Artida
Improving Clinical Performance with Innovative Technology

Tsuyoshi Yoshie

Tsuyoshi Yoshie
Toshiba Medical Systems Corporation, Tochigi, Japan

Introduction

Higher expectations in routine Echocardiography, new quantification and visualization techniques and the ever increasing demand for workflow and ergonomic solutions present many challenges to the development of an Echocardiography system. In particular interest in 4D ultrasound is driving changes to system architecture, transducer design and raw data processing capability.

Toshiba's development of Aplio™ Artida™ required innovation in all aspects of ultrasound system design. It was very important to have good clinical input before developing this new technology. Establishing a Medical Advisory Board and user groups were the most important first steps. Strong demand for imaging performance, advanced applications, workflow innovation and ergonomics drove the development of a new range of technologies that significantly impact system performance.

State of the art transducer technology

Conventional transducers feature a row of transducer elements which generate a 2 dimensional image. In recent years transducers with subdicing of the elements and electronic switching to vary the receive element characteristics known as 1 $^1/_2$ D array (or sometime matrix) transducers have been used to minimize beam thickness in 2D scanning. Also in some applications 3D and 4D scanning has been achieved by rapidly sweeping a 1D array transducer across a volume mechanically. However, frame rates and footprint have not been satisfactory for cardiac applications in such transducers.

In order to generate high quality 4 dimensional imaging with excellent image quality, temporal resolution and control flexibility a true matrix transducer approach is required. By being able to electronically control the excitation of a 2 dimensional array of ceramic elements rapidly over time a 4D wave pattern can be created. Similarly a 4D volume can be created by carefully processing the signal received over this array.

Furthermore, ergonomic requirements dictate that such a transducer be compact and lightweight. In particular the length of transducer must be minimized in order to make apical imaging easier. Limited space between patients' ribs dictates a small footprint.

To achieve these requirements a new class of transducers is required. SmartFocus technology was developed specifically to meet these requirements.

Fig.1 *SmartFocus Cardiac 4D Transducer. The smallest, lightest, highest performance 4D transducer to date*

Fig.2 *SmartFocus Cardiac 1D array Transducer*

Fig.3 *Aplio Artida*

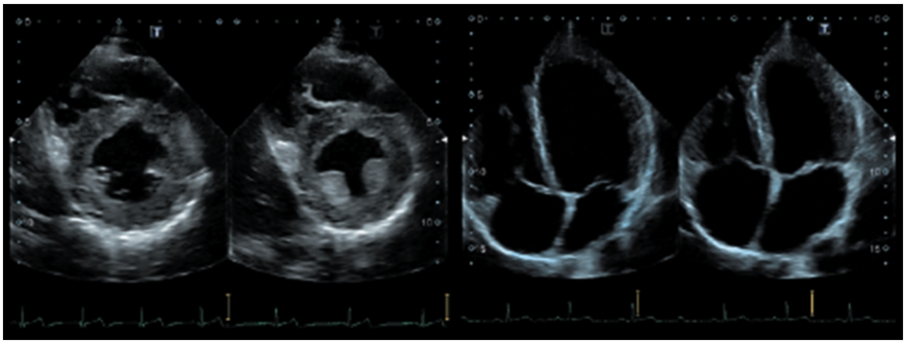

Fig.4 *Tissue Enhancement Mode enhances myocardial definition.*

New piezo electric materials provide greater sensitivity and resolution by increasing the bandwidth of the transducers. Sensitivity is also improved through new heat dissipation technology and low attenuation lenses employing nanotechnology materials.

New materials, smaller subdiced elements, transducer reliability, heat loss characteristics, transducer size and weight limitations mean making such a transducer is not easy. A whole new range of machining and assembly techniques had to be developed in order to make the transducer a reality. The result is the PST-25SX, the smallest (and importantly, shortest), lightest, highest performing 4D transducer available today.

Many of the improvements that enable 4D transducer can also be applied to 1D array transducers. New materials and new manufacturing techniques mean SmartFocus 1D array transducers also feature improved performance in smaller, more ergonomic designs. In particular new machining techniques make it possible to create elements that can vary the beam profile over depth.

SmartFocus transducer design is an integral part of Artida's system performance, however extracting the most from these more sophisticated transducers requires a new beamformer, advanced processing techniques and substantially more computational power.

High Performance Beamformer and Processing Engine

Driving a SmartFocus transducer and processing the volume and complexity of signal data returned is far more challenging than in a conventional echocardiography system. It would not be possible without the development of the MultiCast Beamformer and the SmartCore Processing Engine.

The MultiCast Beamformer is responsible for creating an ultrasound beam that can scan 2D and 4D anatomy more quickly and more accurately. The complexity of the wave pattern generated and the high temporal resolution at which it is created require that it be fast and flexible. It contains a number of innovations. It can simultaneously generate waves patterns that focus at different depths thus allow dual focal points in an image without sacrificing frame rate. The MultiCast Beamformer can simultaneously transmit/receive Doppler data to/from different destinations enabling increased color Doppler temporal resolution. In particular small regurgitant jets can be detected when this increase is combined with the greater sensitivity of SmartFocus Transducers.

SmartCore is the new architecture that provides the raw data processing power required to drive the beamformer and transducers and to provide high quality data to the display and advanced applications that make this data meaningful. It combines over 80 high performance processors with large scale Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs) and high speed Digital Signal Processors (DSPs). The design objective is to provide the fastest, most flexible possible architecture for the processing of complex information. SmartCore can process massive amounts of information and extract the clinical parameters necessary for clinical assessment and diagnosis.

The increased performance of SmartCore allows numerous, previously impossible image processing techniques to be applied. For example, Tissue Enhancement Mode offers a smoother, clearer ultrasound image than was previously achievable. The noise is effectively suppressed, and the uniformity of the image and the visibility of the endocardium and myocardium are greatly improved.

SmartCore is also highly configurable enabling fundamental system performance and functionality to be upgraded in software.

Advanced Clinical Applications

High quality data means excellent imaging performance. Increasingly echocardiographers are also asking for

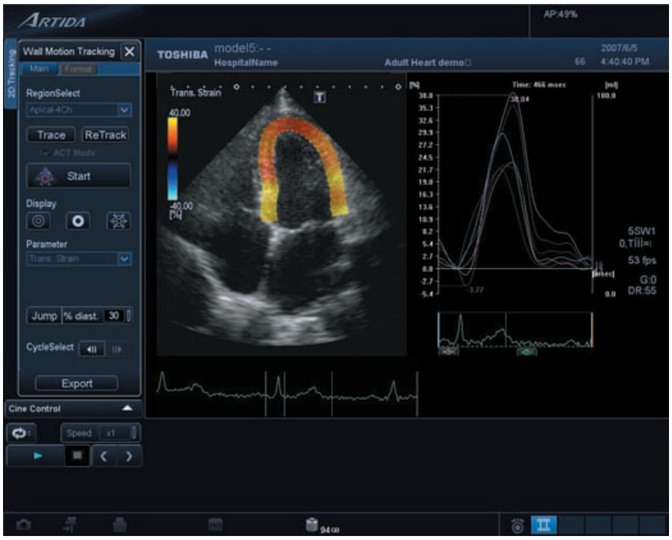

Fig.5 *2D Wall Motion Tracking*

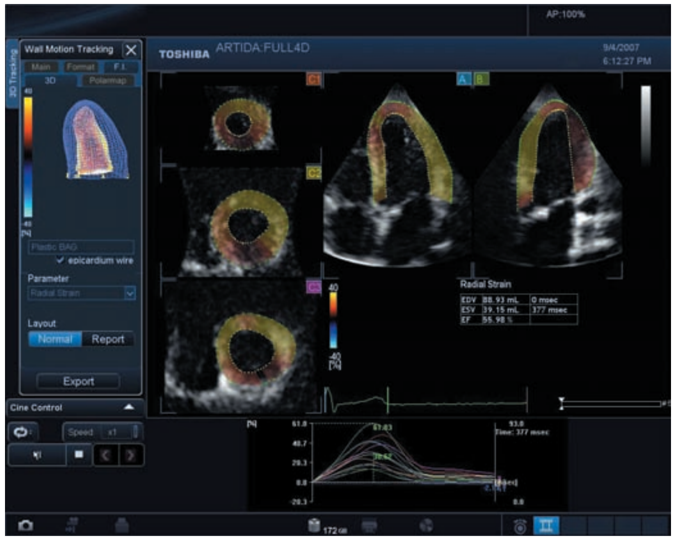

Fig.6 *3D Wall Motion Tracking*

advanced applications. Cardiovascular disease is a leading cause of death and is becoming more frequent. Disease which affects wall motion and its timing can be difficult to detect with the naked eye. Of late quantitative applications have been of particular interest because they offer the promise of earlier, less subjective assessment of cardiovascular disease.

Pattern matching techniques, widely known as speckle tracking, allow detection and quantification of wall motion. Wall Motion Tracking can be used to assess abnormal motion often seen in ischemic heart disease. Such abnormal wall motion can be observed even when it is not apparent to the eye. Regional and global motion can be assessed and a wide range of parameters can be observed like displacement, velocity, strain, strain rate, rotation, etc. These techniques are not subject to the directional limitations of Doppler techniques which depend on the angle of incidence of the ultrasound beam to the moving tissue. Semi-automated tracking techniques means the total myocardium can be quickly identified and assessed and a range of quantitative results and graphical representations can be generated.

Artida features two methods of Wall Motion Tracking. 2D Tracking (2DT) tracks 2 dimensional wall motion (actually, the projection of 3 dimensional movement on a 2 dimensional plane). 2D Tracking can generate high temporal resolution data useful for techniques such as dyssynchrony evaluation.

3D Tracking (3DT) can observe total, global myocardial movement. 3DT is not easily achieved due to the very large number of speckles that must be identified and tracked spatially (throughout the myocardium) and temporally (throughout the cardiac cycle). It is not possible to achieve 3DT by simply conducting 2DT on multiple planes. New data processing techniques including 3D speckle tracking templates had to be developed. SmartCore Engine processing power is the key in this technique. With a full quantifiable volume available, true global assessment of the myocardium can be made and new parameters (like twist, torsion, etc.) can be observed.

The importance of ergonomics and workflow optimization

Ergonomic and workflow considerations are increasingly important in ultrasound design. Minimizing repetitive, unnatural operator movement and reducing the time and effort required to conduct an exam are central to Toshiba's ultrasound design philosophy. Since 4D is a relatively new technology, it was an area of particular focus in terms of ergonomics and workflow.

There are many considerations in making an ergonomic system. Toshiba's ergonomics philosophy is embodied in the iStyle™ concept. It starts at the control panel. Frequently used operations are arranged around the central palm controller so they can be activated with minimum movement. The whole panel is highly configurable. Key assignments can be changed so that frequently used functions can be added to the panel and positioned according to the operator's requirement. A much greater range of functionality is available at the Touch Command Screen. The placement of controls of this screen is also fully customizable. QuickScan one touch image optimization can also substantially reduce key usage. The whole panel can be moved left/right, in/out and up/down and the monitor can be positioned independently. A handle was added to the monitor to make it easy to position. The system is very quiet in order to improve both the operator and patient experience.

There are many workflow and ergonomic challenges in 4D ultrasound. 4D transducers are by necessity larger, there are multiple steps required to assess the data and the practice of 4D is still

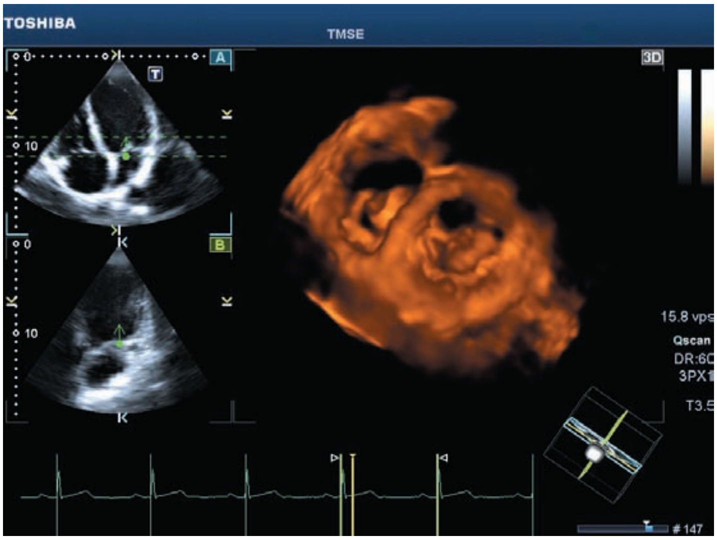

Fig.7 SmartSlice plane selection

Fig.8 iStyle Ergonomics

changing quite rapidly. As the usage of 4D increases, the importance of these issues will likely increase so its important to pay close attention to them on a new platform.

4D transducer design is discussed above in greater detail but the main ergonomic considerations are weight, size (especially length) and footprint. The PST-25SX transducer is the lightest and smallest (and shortest) in class, the cable is lightweight, flexible and long so its very well suited to ergonomic and workflow requirements in clinical usage.

Since QuickScan one touch image optimization is well accepted in 2D echo it's a very worthwhile addition to 4D. It allows rapid optimization of the image quality of the entire volume in one operation.

While a lot of data is available in a 4D volume, extracting the information from that volume can involve multiple steps. Minimizing the operations required offers the possibility of substantial gains over existing 4D solutions. SmartSlice technology was specifically developed to make obtaining results in 4D imaging faster and easier. SmartSlice provides a variety of tools for 4D data manipulation with a focus on simply and quickly achieving the desired view. For example 4D plane selection is reduced to two operations by selecting an observer point in the first and then a view direction and slice thickness in the second.

One difficulty with 4D in cardiology applications is the trade off between temporal resolution and image quality. On Artida it is possible to acquire a complete cardiac volume in one heartbeat. This method provides a very consistent dataset. If users require higher image quality or better frame rates then its possible to acquire the volume over several heart cycles and synthesize a complete volume. A real time display was chosen for this function so that as each data segment is updated the volume is continually displayed. This makes it much easier to monitor the volume for quality before storing or analyzing it. Irregularities caused by patient movement or breathing can more easily be avoided.

Conclusion

Artida features changes to nearly every aspect of echocardiography system design. Far more important than the technical innovation though, is the definition of clinical requirements that these innovations must address. Through close consultation with the Medical Advisory Board and users we could ensure that the new design was targeted at real clinical and research requirements. Artida's basic design philosophy centers on advanced transducer design to provide better data, faster and more flexible signal processing to extract more information more quickly, improvement to conventional clinical applications and new advanced applications. At every level attention to workflow and ergonomics are an overriding factor.

The final result is improved clinical performance and a host of tools that provide new ways to assess 2D and 4D ultrasound data.

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