomic orientation and motion of intracardiac structures.

Real time 3D colour Doppler echocardiography has been recently introduced. It may lead to more precise quantification of valvular regurgitations. The recent advances in computer processing and transducer construction techniques have made that an entire 3D dataset can be acquired in one cardiac cycle. This last generation of 3/4D echocardiographic imaging brings us true real-time, full 3D volume rendering and artifact-free depictions of the entire heart. 3/4D echocardiography eliminates the manual cropping and cutting of conventional 3D workflow, a time consuming process.

There are already several clinical areas where the images provided by real-time 3D echocardiography are already making a difference. The most important is probably the ability to quantify the function and structure of the heart in an easier, faster and more accurate way than conventional 2D echocardiography (Figure 4).

Indeed, 3D echocardiography makes no assumptions about the left ventricular shape and avoids foreshortened views resulting in a similar accuracy with cardiac MRI regarding the assessment of left ventricular mass and volumes. Thus, 3D echocardiography permits a better evaluation of the beneficial effects of therapy on left ventricular function [9]. This 3D technology is also particularly suited to imaging the right ventricle, a geometrically complicated chamber of the heart that has been relatively poorly evaluated with 2D methods. Another area where real-time 3D echocardiography is of interest is the evaluation of cardiac masses.

In mitral valve stenosis, real-time 3D echocardiography is more accurate than other non-invasive modalities in measuring the mitral valve area [10]. The difficulty with 2D echocardiography is in fact to visualise epicardial border. Data obtained with 3D echocardiography are similar to those obtained with MRI. Real-time 3D echocardiography is also of great importance in visualisation of heart valves, particularly the mitral and aortic valves (Figure 5).

It can give a surgical view (en face view), providing surgeons planning to repair a valve with images very similar to what they will see at the time of surgery. In degenerative mitral regurgitation, real 3D echocardiography offers approximately the same accuracy as multiplane transesophageal to diagnose which scallops are involved in the disease process. It can also precisely measure the size of the valve orifices.

In aortic stenosis, the aortic valve area is measured as precise as with the Doppler method. Real-time 3D echocardiography also provides an accurate description of various congenital heart diseases, as well as shunts and valve pathology. Fetal 3D echocardiography is now available. Finally, 3D echocardiography is also particularly useful in the evaluation of cardiac dyssynchrony (Figure 6). Measuring the degree of LV dyssynchrony is useful in helping define which patients with heart failure will benefit from a cardiac resynchronisation therapy [11].
Recent technological advances have resulted in the development of sophisticated breakthrough tools that further refine the ability of echocardiography as a diagnostic modality as well as a guiding technique for various interventions. Echocardiography is a still evolving technique and new transducer technologies would change the cardiologist’s vision drastically. The future of this technique promises to be as productive and exciting as it has been in the previous three decades.

REFERENCES


CONCLUSIONS

With more than 25 million echocardiograms performed annually worldwide, echocardiography is going to remain the leading diagnostic modality in the field of cardiology. Echocardiography has several characteristics that are unmatched by other noninvasive techniques. Indeed, this technology is harmless and combines low-cost high-technology with easy accessibility. It provides rapid quantitative information about cardiac structure and function at the bedside.