ROUTINE CARDIAC OUTPUT MONITORING DURING GENERAL SURGERY – A FEASIBILITY STUDY

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Cardiac output (CO) is an essential tool in the management of a variety of conditions. Because of the difficulties, technical expertise required and expensive, cumbersome equipment needed and the associated morbidity and mortality, measurement of CO has been confined to the Intensive Care Unit and for the more critically ill patient. Physicians have been forced to make do with indirect indices such as blood pressure, pulse rate, urine output and skin temperature to make an educated guess as to the CO when managing patients.

The advent of an entirely non-invasive method of measuring cardiac output (USCOM) suggested that routine CO monitoring during general surgery could be a feasible proposition.

WHY DO WE MEASURE CO?

Blood Pressure (BP) = CO x Peripheral Vascular Resistance (PVR)

We measure BP routinely. The other two factors are desirable, but have not been practical until now. When there is a fall in BP is it due to decreased CO, decreased PVR or both? Using the USCOM, CO is measured directly and the PVR can simply be calculated.

$$\mathbf{PVR} = \frac{\mathbf{Mean\ BP}}{\mathbf{CO}} \quad \textbf{(Strictly, Mean BP-CVP/CO)}$$

Existing Methods of Measuring CO.

HIGHLY INVASIVE

1. Pulmonary Artery Catheterisation-e.g. Swan Ganz. =>5% Mortality. Continuous Thermodilution and Mixed Venous Oxyhemoglobin Saturation Techniques.
2. Pulse Contour Analysis-Arterial Catheters (PiCCO) -Useful for beat to beat monitoring of CO. Requires calibration with PAC.
3. Indicator Dilution - Central Venous & Arterial Catheters

LOW OR MINIMALLY INVASIVE

1. Transesophageal Echocardiography(TEE)
2. Transcutaneous Echocardiography(TCE)
3. Automated Border Detection
4. 3D Echocardiography
5. Doppler Ultrasound
6. Thoracic Bioimpedence
7. Gas Technology

FICK PRINCIPLE:

Cardiac output is the ratio between oxygen consumption(VO2) and arteriovenous oxygen difference(AVDO2)

$$CO = VO2/AVDO2$$

This is applicable with stable haemodynamics and FiO2 less than 60%. It requires central venous and arterial catheters and simultaneous collection of blood samples.
NICO applies the Fick Principle to carbon dioxide. It uses partial rebreathing through a specific disposable rebreathing loop and is non invasive.

$$CO = VCO2/CvCO2-CaCO2$$

Volume of carbon dioxide(VCO2) is calculated from minute ventilation and its CO2 content and arterial carbon dioxide(CaCO2) from the end tidal carbon dioxide (EtCO2). Under normal conditions venous carbon dioxide(CvCO2) can be omitted.

PROBLEMS:

1. Morbidity and Mortality
2. Complexity
3. Cost
4. Limited Accuracy and Precision
5. Availability

Ultrasonic Cardiac Output Monitor (USCOM)

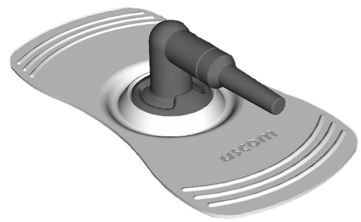
Mode of action:

The USCOM uses the simple concept that if we know the diameter of the aorta or pulmonary artery (PA), and we measure the velocity of the blood flow ejected with each beat of the heart, then we know how much blood is pumped by the heart with each beat, the stroke volume. Multiplying this by the heart rate gives us the total amount of blood pumped by the heart each minute, the cardiac output. The USCOM does not measure the size of the aorta directly, but deduces this from in-built nomograms based on the height and the weight of the patient. The nomograms, which have been extensively validated, provide a diameter for the aorta and PA which are more accurate than direct measurement. However, the monitor also provides for the manual inputting of an exact diameter that has been measured either by echocardiography, MRI scanning, or indeed directly measured during surgery. Relieving the examiner of the difficulty in measuring the diameter of the aorta or PA dramatically simplifies the estimation of cardiac output. The monitor can be used both in adults and in paediatric practice down to, and including, neonates.

Equipment.

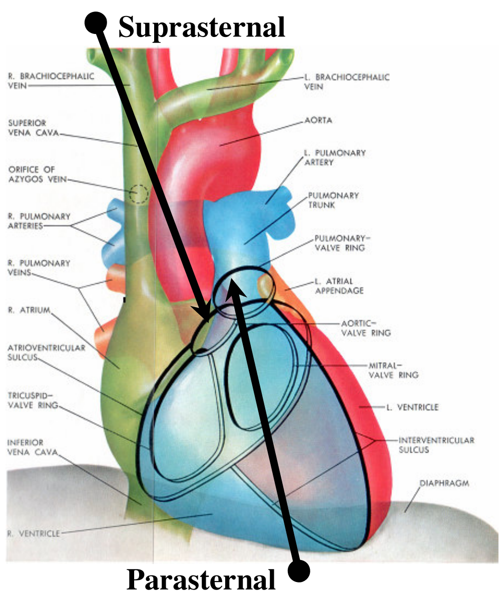
Monitor

Transducer

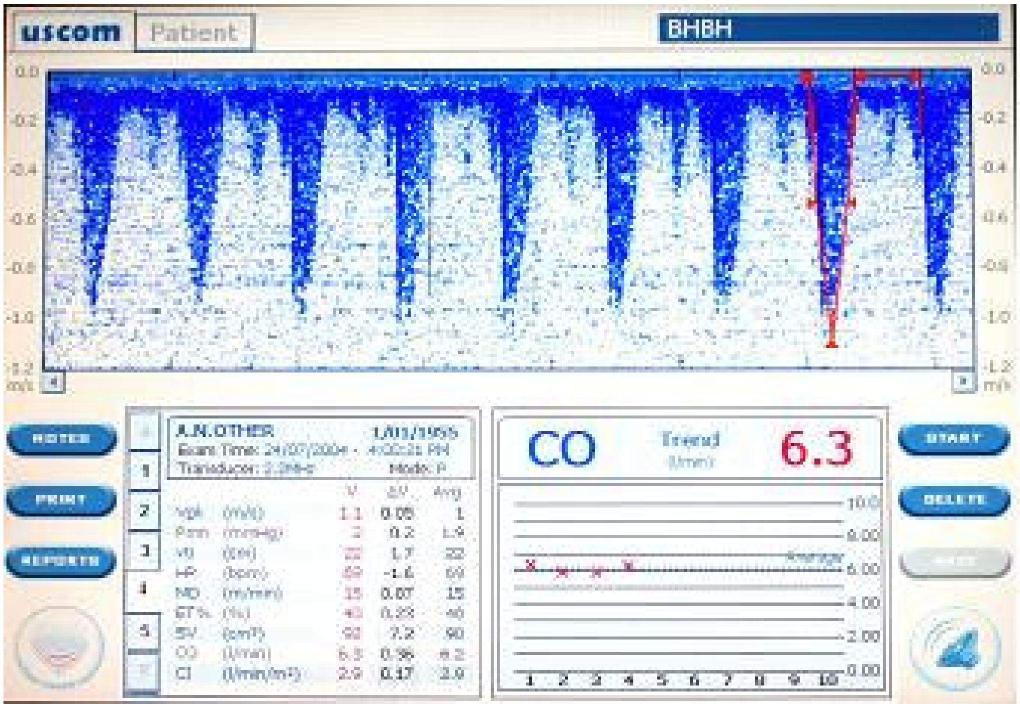


Technique:

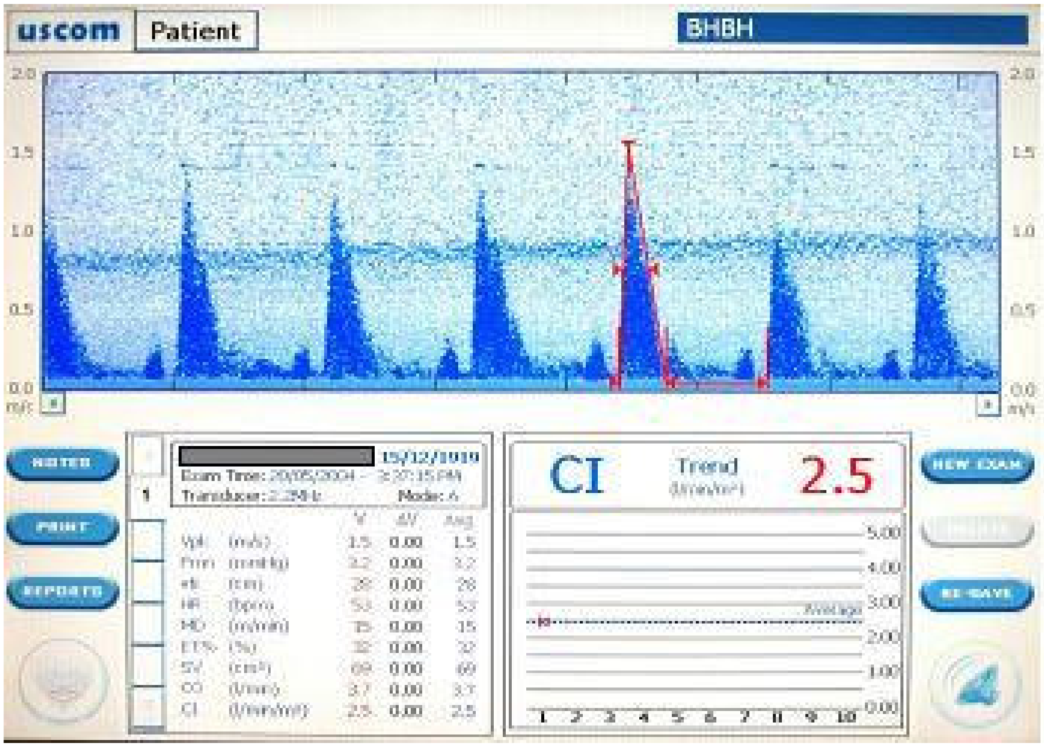
The patients biodata including height and weight are entered before starting measurements. From these data the vessel diameter is calculated. The aortic or pulmonary artery is used for the measurement. For the aorta, the continuous wave Doppler transducer is placed in the suprasternal notch and directed caudally, or at the apex and directed cephalad, whilst for the pulmonary artery, the transducer is sited at the left sternal edge and directed 20^{o} cephalad. The aim is to direct the beam of ultrasound along the axis of the artery, so as to be directly in line with the blood flow. This is achieved by a combination of anatomical landmarks, listening to the blood flow and valve sounds, and by visual inspection of the measured waveform. Once a series of uniform waves are obtained, the image is frozen on screen and flow velocity measurements made using touchscreen sensing.



PULMONARY VALVE TRACING



AORTIC VALVE TRACING

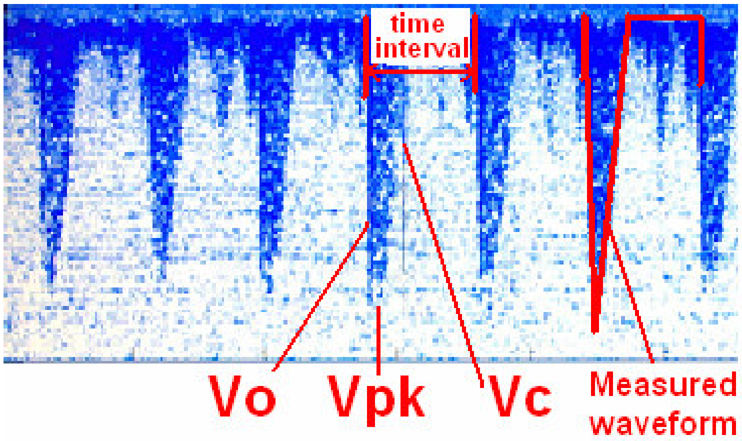


Measured indices:

- Vpk: velocity peak
- Pmn: mean pressure gradient
- vti: velocity time integral
- HR: heart rate
- ET%: ejection time (as percentage of total cycle time)

Calculated indices:

- Minute distance = HR x vti
- SV = vti x XSA
- CO = SV x HR
- CI = SV x HR/BSA



Vo = Pulmonary valve opens Vc = Pulmonary valve closes Vpk = Peak flow velocity

OUR FEASIBILITY STUDY:

Number of Cases	25
Types of cases	General Surgery,Orthopaedic,Gynaecology
Equipment	USCOM

Patients undergoing routine surgery were selected. We positively discriminated for patients with hypertension and cardiac disease. Informed consent was obtained from all patients. CO measurements were made pre-operatively, after induction, and then at regular intervals during the procedure. Post-operatively measurements were made in the recovery unit. Normally, aortic readings were used except where anatomical factors precluded this, in which case the pulmonary artery was used. We recorded the ease of performing an adequate measurement on a five point scale and also measured the degree of inter-observer variability for total cardiac output measurements.

RESULTS:

In our limited study we found that CO measurement using the USCOM was easy and informative during routine surgery. There was no additional pressure on the anaesthetist in terms of time or expertise and there was no clinically significant inter-observer variability.

LIMITATIONS:

1. Vessel/valve diameter assumed, hence vessel or valvular lesions can give erroneous results.

2. Anatomic difficulties, eg obesity, patients with ill-defined suprasternal notch, anomalous vessels, large goitre etc.

CONCLUSION:

The use of the USCOM to measure cardiac output during routine general surgery proved to be entirely feasible and practical with no significant increase in the demands made on the anaesthesiologist. There was minimal and clinically insignificant inter-observer variability on paired estimations.

We commend the use of the USCOM to anaesthesiologists as a new and welcome tool in the anaesthetic armamentarium.