Oesophageal Doppler Monitoring using the CardioQ & CardioQ-ODM

Workbook for Operating Department Practitioners & Theatre Staff
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Welcome to the Deltex Medical CardioQ™/CardioQ-ODM™ Workbook. This workbook is designed to introduce Operating Department Practitioners and Theatre Staff to Oesophageal Doppler Monitoring using the CardioQ/CardioQ-ODM.

Individualised Doppler Guided Fluid Management (iDGFM) using the CardioQ/CardioQ-ODM has been shown to reduce postoperative hospital stay and reduce complications. An oesophageal Doppler probe is inserted into the patient’s oesophagus, and measures velocity of blood flow in the descending aorta. The CardioQ/CardioQ-ODM then displays a velocity/time waveform, providing information for the Clinician to safely manage the patient’s fluid status during surgery.

The workbook is split into 4 sections:

- Section 1 – Anatomy & Physiology
- Section 2 – Oesophageal Doppler Probes
- Section 3 – The CardioQ/CardioQ-ODM
- Section 4 – Waveform Analysis

For your own benefit, we recommend that you work through Sections 1-4 in order and at your own pace, answering the questions for each section before you move on to the next section.

Before you start the workbook, we recommend that you have a basic understanding of oesophageal Doppler monitoring. It would be helpful to have an oesophageal Doppler probe and CardioQ/CardioQ-ODM to hand to familiarise yourself with the probe and monitor. Further useful information can be found in the CardioQ/CardioQ-ODM Operating Handbook and a relevant Anatomy and Physiology textbook.

If you need any further information or help with any part of the workbook, please do not hesitate to contact your Deltex Medical Clinical Trainer/Clinical Application Specialist, who will be happy to help.

Enjoy the workbook.
1. Anatomy and Physiology

This section briefly describes the structures of the heart and key cardiodynamic definitions.

1.1 Anatomy of the Heart

- The heart consists of 4 chambers: 2 atria and 2 ventricles.
- Between the chambers are valves, which stop back flow of blood.
- The blood flows from the vena cava to the right atrium, then into the right ventricle.
- It continues to the lungs where it is oxygenated.
- It passes to the left atrium, then the left ventricle and finally ejected into the aorta.
1.2 Physiology of the Cardiovascular System

It is essential that the organs and tissues be perfused with blood, so that they receive the oxygen and nutrients that they require to function.

**Systole**
- This is the contraction phase of the cardiac cycle.
- As the left ventricle contracts, blood is ejected into the aorta.
- The oesophageal Doppler monitor will detect blood flow in the descending aorta as it passes the probe tip during the systolic phase. This will be converted by the CardioQ/CardioQ-ODM into an audible & visual waveform.

**Diastole**
- Diastole is the relaxation phase of the cardiac cycle.
- During ventricular diastole, the ventricles relax and fill with blood.
- At the end of diastole, the volume of blood that fills the ventricle is called the end diastolic volume.
- Minimal or no blood flow in the descending aorta will be detected by the oesophageal Doppler probe during diastole.

**Stroke Volume**
- The stroke volume is the volume of blood that is ejected from the left ventricle with each contraction. It is measured in millilitres.
- Cardiac output = Stroke volume X Heart rate.
- 3 factors that effect stroke volume are preload, contractility & afterload.

**Cardiac Output**
- Cardiac output is the amount of blood that is ejected from the left ventricle each minute. It is measured in litres/min.

**Preload**
- Preload is the amount that the cardiac muscle fibres are stretched when filling.
- This is dependent on the end diastolic volume - the greater the volume, the greater the stretch on the muscle fibre.
- Stroke Volume will be low if the patient's preload is inadequate, eg hypovolaemia.

**Contractility**
- Contractility is the strength of the contraction for a given preload.
- Patients with poor left ventricular function, will have a reduced contractility.

**Afterload**
- In order for the blood to be ejected into the aorta during systole, the pressure in the left ventricle must exceed that in the aorta. This high pressure causes blood to press against the aortic valve, opening it and ejecting the blood into the aorta. The pressure that must be overcome, is termed as the afterload.
- Vascular resistance affects the afterload.
- Vascular resistance depends on the diameter of systemic blood vessels.
- The diameter of the systemic blood vessels is affected by vasoconstriction & vasodilation.
- The change in vascular resistance will affect the pressure in the aorta, thus affecting the afterload.
- If the systemic vessels are vasoconstricted the lumen will be narrower than normal and therefore the pressure in the aorta that the ventricle must overcome will be greater. The patient is said to have a high afterload.
- If the systemic vessels are vasodilated, the lumen will be wider than normal and therefore the pressure in the aorta that the ventricle must overcome will be less. The patient is said to have a low afterload.
The Frank-Starling Curve

Within limits, the greater the heart muscle is stretched during filling, the greater will be the force of contraction and the greater the quantity of blood pumped into the receiving vessels.

The Frank-Starling curve is the relationship between the preload and the stroke volume. If the patient is on the steep part of the curve, a rapid and reasonable fluid challenge, eg 200mls, will give rise to a >10% increase in the stroke volume. If there is a > 10% increase in stroke volume it would suggest that the patient is not yet fluid optimised and may benefit from a further fluid challenge.

An inadequately fluid filled patient will respond positively to a fluid challenge giving rise to a 10% increase in stroke volume and therefore rising up the Starling Curve. When this rise is less than 10% this would suggest that a further fluid challenge will not be beneficial.
Compensation Mechanisms

If oxygen demand changes, or cardiac output falls, then the body will use various mechanisms to try and compensate. If the cardiac output is inadequate and oxygen delivery is not sufficient, then cellular dysfunction can occur and even cell death. This is called shock.

Compensation mechanisms are as follows:

- A decrease in blood pressure will be detected by baroreceptors in the body.
- They will stimulate the sympathetic nervous system and cause the release of hormones.
- This will cause vasoconstriction of the arterioles and veins in the skin, kidneys and abdominal viscera, which will help maintain venous return.
- There may also be an increase in the heart rate and in the force of the contraction during the systolic phase.
- Due to a reduction of blood flow to the kidneys, the renin-angiotensin-aldosterone pathway will be activated. This will cause the secretion of hormones which vasoconstrict the vessels and cause the kidneys to reabsorb water thus increasing blood volume.
- Water is also conserved by the kidneys following hormone secretion, when a drop in blood pressure stimulates the posterior pituitary gland.
1.3 Questions

1. Describe systole.

2. Describe stroke distance.

3. Define cardiac output.

4. Define stroke volume.

5. Give the equation that relates cardiac output and stroke volume.

6. Define preload.

7. Define contractility.

8. Define afterload.

9. Describe the Frank-Starling law.

10. Describe the mechanisms the body can use to cope with changes in oxygen demands.
2. DPn and I₂n General Probe Information

2.1 DPn and I₂n

- DPn are available for sedated or anaesthetised patients; I₂n are available for sedated, anaesthetised or awake patients.

- DPn are available in 6, 12 and 240 hours.

- I₂n are available in 6, 24 and 72 hours.

- These probes are intended for use on adults (16 years and above) and are single patient use.

- A dedicated paediatric probe and monitor are available separately.

- The probe is latex free.

- The probe is approximately 90cm long with depth markers at 35cm, 40cm & 45cm to facilitate correct probe placement within the oesophagus, at approximately T5-T6.

- Descending aortic signals are normally acquired between 35cm (distal marker) and 40cm (middle marker) when placed orally, or 40cm & 45cm (proximal marker) when placed nasally.

- The probe connector on the Doppler probe allows connection to the Patient Interface Cable (PIC).

- The probe can be withdrawn and stored for re-use on the same patient if necessary, providing that the re-use occurs within the defined probe life. If removal is transitory, refer to the hospital policy for cleaning of equipment.
2.2 Contra-indications

- Doppler probes (DPn and I2n) should not be placed in patients under 16 years of age. A dedicated paediatric probe and monitor are available separately.
- Do not use where nasal injuries are apparent or may have occurred.
- Do not use where nasal polyps exist.
- Do not use where there are circumstances of facial trauma.
- Do not use where there is a risk of brain injury.
- Do not use in patients undergoing intra-aortic balloon pumping.
- Do not use with carcinoma of the pharynx, larynx or oesophagus.
- Do not use with aneurysms of the thoracic aorta.
- Do not use with tissue necrosis of the oesophagus or nasal passage.
- Do use in close proximity to laser surgery.

For detailed precautions and warnings on probe usage, refer to the individual probe packaging for instructions for use.

2.3 Getting Started with the CardioQ

- Ensure the CardioQ is switched on with the Probe Interface Cable (PIC) attached to the monitor.
- Connect probe to PIC and patient data screen will appear.

Patient Data Screen

- Enter the patient’s age, weight & height into the table by rotating the Control Knob and pressing to enter the value, and follow instructions on screen.
- Once the age, weight & height have been entered, the options to either Accept or Change Data are displayed at the bottom of the screen. Once patient data is accepted, the values cannot be altered, so re-check the entered values before accepting the data.
NB. In order for the nomogram to be used, the patient data must fall within the appropriate ranges for age, weight and height. If they fall outside the limits, then the entered value will turn red and no volume parameters will be available for display when monitoring.

Adult nomogram parameters are as follows:

- Age 16 to 99 years.
- Weight 30 to 150Kg (66 to 330lbs).
- Height 149 to 212cm (59 to 83in).

- Once data is accepted, the Probe Focus Screen is activated.
- The probe can now be inserted.

### 2.4 Getting Started with the CardioQ-ODM

- Ensure the CardioQ-ODM is switched on with the Probe Interface Cable (PIC) attached to the monitor.
- Connect probe to PIC.
- Select New patient.

**Patient Data Screen**

- Enter ID number using the Control Knob or press Auto number for CardioQ-ODM generated ID.
- Select Gender.
- Enter patient age, weight and height using the Control Knob and follow instructions on screen.
2.5 Probe Insertion

Liberally apply a water-based lubricant to the tip of the probe - this will aid insertion and signal acquisition.

- Insert the probe to the required depth marker.
- The probe is now ready for focusing.

2.6 Probe Focus

- A good descending aortic signal has the sharpest sound with the highest peak and correct waveform amplification.
- Both audible and visual signals are used to facilitate probe focusing.
- Adjust the volume control to listen for the sharpest clearest sound. A typical descending aortic waveform sound is identified as a whipcrack sound.
- The “ideal” aortic waveform should have a sharp, well-defined outline with a predominantly black centre as shown below.
- It should have a yellow and red colouring in the outline and a small amount of white in the trailing edge of the waveform.
2.7 Additional Features

- Use Peak Velocity Display to identify highest peak.
- Adjust the scale between 50cm, 100cm and 200cm on the CardioQ or adjust the range between 50cm, 100cm, 200cm and 250cm on the CardioQ-ODM if required.
- Activate the filter only to reduce noise from heart valves or from “wall thump”.
- Use auto gain or adjust gain manually to ensure adequate signal strength.
- If the gain is set too low, a faint trace will be displayed. See above images from 2.6 Probe focus.
- If the gain is set too high, this may result in the trace being too bright.

2.8 Probe Expiry

- The bar above the left hand corner of the waveform area shows length of time until probe expiry. See handbook for further details.

2.9 Probe Disposal

- Disposal should be in accordance with hospital policies.
### 2.10 FAQs

**Q. I have a “no probe connected” message on the Screen**

A. Check that the probe is firmly connected to the PIC and that the PIC is inserted into the front of the CQ. If necessary, try a different PIC. If problem persists retain probe and contact Customer Services on 0845 085 0001.

**Q. Why can’t I change the patient details?**

A. Once the patient details have been accepted, the values cannot be changed. If the values are incorrect, use a new Doppler probe.

**Q. When entering the patients’ weight, do I enter dry, ideal or actual body weight?**

A. Enter the patients’ actual body weight at the time of placing the probe.

**Q. Can other tubes be placed in the oesophagus while the probe is in situ?**

A. Yes. Oro/nasograstric tubes and temperature probes can be used. There may be a diminished signal when using the Doppler probe alongside a NG tube if the NG tube is in the path of the Doppler transmission. The air in the tube can diminish the intensity of the Doppler signal. Suggestions to avoid this situation include inserting the Doppler probe before the NG tube, or placing the Doppler probe to the left of the NG tube.

**Q. Can the patient bite through the probe?**

A. There have been no reported cases of this.

**Q. How do I know I have the best waveform?**

A. Typically, the highest peak and the sharpest audible pitch indicates the best signal. Use the volume control and PVD to achieve these.

**Q. The top of the waveform is not visible on the Screen?**

A. In Probe Focus Screen, alter the scale or range setting so that the top of the waveform is visible.

**Q. There are orange spikes at the beginning of systole preventing the monitor from auto gaining the waveform. What are they and how do I stop them?**

A. Low frequency signals may interfere with the measurements, usually excess noise from heart valves. Try adjusting the probe position, or if necessary activate the filter to help eliminate this problem.

**Q. What is the gain for?**

A. Gain will adjust the signal strength to ensure best amplification. This can be done manually or automatically by using “auto-gain” in Probe Focus Screen.
2.11 Questions

1. At what length on the probe are the 3 depth markers?

2. At what level should the probe tip lie in the oesophagus?

3. What is the PIC?

4. What 3 values are required on the Patient Data Screen?

5. What happens if the values entered are outside the ranges?

6. What will aid insertion and signal acquisition?

7. Why is it crucial to have the correct probe depth in the oesophagus?

8. What 3 characteristics should the ideal descending aortic waveform have?

9. What does “Auto-Gain” do?

10. What is the ideal colour scheme for a good, well defined descending aortic waveform?
3. General Information

The CardioQ/CardioQ-ODM uses Doppler ultrasound to monitor cardiac function and fluid status.

The CardioQ/CardioQ-ODM is designed for use with the range of Deltex Medical oesophageal Doppler probes.

For a further general description of the CardioQ/CardioQ-ODM, please refer to the appropriate Operating Handbook.

*Image of CardioQ-ODM with I2S probe*
3.1 User Features for CardioQ

When monitoring, the following features are available;

**Freeze**
- Activate Freeze to stop the display to examine the waveform more closely.
- Adjust the scroll indicator bar, shown in blue, using the Control Knob to view previous data.
- If you wish to store a snap of the window, press Take Snap. You can store up to 5 snaps per patient in the CardioQ memory and view them in the trends.
- Press Run to return to full screen.

**View Trend**
- The CardioQ records data for all parameters and displays the information graphically.
- 48 hours worth of trended information can be viewed.
- Snapshots on SVR calculations and other events are stored on the events line in the historical data.
- Every 30 seconds, information is averaged and stored.
- Information is not collected when in the Probe Focus Screen.
- Press View Trend to display patient history in CardioQ.
- Scroll through the data using the Control Knob.
- Press Next Event or Previous Event to locate events stored.
- The vertical blue line within the graphical data indicates the time of the displayed data.
- Press the Control Knob to view all parameters or any events stored at that time.

**Events / SVR / SVRI**
- To calculate SVR/SVRI, press Events / SVR, then Calculate SVR & enter the patient’s MAP & CVP by rotating the Control Knob and pressing to enter.
- The SVR/SVRI will be stored in the trends as a yellow marker on the events line. Press Finished to return to main menu.

*NB for DO₂ calculations, follow steps for SVR calculations as above, and select DO₂.*

**Cycles Settings**

The number of cycles currently selected will be highlighted in blue.
To alter the number of cycles over which the calculated results are averaged;
- Press Focus and then Cycles;
- Rotate the Control Knob to alter and then press to select;
- Press Finished to return to the main menu;
- Deltex Medical recommend monitoring over 5 cycles, unless your patient has fast AF or the patient is in theatre and there is a lot of diathermy interference.

The cycles should then be altered to:
- Fast AF – 20 cycles;
- Diathermy – Display each cycle.

For additional features refer to Operating Handbook.

For assistance contact Customer Services on 0845 085 0001 or your local representative.
3.2 User Features for CardioQ-ODM

When monitoring, the following features are available;

Snapshots, Screenshots and Creating a Graph

- Press Freeze and use the Control Knob to select the waves to either take a snapshot, save the screen or add a point to a graph. Up to 8 snapshots or 20 screenshots can be stored per patient.

- To view graphs or snapshots, select Home, Graphical trends or Snaps. Then press Select snap or Compare snap.

SVR

- Press Freeze, Home, Additional calculations, SVR and then Calculate SVR. Enter additional data as instructed and then select Accept data.

DO₂

- Press Freeze, Home, Additional calculations and then Sample DO₂ to record time of blood sample. Press Home, Additional calculations, DO₂ and then calculate DO₂. Enter additional data as instructed and then select Accept data.

Events

- Press Home and Events. Add event details as required.

Trends

- Press Home and Continuous trends. Use the Control Knob to select details of data trends, snapshot or events.

Customising a User Setup

- Press Home, Monitor setup, Select user, User settings and then Select results or Machine settings. Follow the on-screen instructions to make changes. Then press Save settings.

NB Changes for Basic and Basic Index settings cannot be saved. A new user would have to be created first;- Press Home, Monitor setup, Select user, Copy user, Change name.

Offloading

- This can be done in a No Probe, Used Probe or Expired Probe Screen. Data is stored on the monitor until the patient is deleted. Patients will be deleted automatically if space is needed for a new patient.

- Insert a USB in the rear of the monitor. Use the Control Knob to select a patient, then press Offload patient data. Trend data, screenshots etc can be viewed on a computer.
3.3 Questions

1. How do I take a snapshot of a particular part of the waveform in CardioQ or CardioQ-ODM?

2. How many snapshots can I store in a) CardioQ and b) CardioQ-ODM?

3. How do I recall the snapshot in CardioQ or CardioQ-ODM?

4. There is a lot of diathermy interference on the screen – which setting could you alter and to what setting would you alter it?

5. How do I clean the equipment between patients?

6. How do I review historical data?
4. Waveform Analysis

The CardioQ/CardioQ-ODM measures the velocity of the blood flow in the descending aorta. An oesophageal Doppler probe is placed with the tip at a level of approximately T5-T6. A velocity/time waveform of the blood flow in the descending aorta is displayed.

4.1 Interpreting Data

It is recommended that the data gained from the CardioQ/CardioQ-ODM must be used in conjunction with assessment of all other patient physiological data.

*Image of Descending Aortic Waveform*
4.2 Key Results

**Stroke Distance (SD)**

- Stroke distance (SD) is the distance in cm that a column of blood moves along the aorta with each contraction of the left ventricle of the heart.
- Values are age and size dependent.
- Changes in SD will be directly related to changes in stroke volume (SV).

**Stroke Volume (SV)**

- Stroke volume (SV) is the amount of blood ejected by the heart during each systolic period.
- Typical values for SV in a healthy adult are 60-100ml.
- Stroke Volume Index (SVI) is the SV normalised for body surface area (BSA).
- Typical values for SVI in a healthy adult are 35-65ml/m².
- A low value for SV/SVI may indicate hypovolaemia or an increased afterload.
- A high value for SV/SVI may indicate decreased afterload.
- Administration of certain drugs may affect the SV/SVI.
- Typical values should not be confused with a physiological target for a specific patient.

**Flow Time Corrected (FTc)**

- Flow time corrected (FTc) is the duration of flow during systole corrected for heart rate.
- Typical values for FTc in a healthy adult are 330-360 ms.
- A low value for FTc may indicate hypovolaemia, or other causes of increased afterload.
- A high value for FTc may be seen in patients with low afterload.

**Peak Velocity (PV)**

- Peak velocity (PV) is the highest blood velocity detected during systole, and may be used as an indication of left ventricular contractility.
- Typical values for PV are: 90-120 cm/s for a 20 year old; 70-100 cm/s for a 50 year old; and 50-80 cm/s for a 70 year old.
- Typical values should not be confused with a physiological target for a specific patient.

**NB** References are available at www.deltexmedical.com
4.3 Individualised Doppler Guided Fluid Management (iDGFM)

When using the iDGFM algorithm to target the patient’s fluid status, consider SV/SD responses to fluid challenges. A rise of 10% in SV/SD following a 200ml colloid challenge, indicates a positive response to filling. See algorithm below.
4.4 Examples of Doppler Waveforms

**Hypovolaemia**

This patient was having an emergency laparotomy and was suspected to be hypovolaemic. Her SV/SD were low and the FTc was short indicating an increased afterload. The most common cause of this is hypovolaemia. Following 200ml colloid challenge, the SV increased to 50ml and the SD increased to 6.4cm indicating a positive response to filling.

**Vasodilated Circulation**

This patient was undergoing an elective laparotomy, with an epidural infusion in progress. His SV/SD were high and FTc was lengthened. This may indicate a vasodilated circulation, often seen in this situation. Following a 200ml colloid challenge, the SV increased to 118ml and the SD increased to 14.2cm indicating a positive response to filling. A further fluid challenge only increased the SV to 125ml and the SD only increased to 14.8cm. A vasonstrictor was commenced as the patient’s BP remained low.
Vasoconstricted Circulation

This patient was undergoing elective bowel resection and a vasoconstrictor was administered, resulting in an increased afterload. This is indicated by the low SV/SD, short FTC and reduced PV.

Cardiac Failure

This patient was having a hip replacement and has a history of left ventricular dysfunction. Cardiac failure is indicated by low SV/SD, reduced PV with rounding of waveform.
Poor Focus

Typically represented by reduced brightness of waveform, therefore the green line cannot follow the waveform. The audible sound will also be reduced. Re-focus the probe.
4.5 Questions

1. What does the CardioQ/CardioQ-ODM measure?

2. What is stroke distance?

3. What is peak velocity?

4. What would indicate a change in afterload?

5. What is iDGFM and how does it relate to the Frank-Starling law?