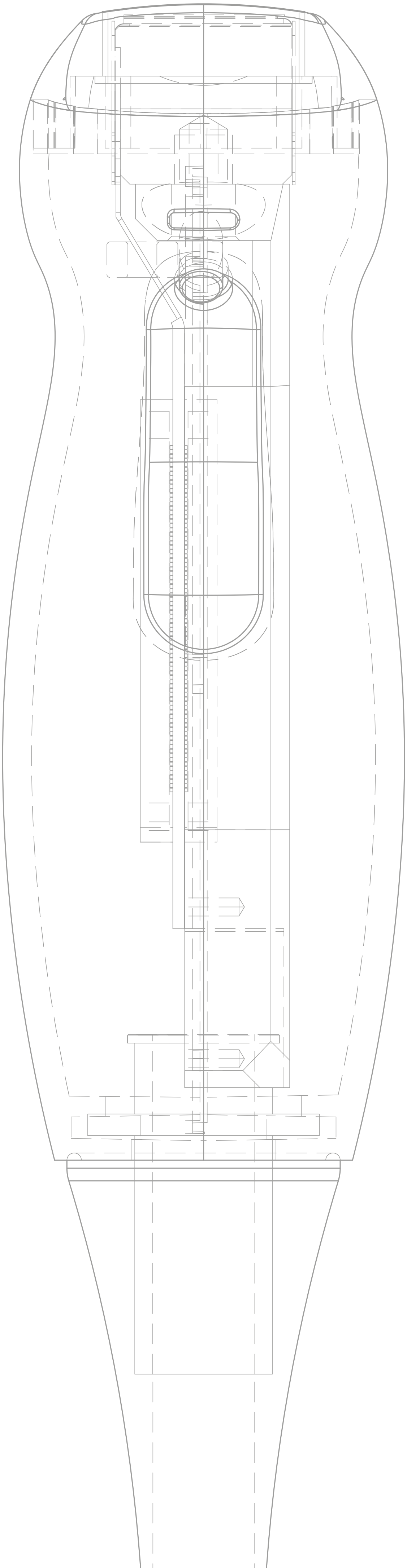
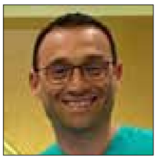


White Paper

PX 1-5 diamond single crystal technology

esaote

“Esaote has developed the PX 1-5, an elegant and easy-to-use probe, to deliver enhanced echocardiography performances and workflow, increasing the level of patient care.”



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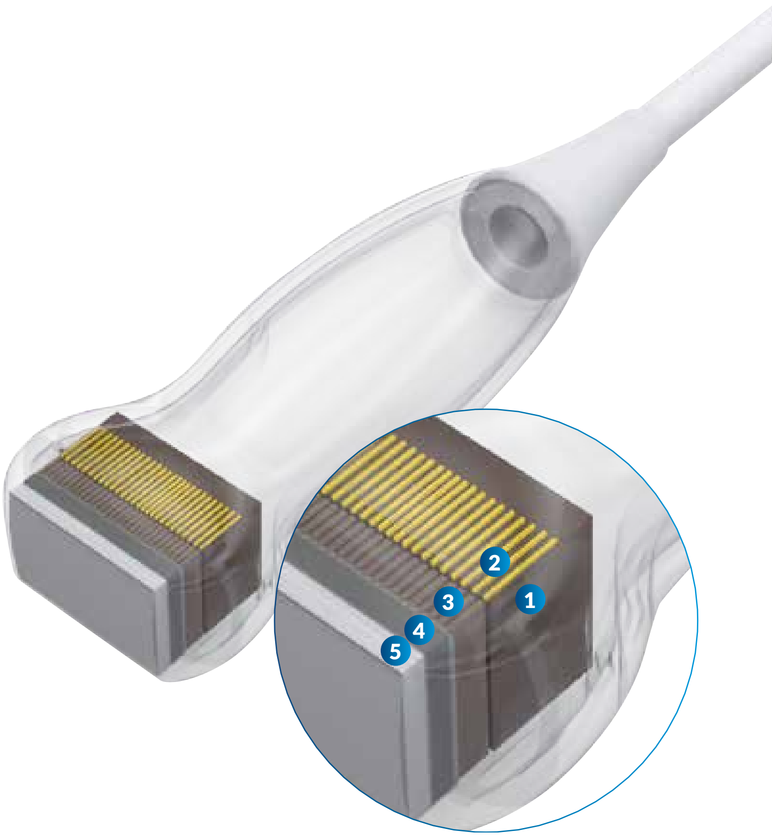
The Esaote PX 1-5 phased array probe features a sophisticated acoustic model to achieve superb imaging performance, even in technically difficult patients. To address this challenge, the transducer is equipped with diamond single crystal technology and a thermal efficiency mechanism.

The innovative PX 1-5 design combines high image quality with ease of use. It provides sharped details of fine structures and a high signal-to-noise ratio, while delivering enhanced plunkability. This results in an enhanced level of workflow and patient care, which are the pillars of our mission.

Transducer technology

To ensure superior clinical performance, ergonomics, and reliability, the ultrasound probe (Figure 1) design requires the optimization of the transducer, shape, cable, and system connector, together with an efficient manufacturing process. We have worked to meet these challenges by listening to customer demands and by taking the most advanced engineering technologies into consideration, from acoustics and mechanics to chemistry and electronics.



1. *Backing block*
2. *Electrical connections*
3. *Piezoelectric elements*
4. *Matching layers*
5. *Acoustic lens*

Fig. 1 - The core of the ultrasound probe is the transducer, which has four main parts: piezoelectric elements that convert electrical energy to acoustic energy and vice versa; backing material that both dampens the piezoceramic ringing and attenuates unwanted ultrasound traveling in the direction opposite to the patient; matching layer(s) improving ultrasound transfer into the patient and unlocking transducer energy conversion efficiency; an acoustic lens that focuses the ultrasound beam in the plane perpendicular to the electronic focusing plane[1].



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The PX 1-5 incorporates the newly developed diamond single crystal technology, leading to enhanced image quality without compromise. Compared to conventional lead zirconate titanate (PZT) piezoceramics, single crystal provides up to 20-25% wider bandwidth (Figure 2), greater sensitivity, and deeper penetration than PZT, enabling more detailed diagnostic information even for difficult-to-image patients. As a result, single crystal offers noticeably better performance than PZT, in terms of contrast and spatial resolution, uniformity from near field to far field, and penetration. **Standard imaging, Doppler, color flow and harmonic imaging performances are all enhanced**.

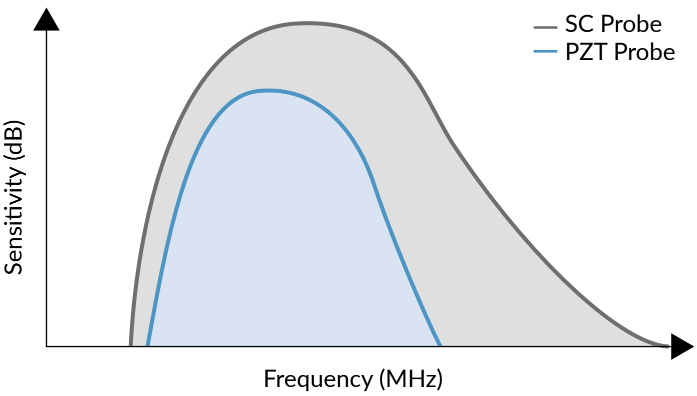


Fig. 2 – Single crystal material offers up to 20-25% wider bandwidth and greater sensitivity than PZT

In addition to the single crystal technology, the innovative backing aids the enhancement of the image quality, increasing the ultrasound energy transmitted into the patient body, while maintaining very wide bandwidth, and improving the thermal efficiency (Figure 3, Figure 4). This directly translates to the highest level of harmony of imaging sensitivity, penetration, and resolution achievable in the whole field of view and leads to improved diagnostic confidence and accuracy for a wide range of patients. As result, **speckle noise is reduced, improving the sharpness of edges and fine details of valves and interventricular and interatrial septa, and pulmonary venous color Doppler is enhanced**.

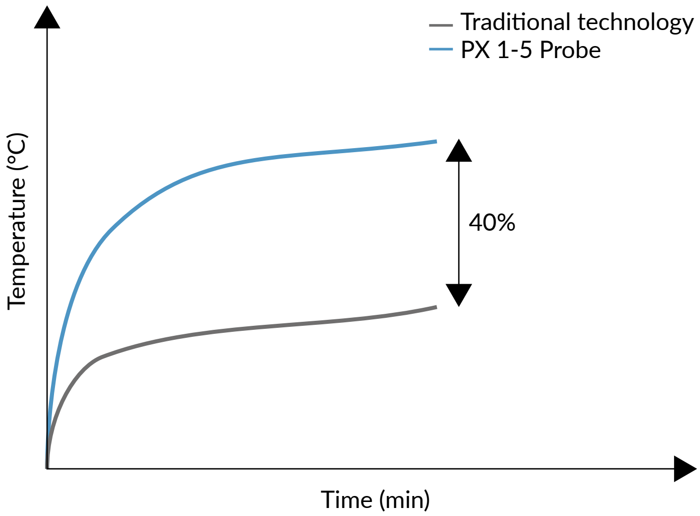


Fig. 3 – The newly developed technology allows a 40% increase in thermal efficiency, resulting in decreased probe heating

Fig. 4 – Thermal behavior of the probe without (left) and with (right) thermal efficiency technology. In both cases, the amount of heat does not exceed that allowed by the standards. Nevertheless, due to the lower temperature of the probe surface, the PX 1-5 delivers higher transmit and receive sensitivity and therefore produces a higher quality image and Doppler signal.

The lens consists of specifically designed material and geometry to provide a slice thickness (Figure 5) enabling uniform sensitivity and high signal-to-noise ratio across the whole field of view, facilitating access to image windows between ribs, minimizing reverberations, increasing contrast resolution, and improving border definition of anatomical structures. This contributes to **aiding apex clarity in the four-chamber view and to imaging small vessels in transcranial applications**.

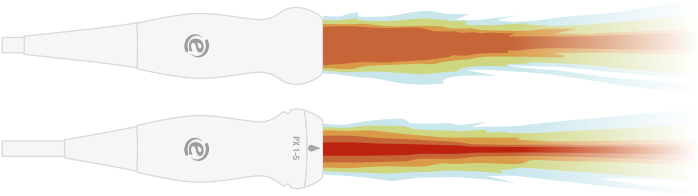


Fig. 5 – PX 1-5 transducer elevation focusing was designed to adequately sample a wider range of depths: the focusing in the lens direction provides a sharper, finer and more uniform ultrasound beam, which positively impacts contrast resolution, useful penetration, and plunkability

In conjunction with more precise clinical images, the acoustic lens design provides **effective robustness of the transducer** against automation and aggressive cleaning and disinfection methods. This results in a **longer product life**.

Probe ergonomics

Esaote has a well-established ergonomics design culture that addresses the challenge of combining aesthetics, function, and comfort. The compact and elegant shape of the PX 1-5 (Figure 6) is the result of an industrial design aiming to fit the customer needs and to reflect our brand identity. **Functionality, plunkability, comfort, and workflow are all enhanced**.

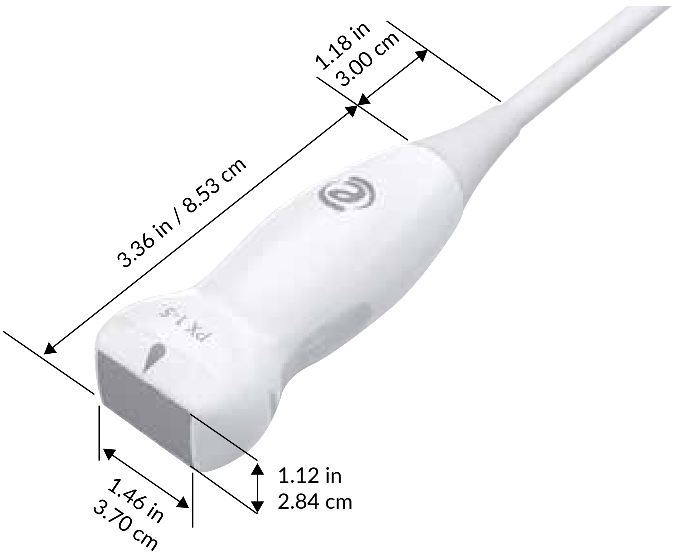
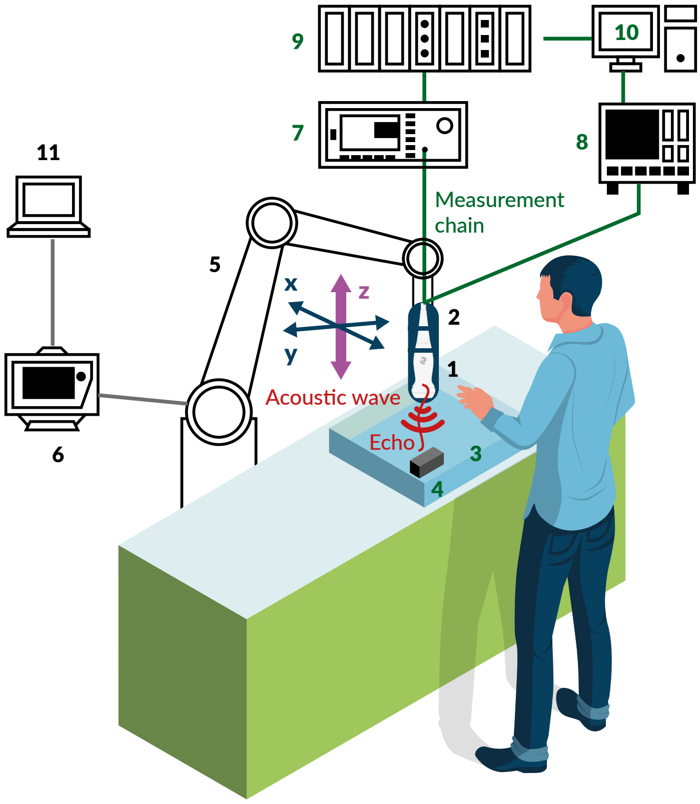


Fig. 6 – The ergonomics of the PX 1-5 probe are the result of comprehensive analysis and understanding of the customer's needs

Ultrasound probe manufacturing process

In the industrial production scenario, the goal of engineering is focused on the continuous improvement of the process performance by maximizing the effectiveness of the manufacturing and the quality of the products[2]. The combination of the flexibility and problem-solving ability of humans with the strength, endurance, and precision of robots allows for improvements in product quality assessment, as well as in working conditions for staff. Collaboration between a collaborative robot, a so-called co-bot, and a human opens up tangible efficiency advantages with regard to automating the complex multi-stage manufacturing process of ultrasound probes (Figure 7).



1 US probe
2 WSG Schunk gripper
3 Water tank
4 Reflector
5 UR5 robot
6 UR5 control box
7 Function generator
8 Digital oscilloscope
9 MUX/DEMUX scanner
10 Host computer
11 Laptop with user interface

Fig. 7 – Co-bot based measurement chain for the ultrasound probe quality assessment

The higher repeatability performance of the co-bot, combined with the reduction in calibration time when compared with the manual approach, helps the trained worker by enhancing quality assessment in industrial scenarios, where the demand for medical ultrasound probes can reach thousands per year[3]. Performing measurements with the same reference throughout all processes — from material reception to processing, assembly, inspection, and shipping — makes it possible **to create products that match the design requirements and to guarantee product quality**.

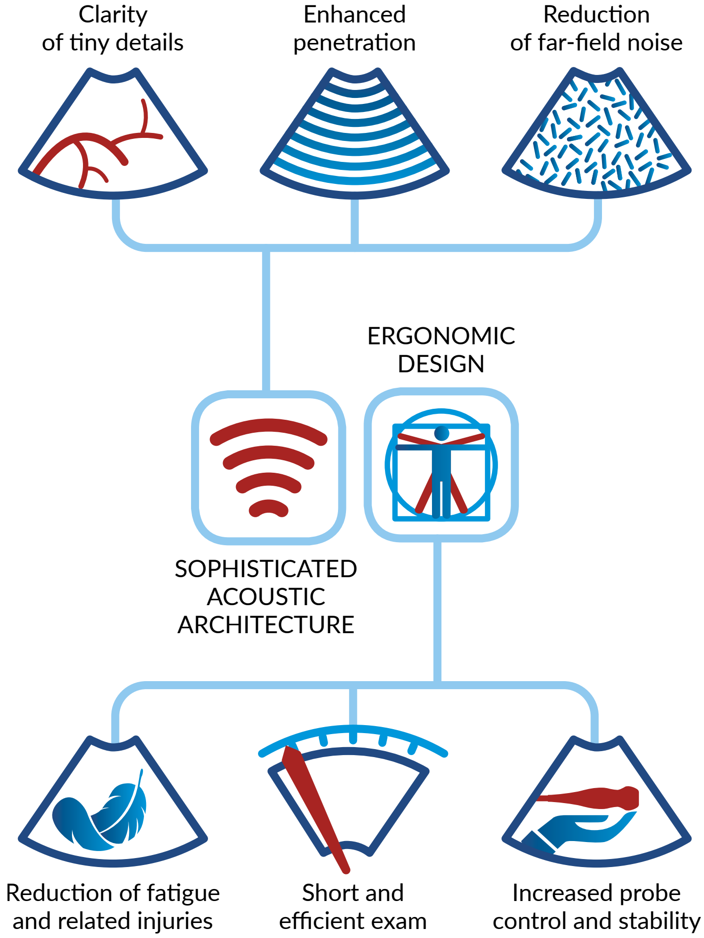
Technical highlights

The diamond single crystal technology offers wide bandwidth and great sensitivity while optimizing thermal efficiency, for exceptional performance. The ability to generate strong signals while managing heat dissipation enables significantly higher resolution, deep penetration, and extraordinary clarity through the whole field of view, allowing effective imaging of a wide range of patients. To enhance operator productivity and comfort, the targeted ergonomics design allows the user to hold and maneuver the probe to easily and quickly access the multiple acoustic windows and scan planes.

In addition to our focus on clinical performance and applied human factors, we are constantly and strongly involved in the optimization of the manufacturing probe process to deliver more and more reliable devices. The role of worker sensitivity and expertise, the continuous improvement methodology and automation are the fundamental key factors for the quality assessment of ultrasound probes in a manufacturing industry scenario.

Clinical highlights

Thanks to the diamond single crystal technology, the PX 1-5 provides robust imaging performance enabling strong clinical confidence and high efficiency from early detection and diagnosis to treatment and follow-up. Optimal spatial resolution in both near and far field allows a better atrial identification and also a sharper definition of the right heart (RV endocardium free wall), which is a current focus of the entire scientific community. The optimization of the lateral resolution plays a key role for the speckle tracking method (2D Strain), which is designed to analyze the contractility of the myocardium and requires superb image quality to accurately trace the speckle and minutely represent the endocardial border. The enhancement of the signal-to-noise ratio in the near field allows remarkable tissue characterization of the middle and apical segments and also an easy identification of apical thrombus formation. The improved plunkability results in an easier acquisition of the echocardiography section, which can help to reduce exam time. This also results in an enhancement of the Doppler examination: a more accurate and faster alignment of the beam increases the Doppler signal in both tissues and flows.

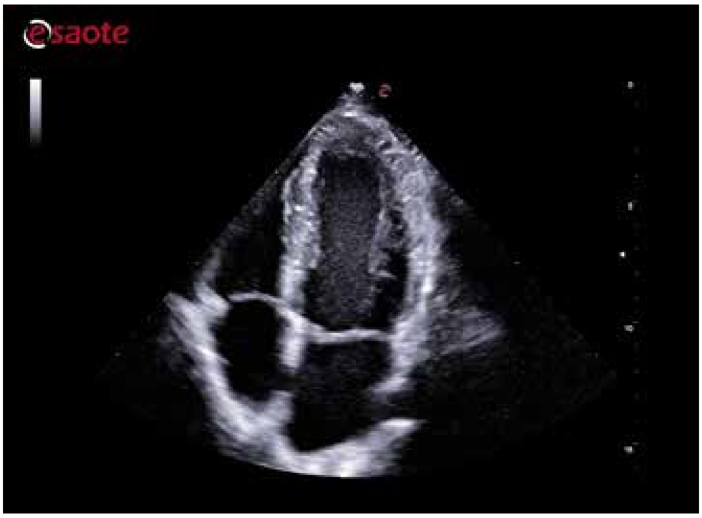


References

1. De Luca et al., *An Educational Overview of Ultrasound Probe Types and Their Fields of Application*. Archives of Acoustics, 2021
2. Bertocci et al., *A Guideline for Implementing a Robust Optimization of a Complex Multi-Stage Manufacturing Process*. Applied Sciences, 2021
3. Bertocci et al., *Design of Robot-based Measurement System for the Quality Assessment of Ultrasound Probes for Medical Imaging*. 2020 IEEE International Symposium on Medical Measurements and Applications (MeMeA)

Clinical images

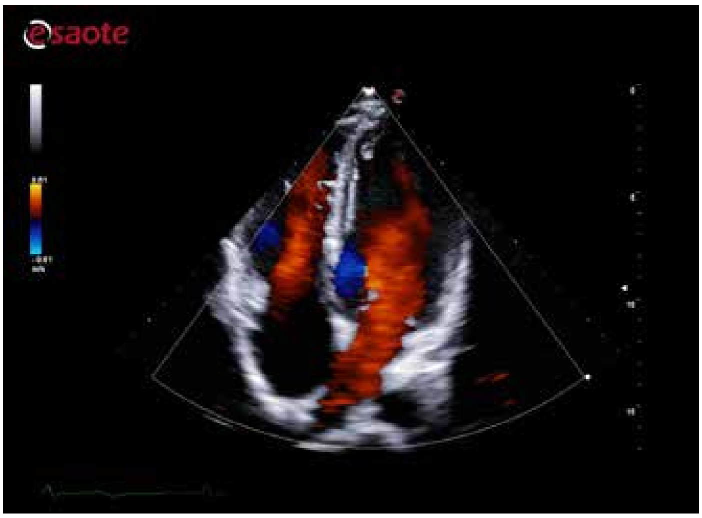
Superb parasternal long axis (PLAX)



The apical 4-chamber view with superior spatial resolution with imaging of the left ventricle (LV) apex

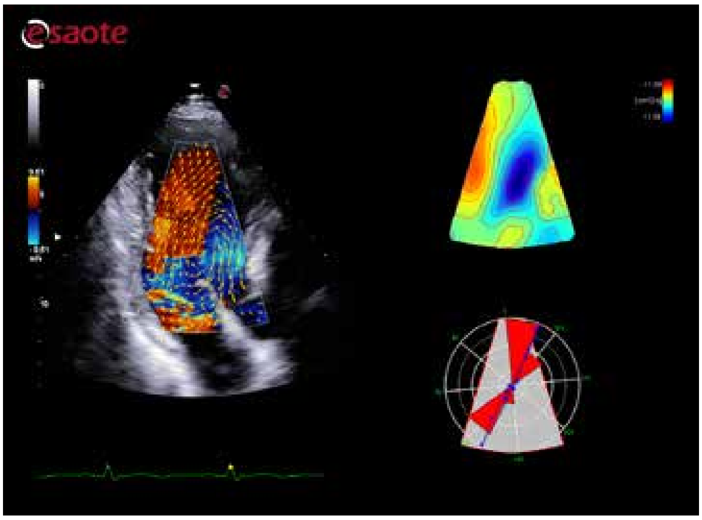
High image quality of the apical long axis (APLAX) view of the left ventricle (LV) is crucial for disease diagnosis and monitoring

Right ventricle (RV) sharpened border definition

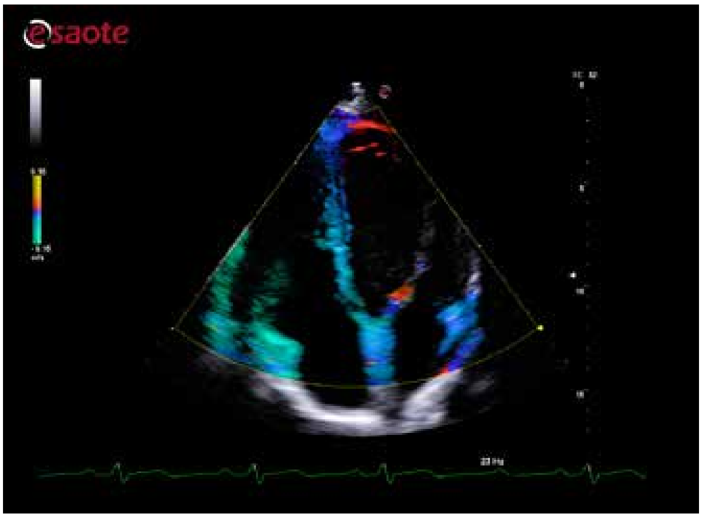


Pulmonary venous color Doppler is enhanced

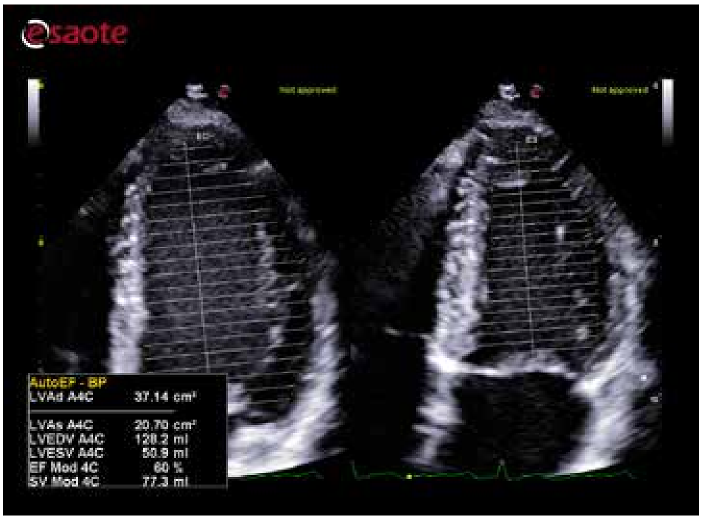
Remarkable sensitivity for Transcranial Color Coded Doppler examinations



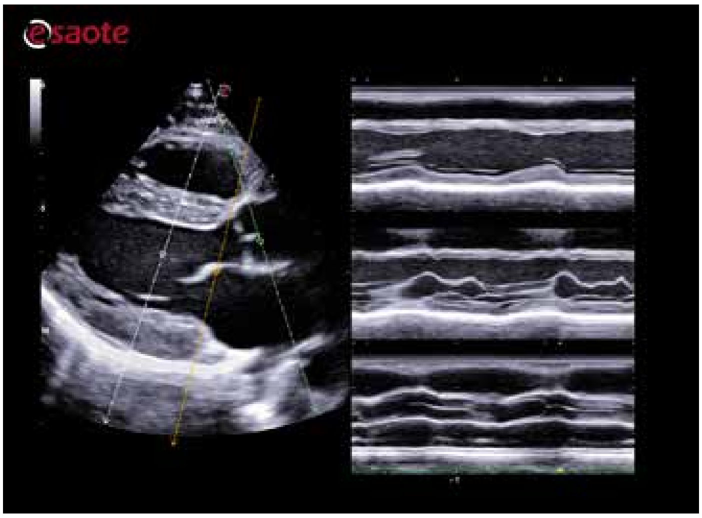
HyperDoppler is an advanced imaging tool for the investigation of intracardiac flows



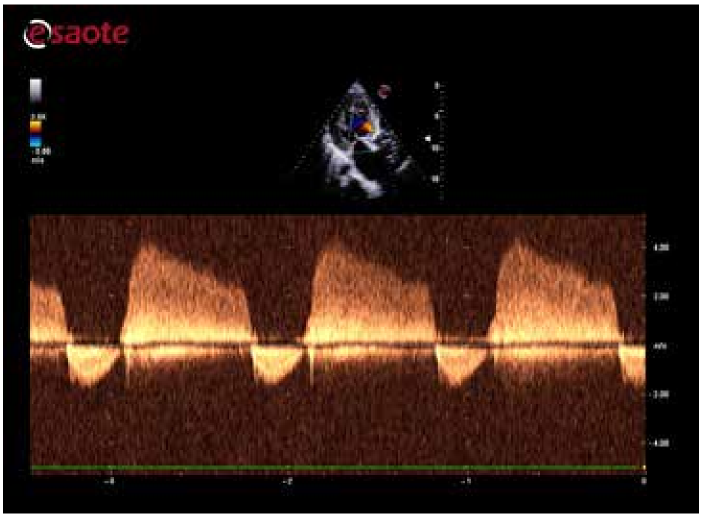
Color tissue Doppler analyzes myocardial velocities within a color sector



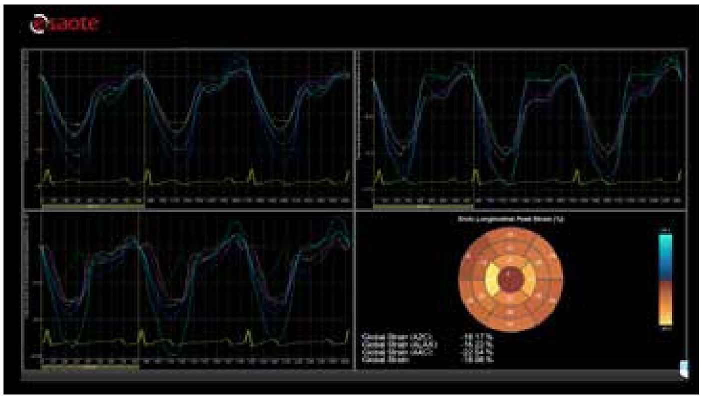
AI allows EF% to be calculated faster and automatically



CMM provides information on regional contractility in different walls at the same time



Continuous wave Doppler echocardiography for the evaluation of aortic insufficiency



Quantitative information generated by measuring longitudinal strain from three apical views

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