Technical Note

Technologies that Measure Cardiac Output

INTRODUCTION

Cardiac Function Assessment with the HD03 Hemodialysis Monitor expands the role of the hemodialysis care team to managing the cardiovascular health of the patient. Transonic's measurement of cardiac output (CO) has the great advantage that it can measure CO during a dialysis session, thus observing and profiling cardiovascular function during the stress of removal of large amounts of liquid. These tests provide the nephrologist with on-site diagnosis of cardiac disease and with early indications of deteriorating cardiac conditions that may lead to disease.

Other technologies that measure CO include:

THERMODILUTION (Swan-Ganz, PA) CATHETER

This catheter is inserted into the superior vena cava and guided through the heart into the pulmonary artery. Indicator dilution changes are introduced via the injection of cold saline, and sensed with a thermistor.

+ It is today's gold standard for cardiac output measurement, also used for measuring pressures, fluid management and medication management. It has been on the market for more than 40 years.
- Highly Invasive (through the heart); has high variability (you must average 3 sequential measurements); mostly used in ICU and OR; 1% risk of damaging the heart; can be central gateway to infection; and requires expert skill to position through the heart and obtain reliable data. Is banned in some hospitals because of reports of a 24% higher risk of patient mortality within 30 days of PA catheter use (Connors *et al*, JAMA 1996; 297: 889-897) www. baxter.com

TRANSONIC ADVANTAGE: Compared to measurement of CO with the Transonic Hemodialysis Monitor, the Swan-Ganz catheter is very invasive, requires a separate hospital visit, is more costly, patient must be sedated, only of use in the ICU and OR.

CONTINUOUS CARDIAC OUTPUT ("CCO")

It is the same thermodilution catheter method as Swan-Ganz, but now the measurement is made continuously, and can be done automatically every 2 minutes. The thermal indicator change is introduced through a heating element in the PA catheter; as a consequence it uses more expensive Swan-Ganz catheters. Website: www.baxter.com

+ Automatic measurement, easy, no injections, no extra nursing time.
- Mostly the same as the standard PA catheter method (above): Highly Invasive; mostly used ICU and OR; risk of damaging the heart; can cause infection; requires expert operator; is banned in some hospitals because of reports of high co-morbid complications.

TRANSONIC ADVANTAGE: Compared to CO measurement with a Transonic Hemodialysis Monitor, the CCO catheter is very invasive, requires a separate hospital visit, is more costly, patient must be sedated, only of use in the ICU and OR.

ARTERIAL PRESSURE CURVE MEASUREMENT OF CO (PICCO).

This method employs "transpulmonary thermo-dilution" (a modified PA catheter method) to calibrate an "arterial pulse countour" method to indicate cardiac output rather than pressure from an arterial pressure sensor. It uses catheters inserted into a peripheral artery and vein, and is thus safer and quicker than conventional PA catheters. The method translates the pressure area under the curve into CO.

+ Less invasive than the PA catheter, and easier to install in patients. The presented CO data is more real time. For use on adult as well as pediatric patients.
- Inaccurate: while the correlation between pressure and cardiac output is correct at the thermal indicator calibration point, it is a wild guess to assume that changes in pressure from this calibration point correlate with changes in CO. (It is well known that during hemodialysis CO changes while pressure often remains constant.) For use mainly in the ICU and OR. Website: www.pulsion.de

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Technologies that Measure CO cont.

TRANSONIC ADVANTAGE: Compared to CO measurement with the Transonic Hemodialysis Monitor, PiCCO is invasive, requires a separate hospital visit, is more costly, patient must be sedated, only of use in the ICU and OR.

TRANS-ESOPHAGEAL ECHOCARDIOGRAPHY (TEE)

A probe as thick as a thumb is put into the esophagus. From there it can scan the heart in different modes: M-mode to see structures or Doppler to measure velocity in an certain area and depth. Websites: www.acuson.com, www.philips.com

+ Less invasive, lots of interest in medical field, sophisticated, gives a total view of the heart. It is a diagnostic tool that is well-accepted in cardiology and in anaesthesia.
- Very operator dependent; the physician must be a skilled and trained operator; patient must be sedated; expensive both in hardware investment, and in specialist's time to make the measurements; usually only done within ICU & OR.

Transonic Advantage: Compared to CO measurement with the Transonic Hemodialysis Monitor, TEE is invasive, requires a separate hospital visit, is more costly, patient must be sedated, only of use in the ICU and OR.

ULTRASOUND DOPPLER FLOW

Ultrasound technology uses a probe, as does TEE but a much thinner, pencil size probe, inserted into the esophagus. It is advanced to the point where the esophagus runs parallel to the descending aorta; this is where flow is measured. The measurement compares with police radar car speed measurements: it only measures flow velocity (meters/sec), not total heart output (Liters per minute).

+ Less invasive and easier to operate than TEE, real time monitoring.
- Still not easy to operate: it must be done by a physician trained to interpret Doppler signals.
- Patient must be sedated; not widely accepted and used, even after more than 20 years of development. It can only estimate CO because the cross sectional area of the aorta is not measured, and flow at this measurement point equals CO minus coronary and other side-branches. Extensive training is needed to interpret the Doppler velocity readings. Websites: www.arrowintl.com; www.deltex.com

TRANSONIC COMMENT: Compared to CO measurement with a Transonic Hemodialysis Monitor, US Doppler method is very invasive, requires a separate hospital visit, is more costly, patient must be sedated, only of use in the ICU and OR.

BIOIMPEDANCE

Non-invasive trans-thoracic impedance method, measures conductivity of the chest. Beat-to-beat changes of the heart and great vessels changes the conductivity of the chest. Software (into which the operator needs to feed patient data) estimates CO from these impedance variations.

+ Non-invasive, real time measurement
- An absence of the theory of operation is problematic. Thus sources of the errors are not well identified. Especially incorrect if used during hemodialysis because of significant changes of electrical parameters of blood and tissue. Nevertheless. it was heavily marketed for years. Measurement is operator-dependent, requires extensive training. In essence, the operator must enter data into the software program from which CO in healthy patients can be estimated; the software will then tell the operator that it measured the CO value he expected to begin with!! The method reports inaccurate and false CO in patients with heart problems. Website: www.cardiodynamics.com

TRANSONIC COMMENT: Bioimpedance is highly error prone. Should not be used during hemodialysis.

THE FICK METHOD

In the traditional, well validated version of this method, O_2 uptake or CO_2 output of the lungs is measured by placing a mask over the patient's mouth. Arterial and venous blood samples are taken and analyzed for O_2 or CO_2 content. CO is calculated from indicator dilution equations. This is an experimental, not clinical method, demanding skills and resources and steady-state patient conditions. A Novametrics version of the method goes under the brand name $NICO_2$. It uses a "partial rebreathing" technique to estimate blood CO_2 levels rather than blood samples.

+ Real time, non invasive.
- Patient most breath through a mask and needs stable cardiopulmonary state

TRANSONIC COMMENT The novel partial rebreathing method is less accurate than the Transonic CO method. It requires specialized hardware, and breathing through a mask.

Technologies that Measure CO cont.

ANGIOGRAPHY

This method requires catheter insertion in the lab. The catheter is inserted into he femoral artery in the upper leg and is guided into the coronary arteries. Contrast is then injected to make a picture or film.

+ Widely accepted as a standard heart diagnostic. Is the gold standard method for showing the size and mechanical motion of the heart.
- Highly invasive and high risk: every 1:1000 pt has cardiac arrest. Contrast medium cannot be eliminated from the blood stream in patients without kidney function. Costly, labor-intensive, must be done by an invasive cardiologist. CO measurement is very inaccurate (it must be estimated from the speed by which the contrast medium is cleared from the heart.)

TRANSONIC COMMENT: This method is not good for routine screening of hemodialysis patients: it is very invasive, requires a separate cath lab visit, is more costly, patient must be sedated, and it only identifies heart structure.Once cardiovascular problems are suspected, angiography is a good method for follow-up studies of the patient.

COLOR DOPPLER

With the use of a Doppler ultrasound scanner head applied to the chest, a trained cardiologist can visualize the structure of the heart, and estimate cardiac output from measured flow velocities and observed cross-sectional area of the ascending aorta or pulmonary artery.

+ Widely accepted as a standard heart diagnostic. Combines real-time pictures of the mechanical size and motion of the heart with estimates of cardiac output.
- Costly, labor-intensive, must be done by expert cardiologist, is very operator-dependent. Measurement is inaccurate because of the complex flow profiles in cardiac vessels, because flow velocities are measured off-axis, and because aortic cross sectional area is inaccurate as well.

TRANSONIC COMMENT: This method is not good for routine screening of hemodialysis patients because it requires a separate cardiac lab visit, and the expense of an expert cardiologist. Once cardiovascular problems are suspected, Color Doppler is a good method for follow-up studies of the patient.

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Transonic Systems Inc. is a global manufacturer of innovative biomedical measurement equipment. Founded in 1983, Transonic sells "gold standard" transit-time ultrasound flowmeters and monitors for surgical, hemodialysis, pediatric critical care, perfusion, interventional radiology and research applications. In addition, Transonic provides pressure and pressure volume systems, laser Doppler flowmeters and telemetry systems.

AMERICAS
Transonic Systems Inc.
34 Dutch Mill Rd
Ithaca, NY 14850
U.S.A.
Tel: +1 607-257-5300
Fax: +1 607-257-7256
support@transonic.com

EUROPE
Transonic Europe B.V.
Business Park Stein 205
6181 Elsloo
The Netherlands
Tel: +31 43-407-7200
Fax: +31 43-407-7201
europe@transonic.com

ASIA/PACIFIC
Transonic Asia Inc.
6F-3 No 5 Hangsiang Rd
Dayuan, Taoyuan County
33747 Taiwan, R.O.C.
Tel: +886 3399-5806
Fax: +886 3399-5805
support@transonicasia.com

JAPAN
Transonic Japan Inc.
KS Bldg 201, 735-4 Kita-Akitsu
Tokorozawa Saitama
359-0038 Japan
Tel: +81 04-2946-8541
Fax: +81 04-2946-8542
Japan@transonic.com