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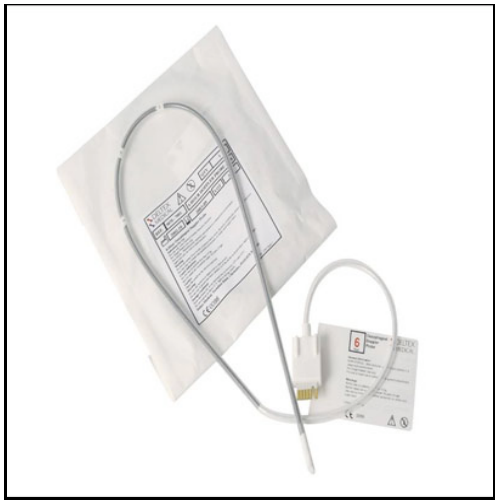
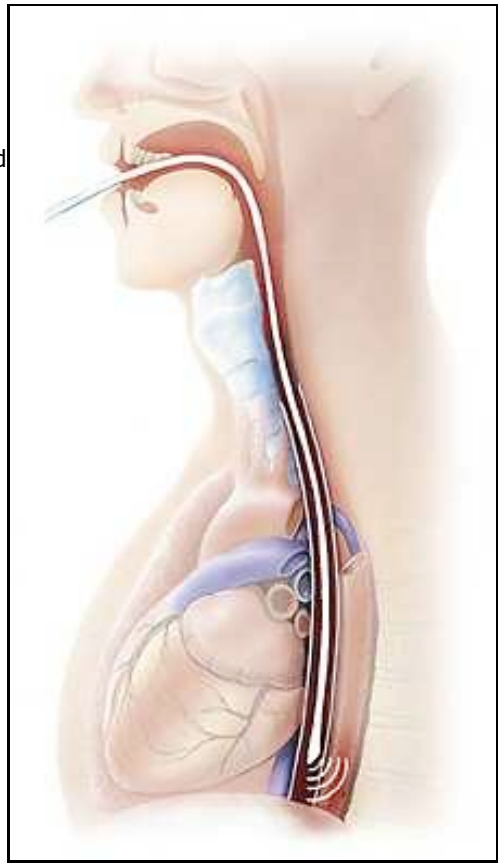
Positioning the probe

The CardioQ utilises descending aortic flow to provide an immediate assessment of left ventricular performance. The technology uses a thin latex-free silicone probe; about 6 mm in diameter with an internal spring coil to ensure flexibility and rigidity. The probe contains crystal which produces a continuous ultrasound wave of 4 MHz.



The lubricated oesophageal probe is inserted with the bevel of the tip facing up at the back of the patient's throat. The probe is inserted down to the 40 cm marker, rotated and slowly pulled back while listening to the audible signal. The ideal probe tip location is at the level between the fifth and sixth thoracic vertebrae because at that level the aorta is adjacent and parallel to the oesophagus.

This location is achieved by superficially landmarking the distance to the third sternocostal junction anteriorly. Because of the mild discomfort associated with placing the probe and maintaining it in a fixed position, patients require adequate sedation. Insertion of the oesophageal Doppler ultrasound probe has been described in the awake patient. This would extend the use of this device to include patients not heavily sedated or anaesthetised. The technique described involves using local anaesthetic to the nasal mucosa and posterior oropharynx and application of nasal vasoconstrictors.



Once inserted, the oesophageal probe is connected to the CardioQ monitoring system via a smart connector which stores patient data.

All of the probes are sleeved in a non-toxic latex free silicon rubber. The highly flexible nature of the probe allows it to be inserted through either the nose or mouth. The lateral stiffness created by the design of the probe, allows the probe to be positioned easily through rotating precisely without twisting the sleeve.

All of the probes are single use design, therefore any cross contamination risks associated with the cleaning of probes due to multiple use is removed.

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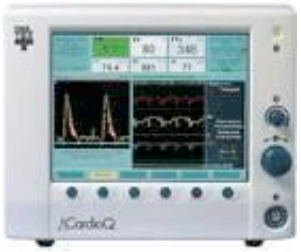
CardioQ monitor

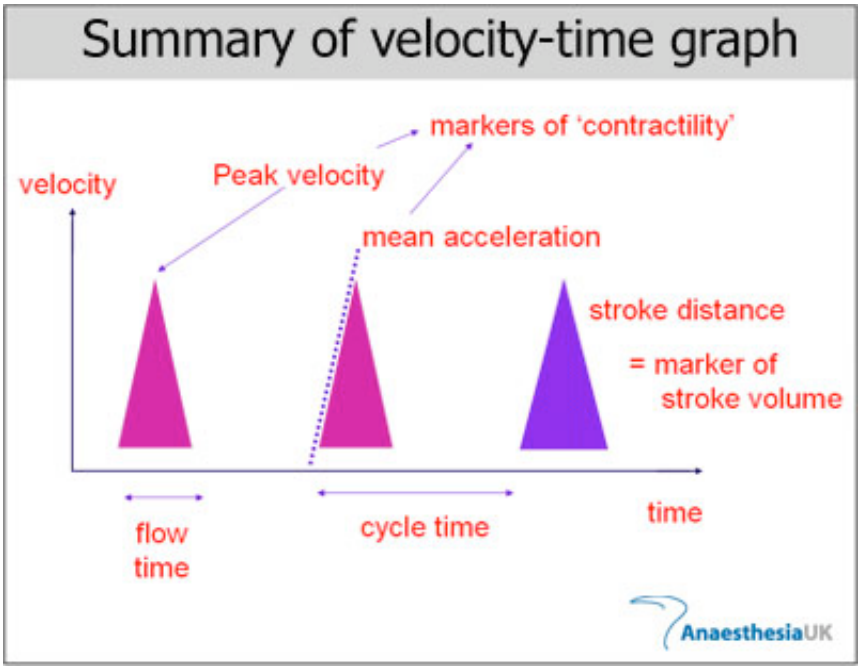


The CardioQ uses an interactive monitor. The screen displays the waveform which confirms optimal probe position. There is a continuous display of the patient's haemodynamic parameters.

The CardioQ's default display parameters are

- CO (cardiac output)
- SV (stroke volume)
- FTc (corrected f low time)
- PV (peak velocity)
- MD (minute distance)
- HR (heart rate)

CardioQ waveform and measured variables



With the exception of systemic vascular resistance, any six of the above parameters can be displayed at once and all are automatically trended. A navigator control knob is rotated to browse the menu and pushed to select. This includes the input of patient biometric data into the fixed stored nomogram that is used to estimate aortic cross sectional area. Speakers are included in the unit which gives an audible display of the doppler frequency shift spectrum produced by red blood cells moving in the path of the ultrasound beam. Listening to the audible signal aids optimization of the waveform.

Spectrogram

All newer generations of doppler equipment contain sound frequency or velocity spectrum analyzers for hard copy recording. They display a spectrum of the various velocities present at anytime and are, therefore, called spectral velocity recordings. This results in the typical waveform seen on the monitor of blood flow velocity in the descending thoracic aorta. The display is accomplished by microcomputers that are able to de-code the returning complex doppler signal and process it into its various velocity components. There are two basic methods for accomplishing this. The most popular is Fast Fourier Transform and the other is called Chirp-Z Transform.

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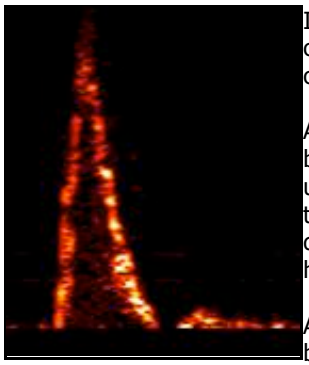
Waveform



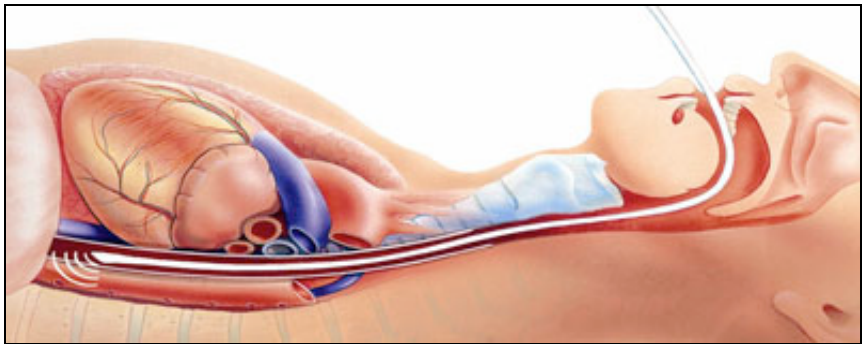
Identification of the descending aortic waveform is essential for the correct use of the oesophageal doppler. Waveforms from other structures e.g. pulmonary artery, azygous vein or coeliac axis may be encountered and confuse the user.

After acquiring the characteristic descending aortic waveform, the signal should be optimised before starting monitoring. This should be accomplished by moving the probe a centimetre up or down until the waveform indicates the best possible velocity and colour intensities and then rotating the probe to see if the signal can improve even more. The Peak Velocity display is used as a reference to the highest identified wave. The use of the audio signal is highly recommended.

A green line termed the Maximum Frequency Follower must trace the waveform accurately between the two white triangles on the baseline and the arrow at the peak, thereby matching the beginning and the end of systolic flow for all the waveforms during a measurement cycle. This Velocity/Time envelope is used by the monitor to make calculations. Following the adjustments, the Auto Gain control completes the optimisation process.

Optimum signal is usually located where the oesophagus lies parallel with the descending aorta at T5 – T6.

- Audible – sharpest pitch – "whip crack"
- Visual – highest peak – PV (peak velocity)
- Visual – colour – red/yellow on ascending side with traces of white on descending



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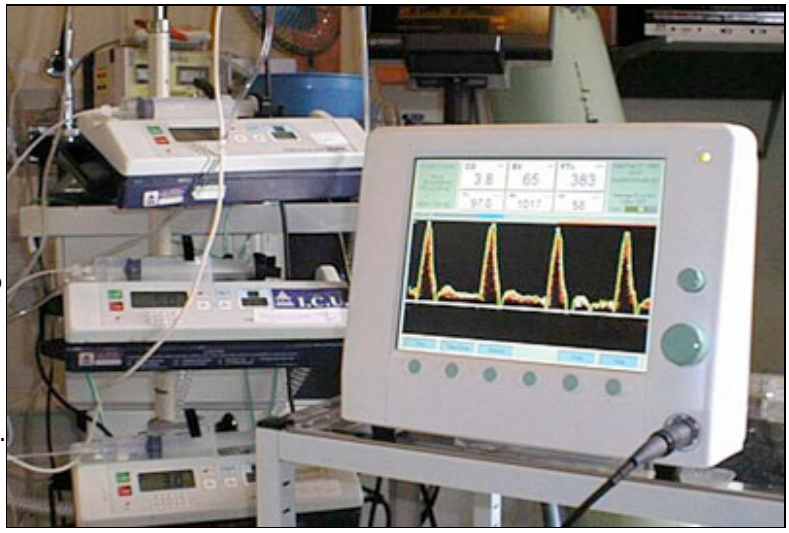
Oesophageal doppler variables



FT (Flow time)
The time of systolic aortic blood flow (sec)

FTc (Flow time corrected)
This corrects flow time to a heart rate of 60 bpm (msec)

PV (Peak Velocity)
Peak Velocity of blood flow. In systolic phase (cm/sec). This is the value at the peak of systole indicated by the white arrow at the top of the velocity waveform. It decreases linearly with age and is affected primarily by left ventricular contractility. A low PV occurs with left ventricular failure or beta-blockade. Peak Velocity rises with inotrope therapy and exercise. Changes in afterload also play a role.

MA (Mean Acceleration)
The mean acceleration is the average acceleration of the blood between the start of systole and the time when the peak velocity is detected (cm/sec). Mean Acceleration is affected primarily by changes in left ventricular contractility, but also by changes in afterload and, to a lesser extent, preload.

SV (Stroke Volume)
Blood ejected during each systolic phase (ml)

CO (Cardiac Output)
Litres of blood pumped per minute (L/min)

CI (Cardiac Index)
Cardiac output normalized for body surface area (l/min/m2)

SVR (Systemic Vascular Resistance)
Resistance the left heart pumps against; afterload;

Normal ranges

FTc: Flow Time corrected 330 -360 milliseconds

PV: Peak Velocity-an index of contractility

20 yrs: 90 - 120 cm/sec
50 yrs: 70 - 100 cm/sec
70 yrs: 50 -80 cm/sec

Concurrent shifts in FTc and PV indicates changes in after load

MA: Mean Acceleration depends on the patient

SD: Stroke Distance depends on the patient

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Calculation of stroke volume and cardiac output

Once blood flow velocity in the descending thoracic aorta has been determined, the technology combines this with an estimated aortic cross sectional area to produce stroke volume and cardiac output measurements. Thus, linear variables are converted to volumetric variables. Stroke Distance calculation is a key step in this process. It is described as the distance a column of blood travels down the descending thoracic aorta with each systole (cm). It is also represented by the area under the velocity time waveform.

In a tube:

Volume = Length (distance) x cross sectional area

Compare with CardioQ measurements:

Stroke volume = SD x Aortic cross-sectional area

There are three primary assumptions used in the calculation of the Left Ventricular Stroke volume:

- CardioQ nomogram: The CardioQ uses a fixed stored nomogram that provides an estimate of the patients aortic cross sectional area. The patient's biometric data consisting of age, height and weight are imported manually by the operator. The limits accepted by the nomogram are given below:

Table of nomogram (Well validated in the adult population)

Limits

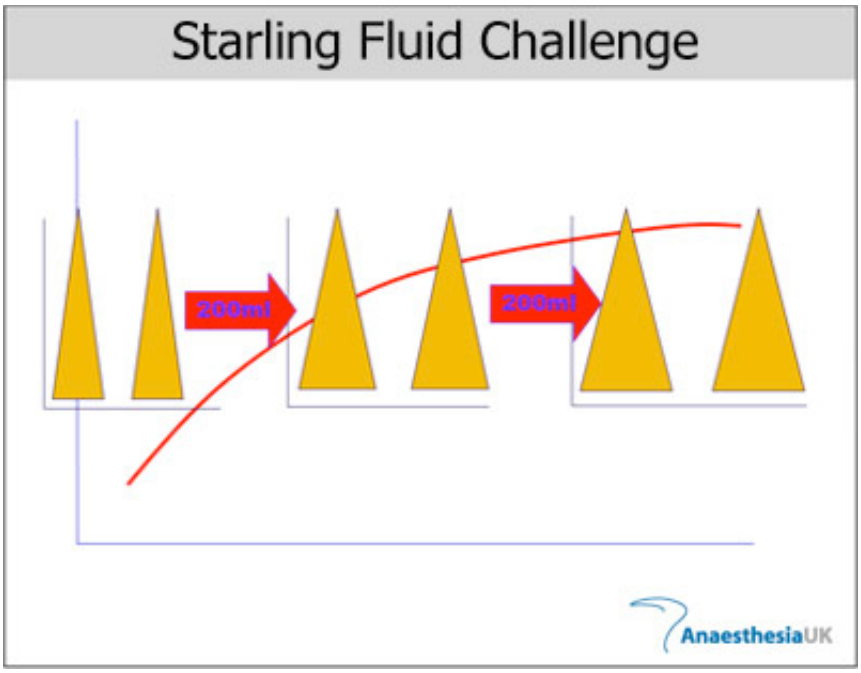
Age 16-99 years
Weight 30-150 Kg (66-330 lb)
Height 149cm-212cm

It is assumed that the imported biometric data is correct and that the patient's actual aortic dimensions are accurately represented by the stored nomogram. A 2mm miscalculation of a 25 mm aortic diameter will result in an automatic 16% error in cross sectional area (and
cardiac output).

- Constant angle of insonation: The angle of the CardioQ oesophageal probe to blood flow in the descending aorta is 45 degrees. Velocity measurements from the doppler equation use the cosine of this value. A wider angle will result in a greater reduction in measured velocity compared to true velocity.

- Constant proportion of left ventricular output: The CardioQ assumes that descending aortic flow represents 70% of left ventricular output and that this remains constant throughout the spectrum of haemodynamic changes. During some procedures e.g. during aortic cross clamping, there may be redistribution of blood to the supra-aortic regions. This leads to underestimation of the complete cardiac output.

Volume optimisation



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Assessment of pre-load

Although CO is the most valuable haemodynamic parameter, assessment of ventricular filling is also believed to be important in the management of perioperative and critically ill patients. Unlike the use of PAC thermodilution for CO determination, there is unfortunately no bedside gold standard for determining optimal ventricular filling. In the absence of a good measure, the pulmonary capillary wedge pressure (PCWP) using a PAC is commonly used. However, the PCWP is subject to a number of technical and disease related problems. Oesophageal doppler waveform analysis has been increasingly evaluated as a method for determining optimum cardiac preload.

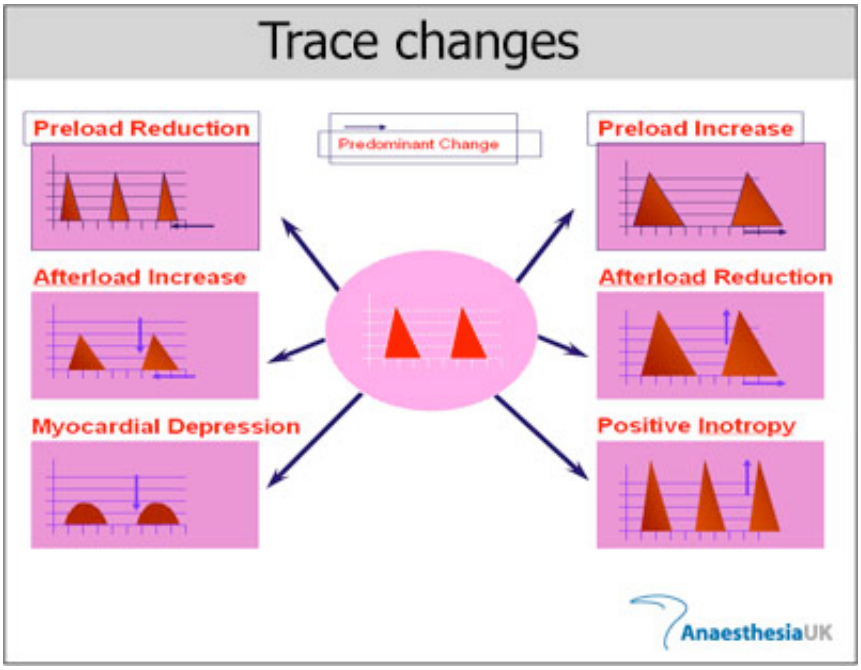
The key preload parameter of interest is the flow time; the time required from the start of the waveform upstroke to return to baseline. Flow time represents the duration of left ventricular systole and makes up one third of the cardiac cycle or cycle time. Since the flow time (FT) is heart rate dependent it is typically corrected (FTc) to a rate of 60 bpm and compensates for the change in duration of systole.

It is analogous to the corrected QT interval on the ECG.

FTc = FT ÷ vcycle Time

Heart Rate (bpm)	Cycle Time (s)	Flow Time (s)
60	1	0.333
45	1.333	0.444
75	0.8	0.266

A low FTc value (<330 msec) is seen with a vasoconstricted circulation e.g. hypovolaemia, excess arterial constriction (e.g. vasoconstrictors), major circulatory obstruction (e.g. pulmonary embolus). A raised FTc (>360 msec) is seen with a vasodilated circulation e.g. sepsis, hyperpyrexia



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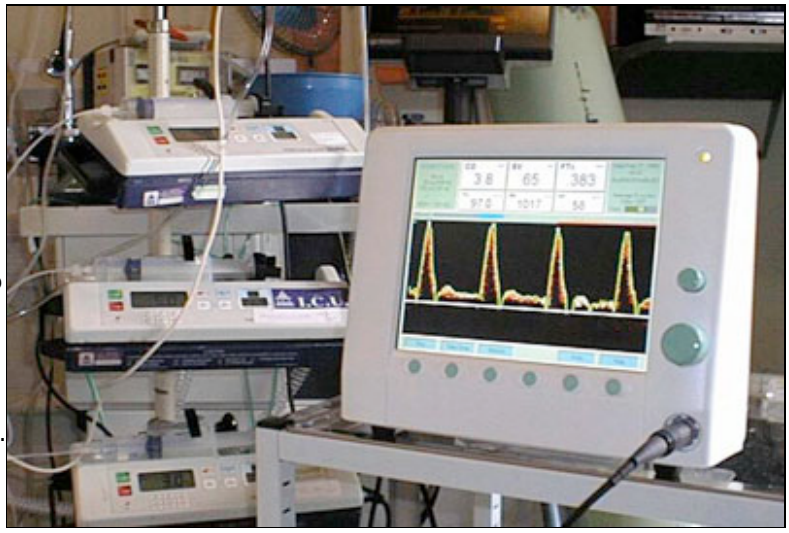
Oesophageal doppler variables



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Examples of CardioQ waveforms

AnaesthesiaUK would like to thank Dr Robert Kong, Consultant Cardiac Anaesthetist, Sussex Cardiac Centre, Royal Sussex County Hospital for providing these images.

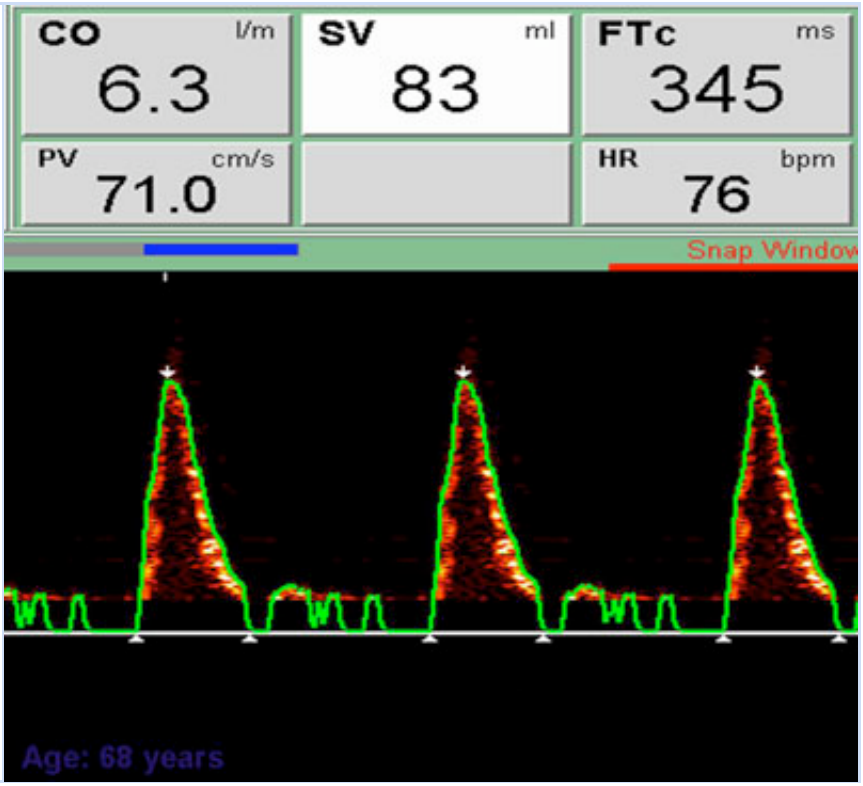
Normovolaemia

Whip crack sound

Wide bases – within normal ranges

Tall peaks – adequate Peak Velocity for age

All parameters appear to be within the normal limits

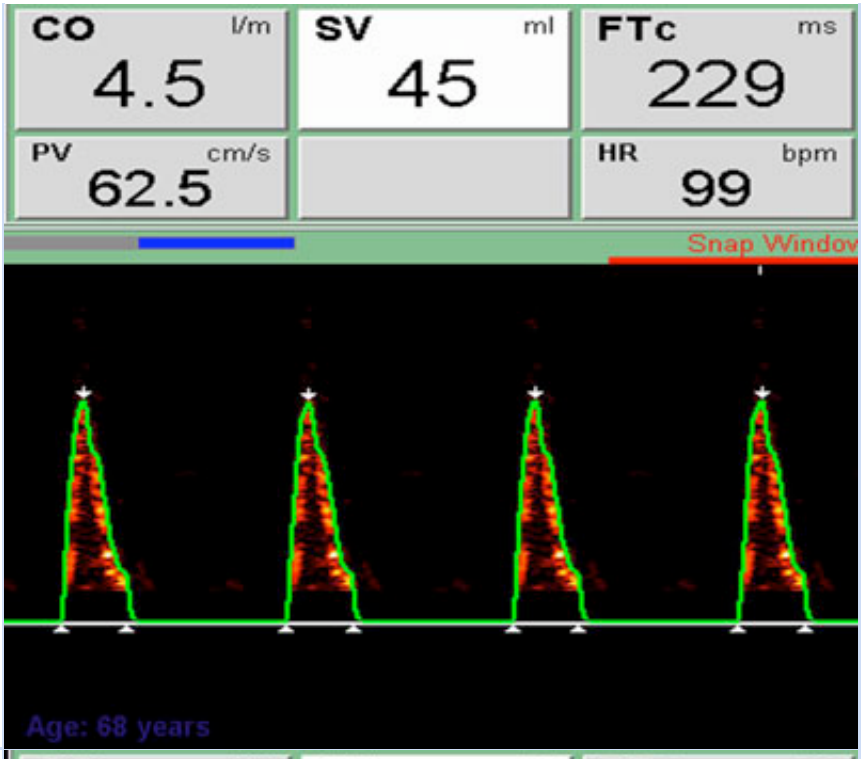


Hypovolaemia

Narrow waveform thus low FTC

Good PV

Decreased CO,
SV & borderline high HR

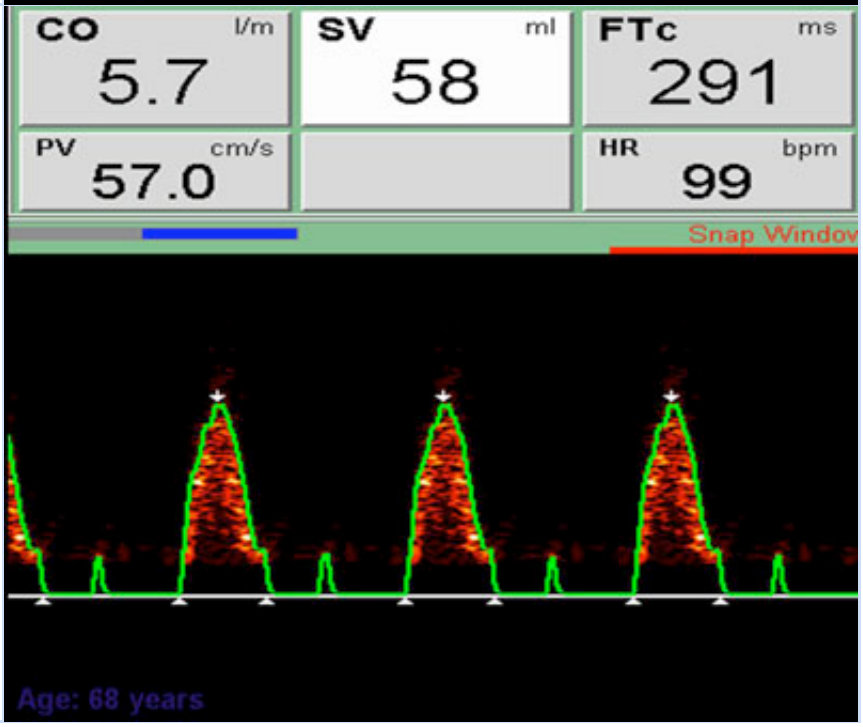


Hypovolaemia
following fluid challenge 200mls

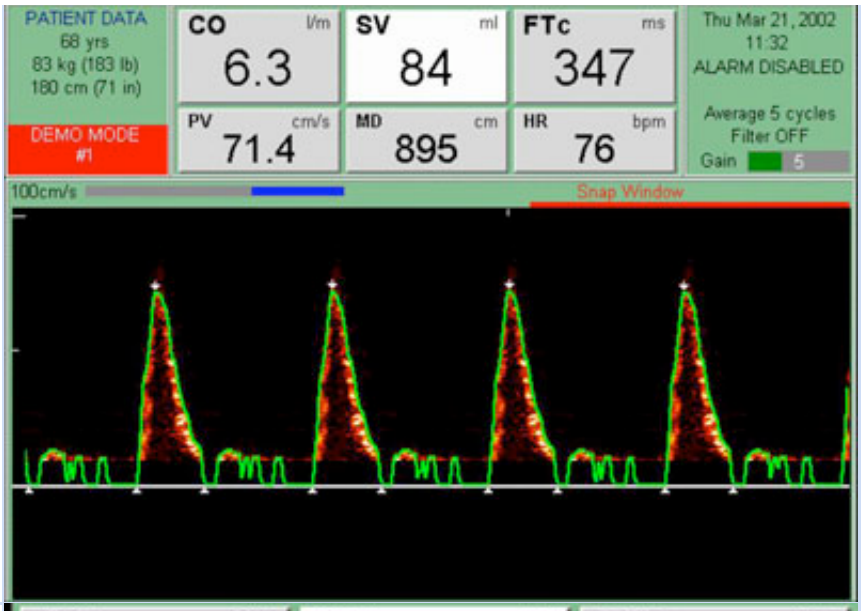
Audible change;

Widened bases – FTc improving

Good peaks – PV within range
CO, SV improving



Hypovolaemia
following fluid challenge 600mls



Compensated hypovolaemia

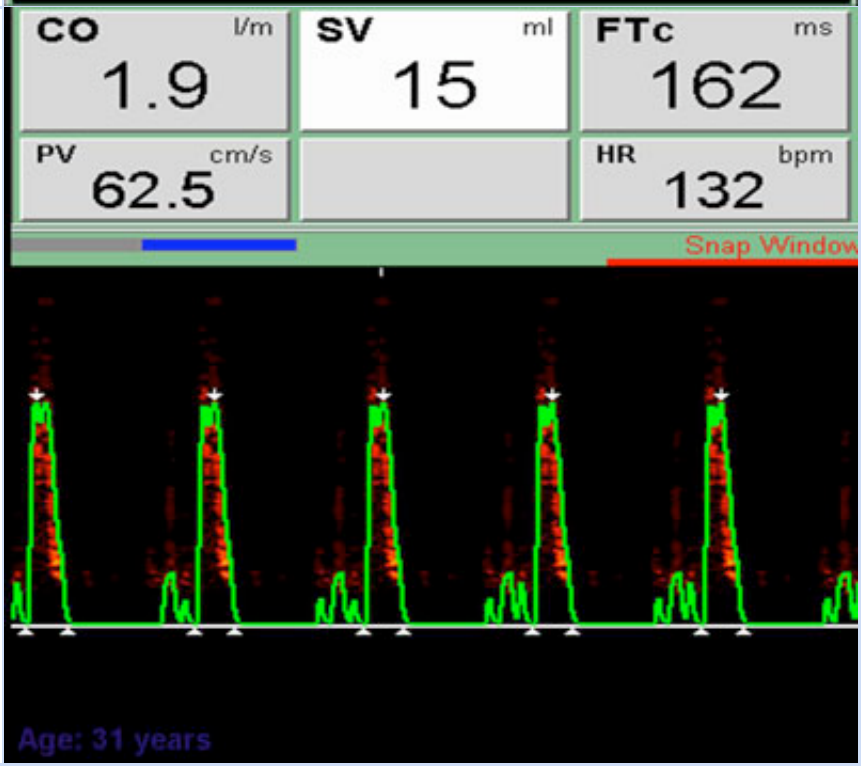
Chihuahua sound;

Narrow bases – low FTc;

Diminished peaks – low PV for age;

Decreased CO, SV;

Increased HR;



Increased afterload

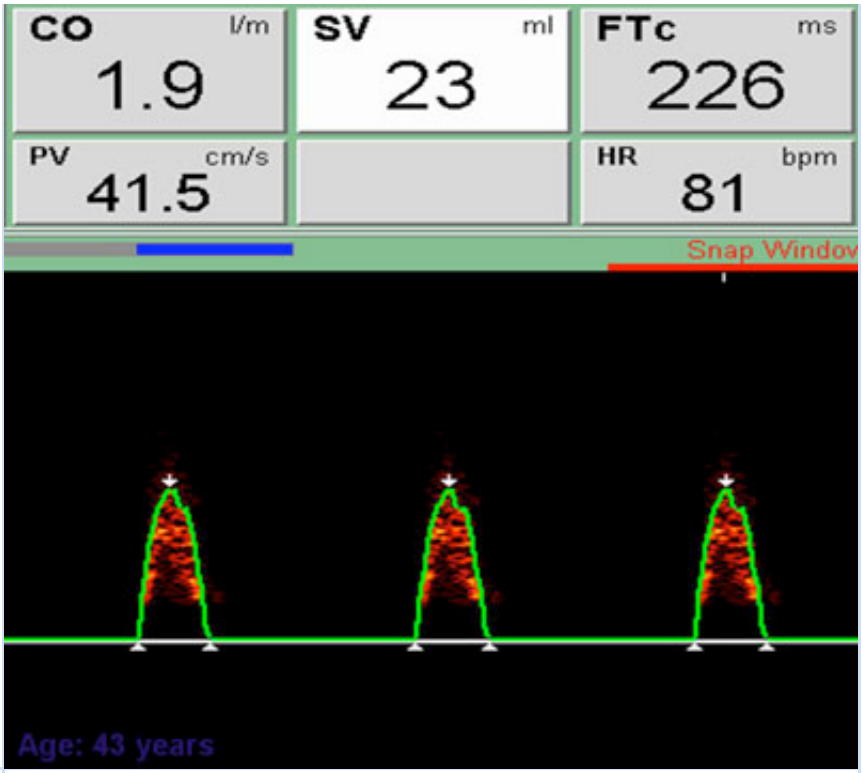
Characteristic sound

Narrow bases – low FTc

Low peaks – low PV for age

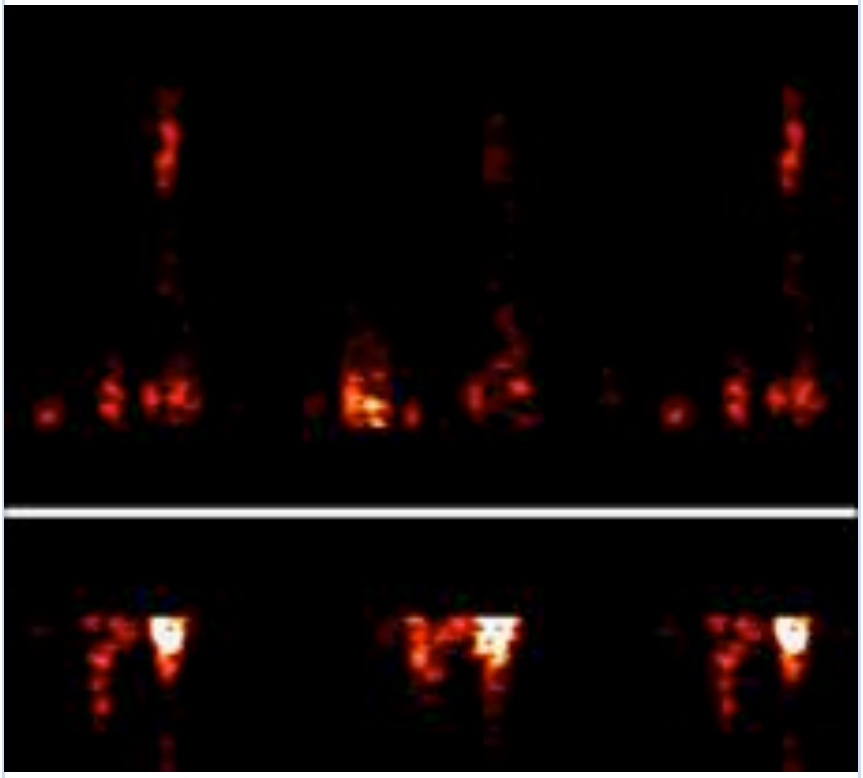
Decreased CO & SV

Unchanged heart rate



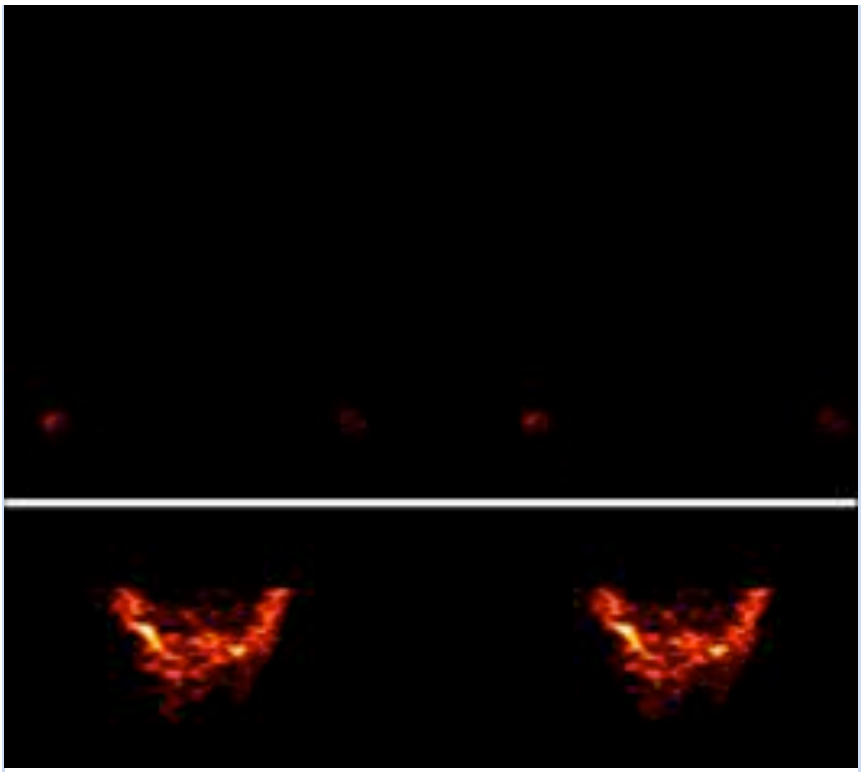
Intracardiac

Correct depth, rotate tip

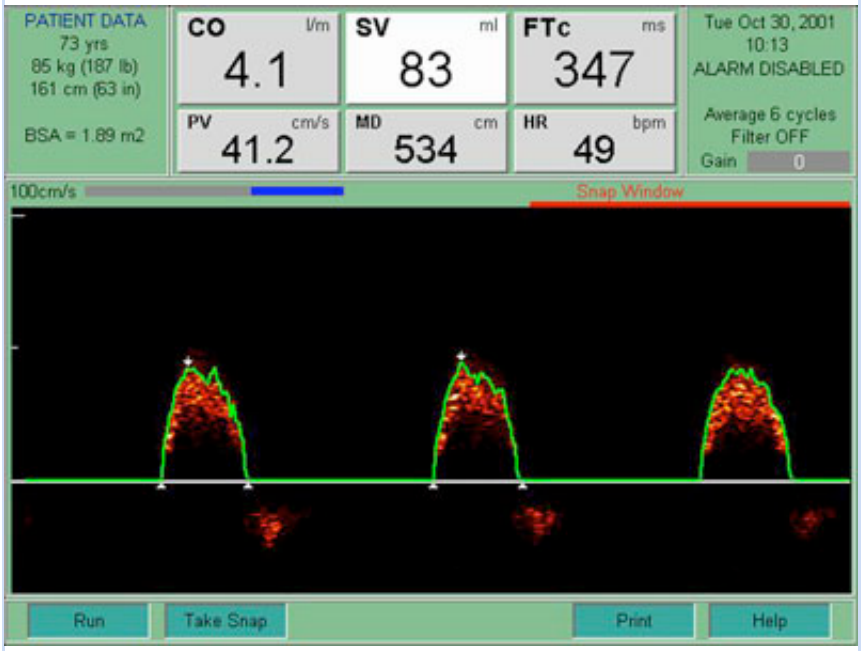


Venous

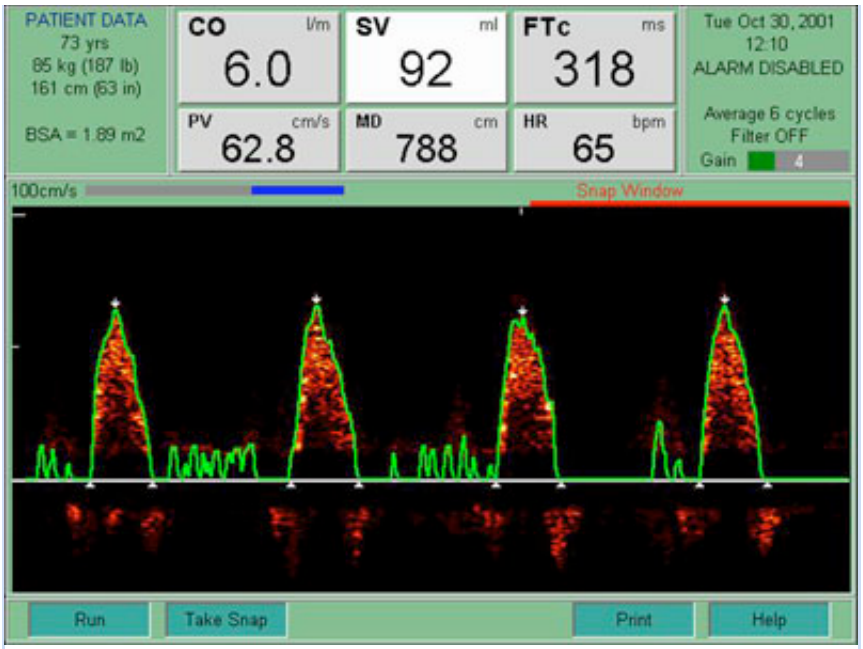
Correct depth, rotate tip



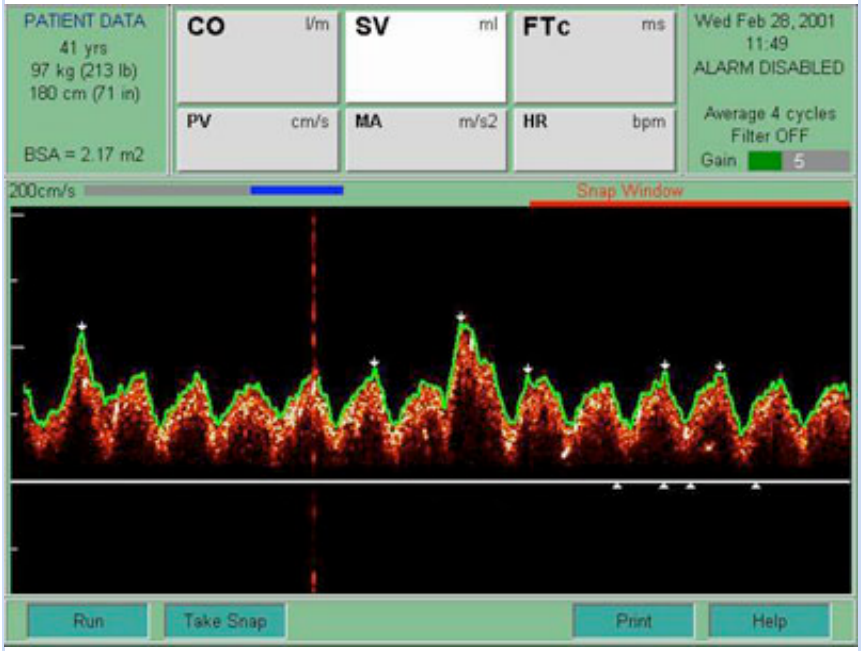
Aortic Stenosis before surgery



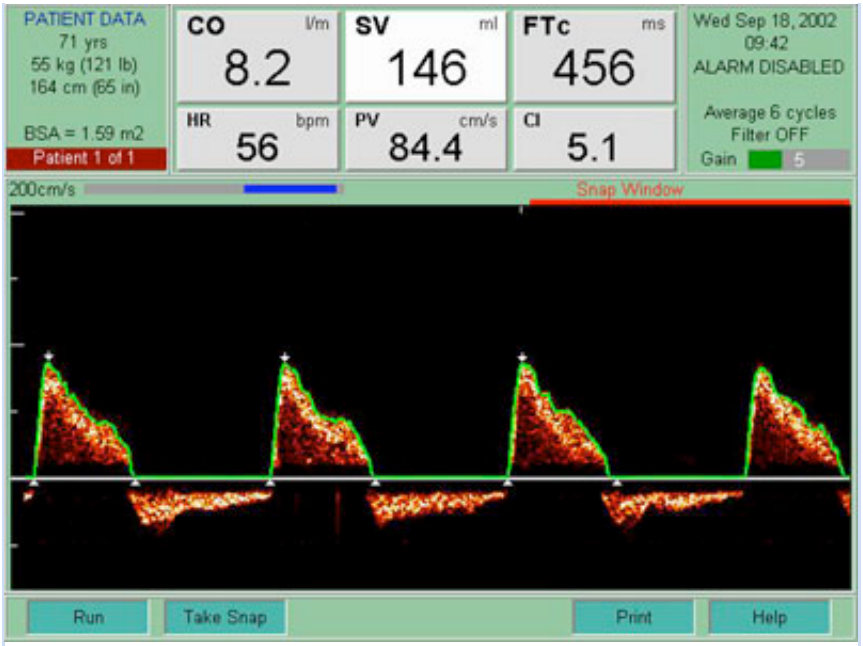
Aortic Stenosis- After AVR



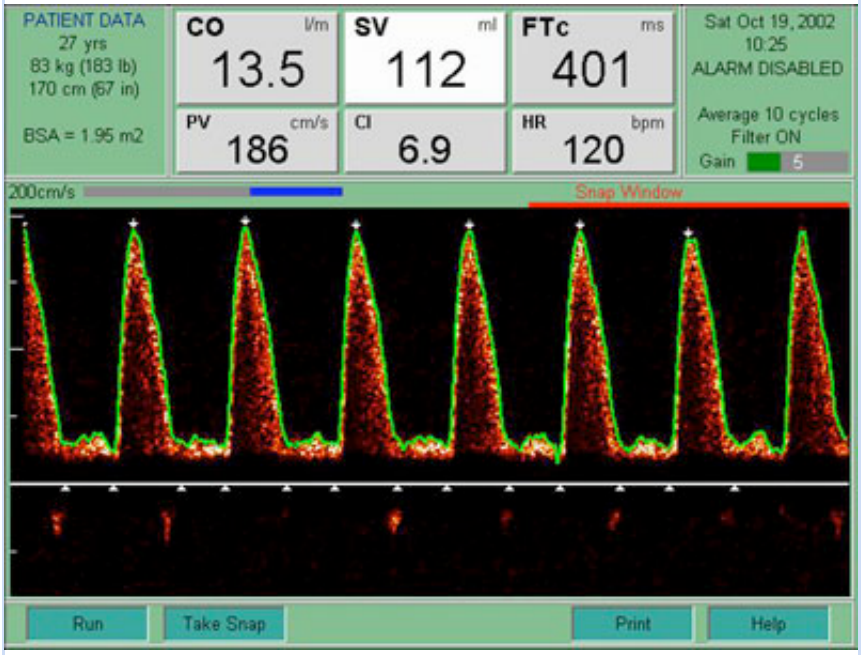
Cardiopulmonary bypass pulsatile flow



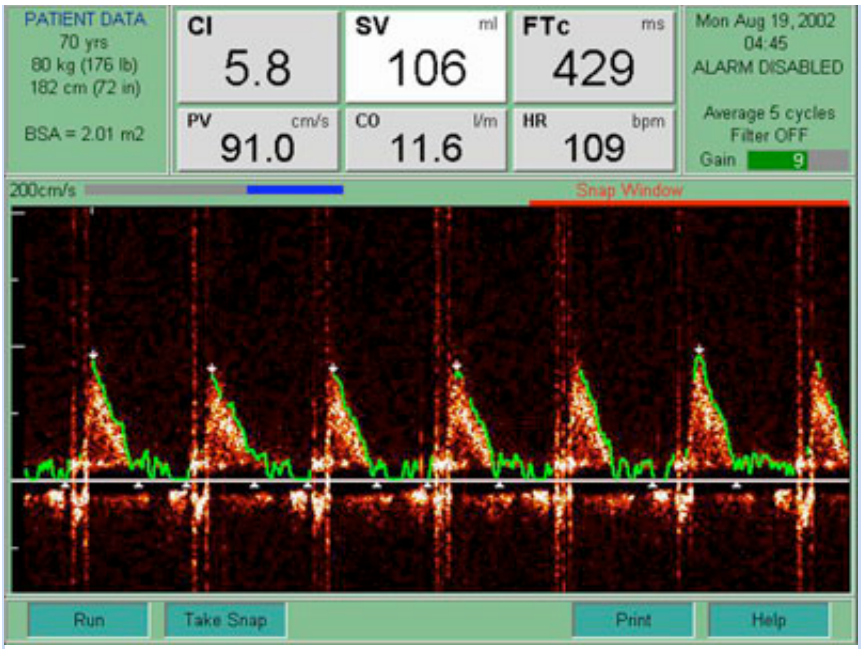
Aortic Regurgitation



Hyper-Dynamic



Wall Thump



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Summary

Interpret the waveform

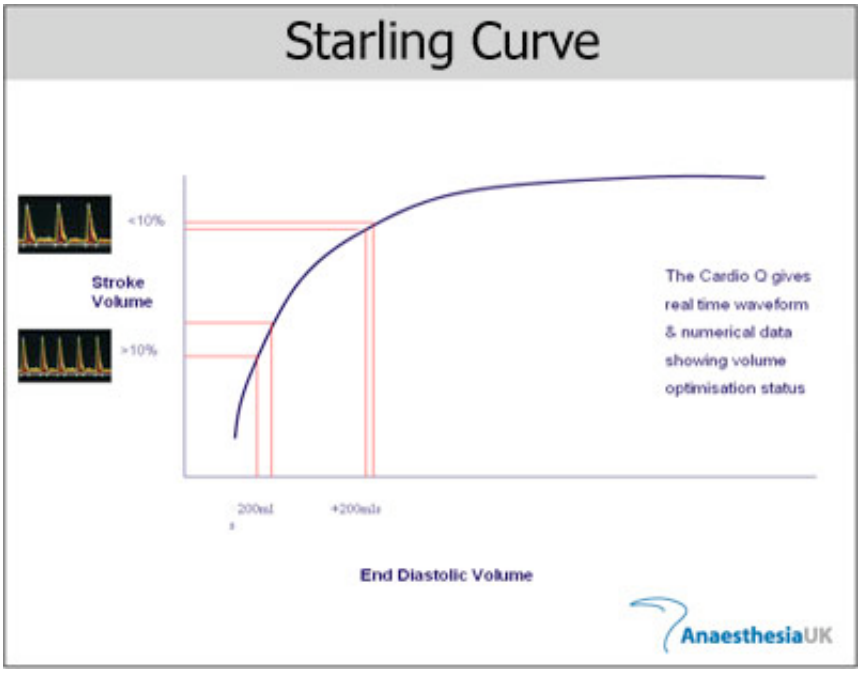
- FTc is inversely related to SVR
- PV can be used as an index of contractility
- Concurrent shifts in FTc and PV can indicate changes in afterload

Optimal descending aortic waveform signal

- Sharpest sound
- Tallest peaks
- Spectrum of colours

Fluid challenge

- Follow Frank-Starling law
- Look for at least a 10% increase in Stroke Volume after giving a fluid challenge



To obtain further information about the CardioQ, please contact Deltex Medical using one of the following methods:

UK Sales
Deltex Medical Limited
Terminus Road
Chichester
PO19 8TX

Customer Service
0845 085 0001

Fax