LiDCOplus

CONTINUOUS, REAL-TIME CARDIOVASCULAR MONITORING

LiDCO Cardiac Sensor Systems

Introducing the LiDCO*plus* Hemodynamic Monitor

CONTINUOUS, REAL-TIME MONITORING OF CARDIAC OUTPUT

Monitoring of the key cardiovascular parameters of blood pressure, cardiac output and oxygen delivery is essential for many major surgical and acutely ill patients. In addition, there are many other patients that could benefit from real-time cardiovascular monitoring if it were available in a safe and easy to apply manner. This was the philosophy that resulted in the development, design and manufacture of the unique LiDCO*plus* Hemodynamic Monitor.

The LiDCO*plus* system is a combination of the two innovative and novel monitors - the LiDCO System indicator dilution cardiac output monitor and the PulseCO System real time, continuous arterial waveform monitor, produced by LiDCO Ltd.

This unique combination provides beat-to-beat measurement of cardiac output with lower risk and high precision [68].

INTRODUCING LiDCO LTD

- LiDCO Ltd's starting point for its products is with the requirements of the clinician, nurse and hospital patient for advanced minimally invasive cardiovascular monitoring.
- LiDCO Ltd's products result from the consolidation of a physiological knowledge base and leading physiological software and sensor technology.
- LiDCO Ltd's minimally invasive monitoring products improve hospital standards of care, improve patient outcome and reduce costs [88].
- LiDCO Ltd's products provide medical staff with essential hemodynamic information, not just data, in an 'easy to interpret' manner.

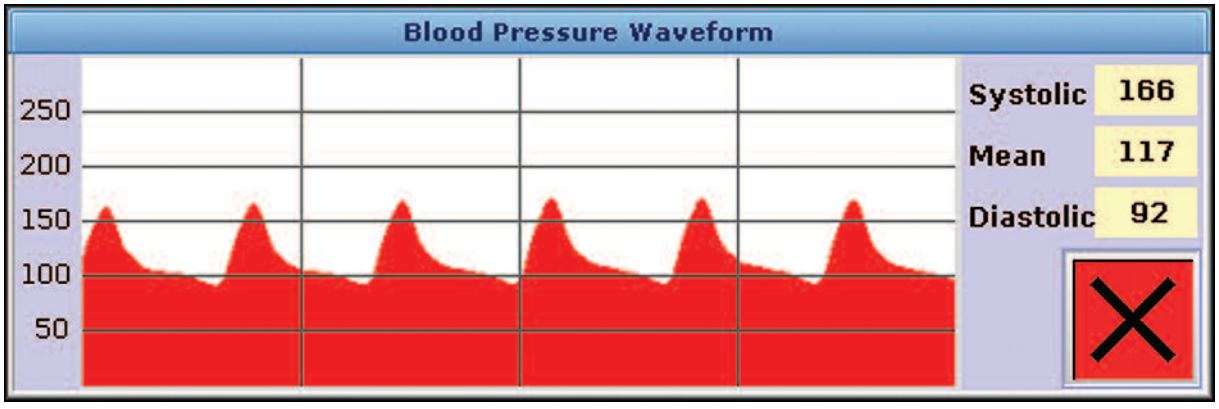
LiDCO Cardiac Sensor Systems

The LiDCO*plus* System combines the LiDCO & PulseCO Systems software and provides a real-time and continuous assessment of a patient's hemodynamic status.

The LiDCO™ System cardiac output method provides a bolus indicator dilution method of measuring cardiac output. A small dose of lithium chloride is injected via a central or peripheral venous line; the resulting arterial lithium concentration-time curve is recorded by withdrawing blood past a lithium sensor attached to the patient's existing arterial line. In terms of accuracy, clinical studies have demonstrated that over a wide range of cardiac outputs the LiDCO method is at least as accurate as thermodilution and even in patients with varying cardiac outputs [7-12]. In one study LiDCO and thermodilution cardiac output were compared with an electromagnetic flow probe. The results of this study indicated that LiDCO had a higher precision compared with conventional bolus thermodilution cardiac output [12]. The dose of lithium needed (0.15 - 0.3 mmol for an average adult) is very small and has no known pharmacological effects [74].

The PulseCO™ System software (incorporated in the LiDCO™*plus* Monitor) calculates continuous beat-to-beat cardiac output by analysis of the arterial blood pressure trace following calibration with an absolute LiDCO cardiac output value. This method has been shown to be accurate and reliable in various clinical settings. It has also been shown that recalibration is unnecessary for at least eight hours [2-6, 79, 80] and more recently for 24 hours [94].

PULSECO SYSTEM AUTOCORRELATION ALGORITHM

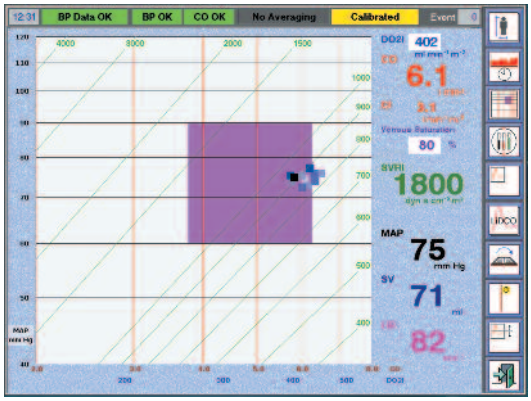


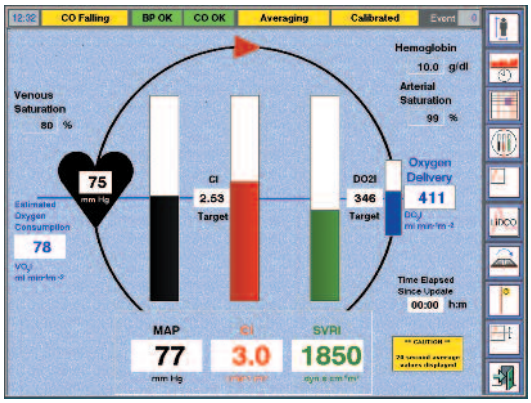
The analogue arterial blood pressure trace is slaved from the conventional blood pressure monitor and undergoes a three step transformation

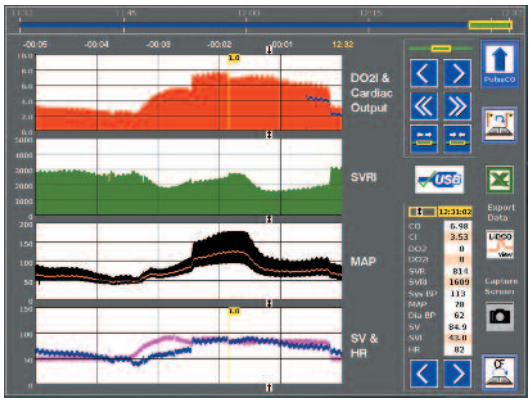
- Step 1 Arterial pressure transformation into a volume-time waveform (incorporating arterial tree compliance)
- Step 2 Deriving nominal stroke volume and heartbeat duration
- Step 3 Actual stroke volume via calibration with an absolute cardiac output value

Components of the LiDCO*plus* Monitor

The PulseCO software calculates continuous beat-to-beat cardiac output by analysis of the arterial blood pressure trace following calibration with an absolute cardiac output value. This absolute cardiac output value is accurately and precisely measured using the innovative LiDCO lithium chloride bolus indicator dilution method.







The PulseCO software calculates the pulse power and derived stroke volume from the arterial waveform. This avoids the necessity for detection of any particular waveform features such as the dichrotic notch. Furthermore, arterial wave reflection does not have to be estimated. Due to this innovative and patented method of calculation, the PulseCO remains accurate and reliable over a wide range of hemodynamic states in surgical, post operative and intensive care settings [2]. Studies have demonstrated that re-calibration is unnecessary for at least eight hours [2-6] and more recently 24 hours [94].

The LiDCO*plus* serves as a reliable alternative to continuous cardiac output monitoring with the pulmonary artery catheter and can easily be used intraoperatively, in the ICU/HDU, trauma or burns unit, and cath lab.

LiDCO*plus*'s accuracy is ensured with the proven LiDCO*plus* lithium indicator dilution calibration procedure that uses existing venous and arterial access, making it fast, cost effective and minimally invasive.

The LiDCO*plus* calculates cardiac output continuously by analysis of the arterial blood pressure trace following calibration with the absolute LiDCO cardiac output value. The concept of estimating cardiac output from the arterial pressure waveform has been extensively researched with the first researchers (Erlanger and Hooker) publishing in 1904 [1].

The LiDCO System is an innovative bolus indicator dilution method of measuring cardiac output and Intra-Thoracic Blood Volume (ITBV) - the innovation is the use of lithium chloride as the indicator. A small dose of lithium chloride is injected via a central or peripheral venous line (Fig 1); the resulting arterial lithium concentration-time curve is recorded by withdrawing blood past a lithium sensor attached to the patient's existing arterial line (Fig 2); the Monitor then calculates the cardiac output from the area of the primary dilution curve (Fig 3). The mean transit time of the lithium is derived for calculation of the ITBV.

The signal to noise ratio and hence accuracy for lithium is better than that seen with thermodilution - due to the fact that the lithium dose can be scaled to the size and cardiac output of the patient. Thermal noise from fluid infusion, respiration and patient warming has little, if any, effect on the lithium curve. The precision of the LiDCO System method means that only one lithium injection is required to accurately determine the cardiac output. In terms of accuracy, clinical studies have demonstrated that the single bolus LiDCO System method is at least as accurate as triplicate bolus thermodilution over a wide range of cardiac outputs and even in patients with varying cardiac outputs [7-12].

The lithium chloride indicator dilution method of measuring cardiac output and intra-thoracic blood volume (ITBV)

Fig 2

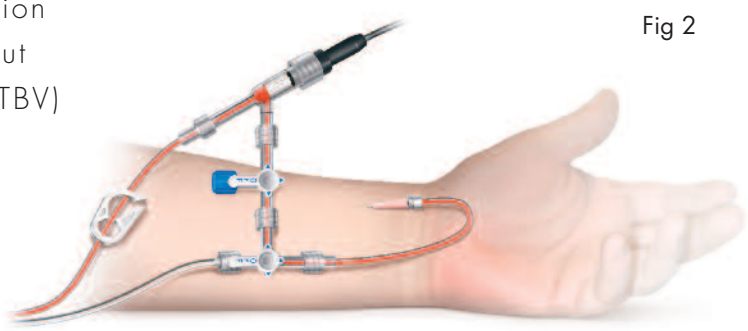


Fig 1

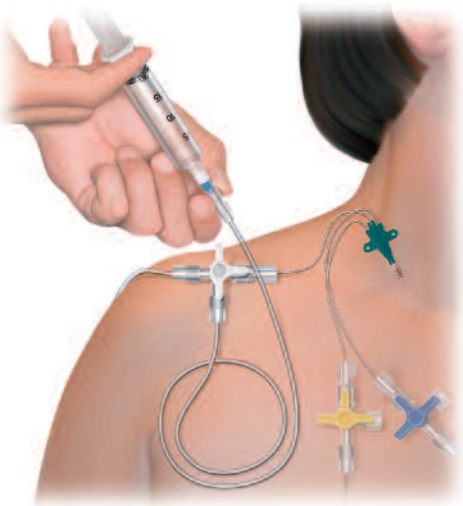
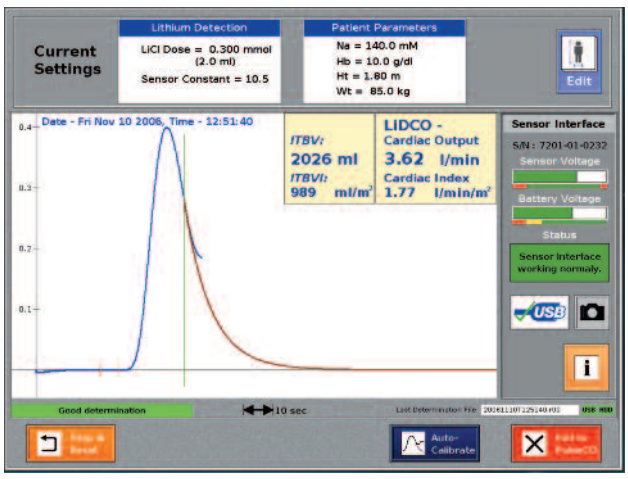


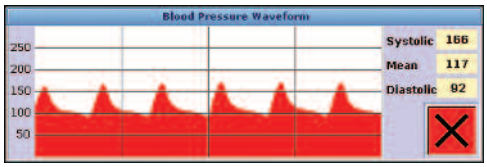
Fig 3



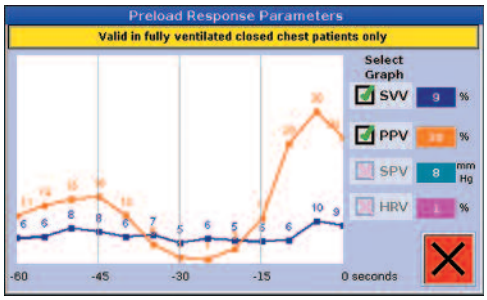
Arterial Pressure

The arterial pressure waveform is slaved from your conventional blood pressure monitor via an analogue cable link. At the touch of a button the arterial pressure waveform is displayed on the LiDCO*plus* screen. This can be viewed on the screen whenever the Trend, Graph and Chart screens are in use.

This Blood Pressure Waveform window is used to check the patient's systolic, diastolic and mean pressure. The pressure waveform shape and values should equate to those displayed on the primary blood pressure monitor.



This window also provides you with access to preload response values or volume status indicators of: Systolic Pressure Variation (SPV), Pulse Pressure Variation (PPV%), Stroke Volume Variation (SVV%) as well as Heart Rate Varation (HRV%).



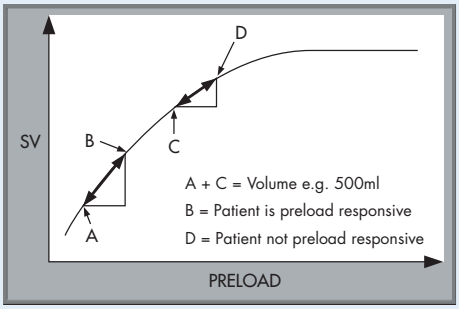
SVV % = (SV max - SV min)/[(SV max + SV min)/2] x 100
Patient with SVV less than 10% are unlikely to be preload responsive.

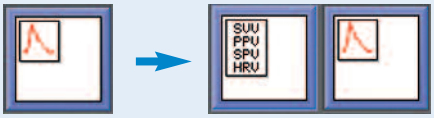
DYNAMIC VOLUME STATUS INDICATORS FOR VENTILATED PATIENTS

Thoracic pressure changes caused by mechanical ventilation induces cyclic changes in Left Ventricular Stroke Volume. These changes can provide an indication of the patient's ventricular preload status (see figure of Frank-Starling curve)[18, 20, 26, 66, 81-83].

By superimposing the Preload Response Parameters Window onto the Trend, Graph, or Chart screens, a continuous measurement of Stroke Volume, Systolic Pressure and Pulse Pressure Variation is displayed numerically and graphically.

For closed chest ventilated patients these volume status measurements provide a way of predicting fluid volume status and likely response to volume infusions. A fluid imbalance can have an adverse effect on a patient's cardiac performance and, in turn, oxygen delivery to key organs [13-35, 50, 56, 66, 67, 81].





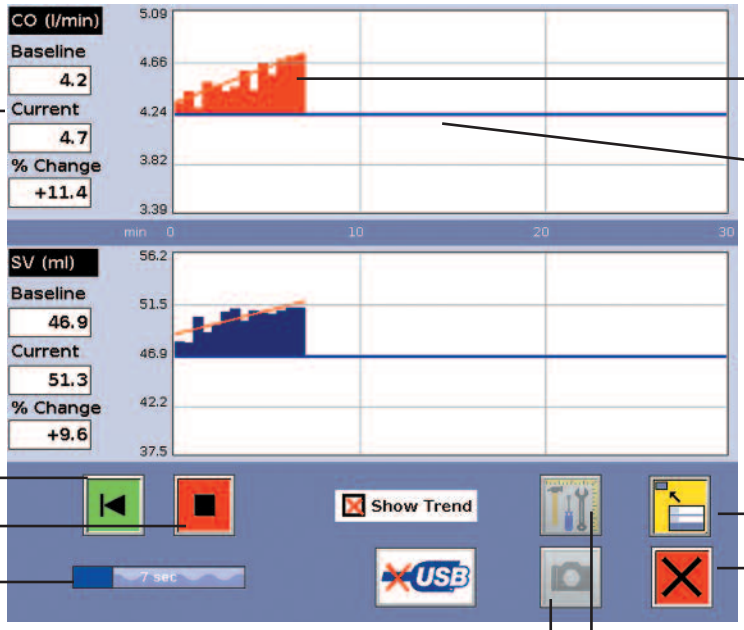
Frank-Starling Curve: Patient Preload Status

Event Response

PRE-LOAD RESPONSIVENESS VIA THE EVENT RESPONSE DISPLAY

The Event Response display allows the user to view up to 2 hemodynamic variables in a higher resolution during a specific period (e.g. fluid challenge, inotrope change). The LiDCO*plus* will also display percent change from start for each variable as a numeric value. Trend lines can also be added to the graphical display.

This feature is very useful when evaluating the patient's response to targeted interventions such as a fluid challenges or changes in inotrope therapy. The advantage this screen brings is in averaging the data display to smooth any noise and magnifying the display of changes so that they are easily viewed at a glance from a distance.



Target Variable data: Starting baseline Current value and % Change from baseline

The Trend line is switched on

Baseline value

Press to Restart

Press to Stop

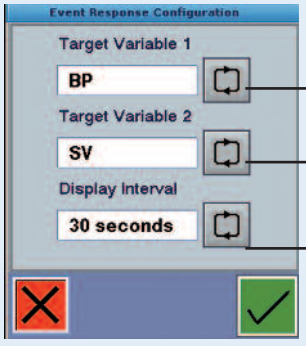
Elapsed time until a new point is plotted

Press to minimize

Press to Exit

Press to capture screen image as JPG

Press to configure Event Response

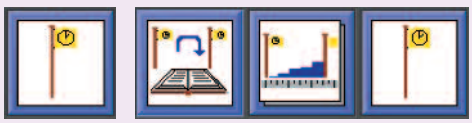


Press to select target variable(s)

Press to select display interval

A new data point is plotted every 10, 20 or 30 seconds.

Press the event button to reveal the submenu below.



Then press  to open the Event Response Window.

Benefits to you and your patient

BENEFITS OF LIDCO*plus* CONTINUOUS CARDIAC OUTPUT MONITORING INCLUDE:

- Provides early warning of patient deterioration
- Optimisation of oxygen delivery
- Optimisation of fluid management
- Rational drug administration (e.g. Inotropes)
- The patient's condition is clearly communicated to clinical staff
- Reduces the work of health care staff
- Decrease the procedural complications
- Is minimally invasive and therefore widely applicable
- Is accurate
- Can be nurse driven
- Provides real time, beat-to-beat cardiac output and oxygen delivery
- Provides real time preload and afterload values
- Provides indexed values
- Provides easy data interpretation
- Provides bedside information management
- Has easy to use event markers
- Provides information not simply data
- Can be linked to most commonly found BP monitors
- Records historical data

BENEFITS OF THE LIDCO – LITHIUM CHLORIDE INDICATOR DILUTION CARDIAC OUTPUT METHOD:

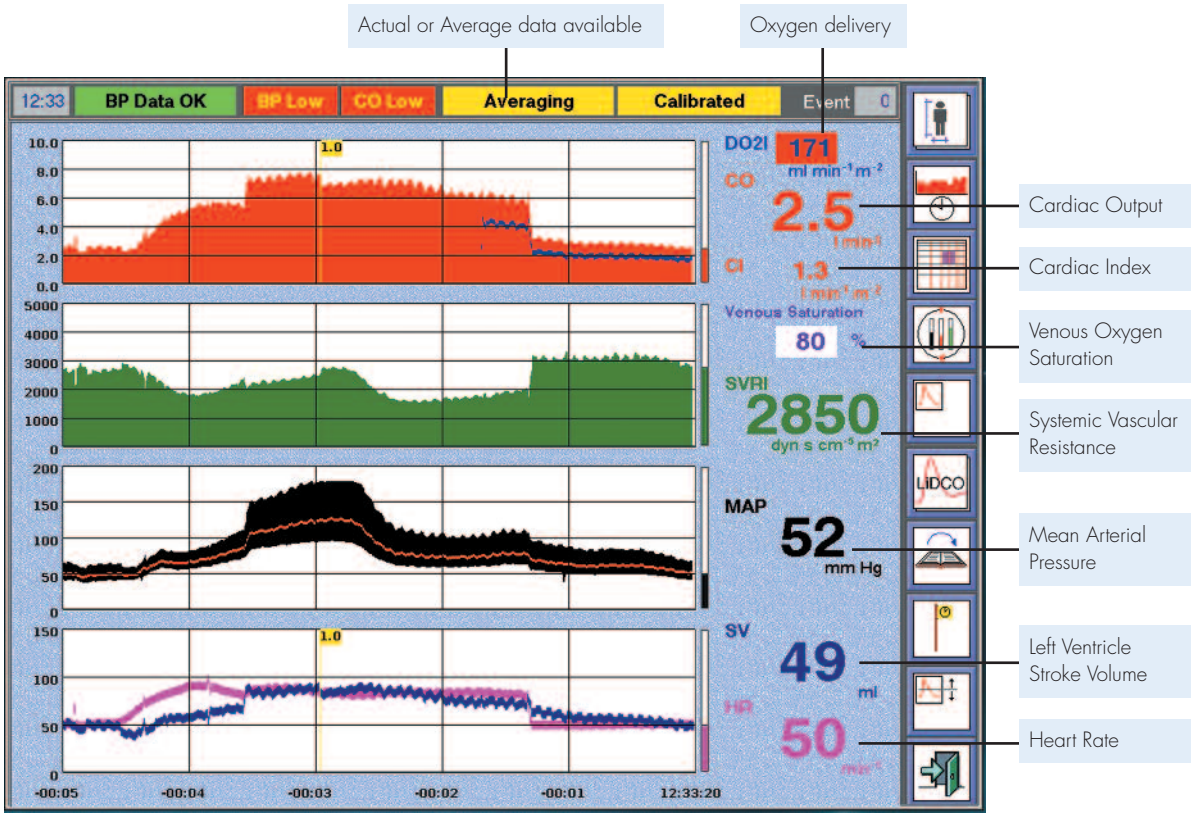
- Provides an absolute cardiac output value via a novel and proven indicator dilution technique
- Provides ITBV
- Requires no additional invasive catheters to insert into the patient
- Is safe – using non-toxic bolus dosages
- Is simple and quick to set up
- Can be used with a range of LiCl dosages
- Is as accurate as meaned triplicate thermodilution
- Is not temperature dependent
- Is less invasive monitoring
- Utilises existing peripheral or central venous and arterial lines
- Can be set up and used by nursing staff
- Is a well studied and validated technique

The Trend Screen

A CLEAR CONTINUOUS DISPLAY

The Trend screen provides a continuous record of the patients hemodynamics. This large, clear and continuously updating screen displays the actual and indexed values for Cardiac Output, Systemic Vascular Resistance, Mean Arterial Pressure, Heart Rate and Left Ventricle Stoke Volume. Oxygen Delivery and Venous Oxygen Saturation can also be displayed if selected. The clinician can accurately track the patients' trend over several hours or minutes.

This screen facilitates intraoperative patient management allowing assessment of the immediate response to fluid challenge, drugs or other therapeutic interventions.



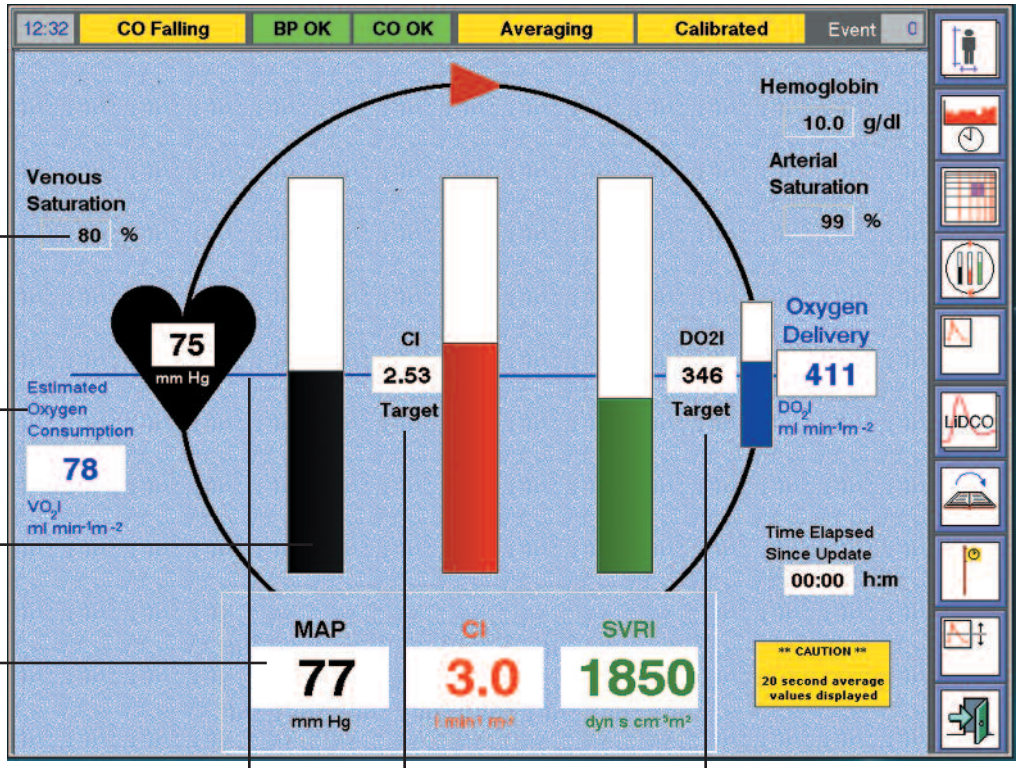
EVENT MARKER

Mark any number of events, such as initiation of inotropic agent or start of fluid infusion, using the event marker button. There are several standard descriptions that can be selected and additional detail added.

The marked event will appear as a small flag on the Trend and History screens and will be recorded in the LiDCO*plus* data file as the patient data is downloaded from the history screen. The event history window will allow selection of any events from the past 24 hours and take the user to the area on the hemodynamic history screen where the event was marked.

The Chart Screen

PARAMETER RELATIONSHIPS AT A GLANCE



Venous oxygen saturation

Oxygen consumption

Patients optimal MAP target, set by the clinician

Indexed value enables this easy to interpret format

Patients ideal status line

Patient optimal CO/CI or DO_2/DO_2I target, set by clinician

Pressure = Flow x Resistance

Showing the relationship between pressure, flow and resistance in an integral bar chart display. This screen simplifies the recognition and diagnosis of hemodynamic imbalance at the bedside. This means that potentially complex hemodynamic data can be easily interpreted and the necessary corrective actions taken quickly.

OXYGEN DELIVERY TARGETS AND $ScvO_2$/SvO_2 DISPLAY

Oxygen delivery optimisation has been demonstrated to be a key factor in the reduction in both length of stay and complications for post surgical patients in the ICU[88]. Oxygen delivery targets can now be set in the patient limits. These will be used on both the Graph and Chart screens to enhance the display of data. Venous Oxygen Saturation can now be inputted to allow tracking as well as calculation of estimated oxygen consumption.

OXYGEN DELIVERY

The goal of monitoring cardiac output is to maximise the delivery of oxygen to the tissue beds. The LiDCO*plus* monitor displays the parameter of oxygen delivery (and oxygen delivery index) in real time. The ability to have these two parameters monitored simultaneously on a real-time basis by the LiDCO*plus* can have a major impact on patient care and outcomes. There is mounting evidence that monitoring oxygen delivery and cardiac output in at-risk patients can significantly reduce mortality and length of hospital stay [50].

In a recent study utilizing the LiDCO*plus* it was shown that optimising oxygen delivery index (DO_2I) to a target of 600ml/min/m^2 reduced morbidity by 50% and mean length of stay per patient by 12.3 days[88]. Use of the LiDCO*plus* facilitates the perioperative optimisation of patients.

HEMODYNAMIC PRE-OPTIMISATION IN HIGH-RISK PATIENTS

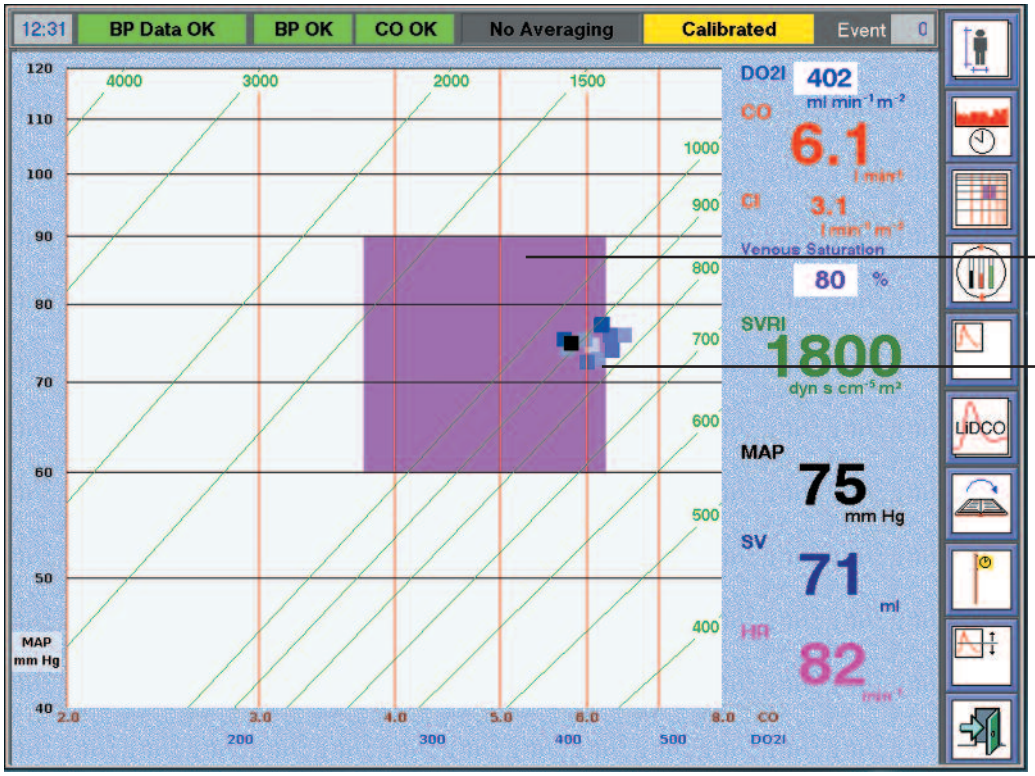
'High risk' surgery patients subjected to a reduction in global oxygen delivery are known to have increased levels of morbidity and mortality. Increasing global oxygen delivery has been reported to result in a dramatic improvement in outcome in these patients [36-67]. For example in the USA there are over 30 million operations performed annually, 10-15% of which (approximately 3 million operations) are deemed to be 'high risk'. These 'high risk' patients have an increased risk of death. A recent review of 21 randomised controlled trials with various approaches to treatment revealed statistically significant mortality reductions when patients with acute critical illness were treated early to achieve optimal goals before the development of organ failure [58]. There is convincing evidence that measurement and manipulation of cardiac output, and therefore oxygen delivery, in selected patients reduces the risk of mortality [59, 68, 69, 70].

MORTALITY OUTCOMES FOLLOWING GOAL DIRECTED STUDIES:

Type of Surgery	Study Author (Year)	Mortality of Control Group (%)	Mortality of Goal Directed Treatment Group (%)
Vascular	Shultz et al (1985) [44]	29.0	2.9
General	Shoemaker at al (1988) [45]	33.0	4.0
Vascular	Berlauk et al (1991) [46]	9.5	1.5
Trauma	Fleming et al (1992) [47]	44.0	24.0
General & Vascular	Boyd et al (1993) [67]	22.2	5.7
Trauma	Bishop et al (1995) [48]	37.0	18.0
Hip Fracture	Sinclair et al (1997) [51]	10.0	5.0
Peripheral Vascular	Ziegler et al (1997) [84]	9.0	5.0
Elective General	Wilson et al (1999) [50]	17.0	3.0
Elective Cardiac	Polonen et al (2000) [85]	3.0	1.0
General & Vascular	Lobo et al (2000) [86]	50.0	15.7

The Graph Screen

KEEPING PATIENT CARE ON TARGET



Patients preferred hemodynamic status presented as a window or 'target zone', set by the clinician.

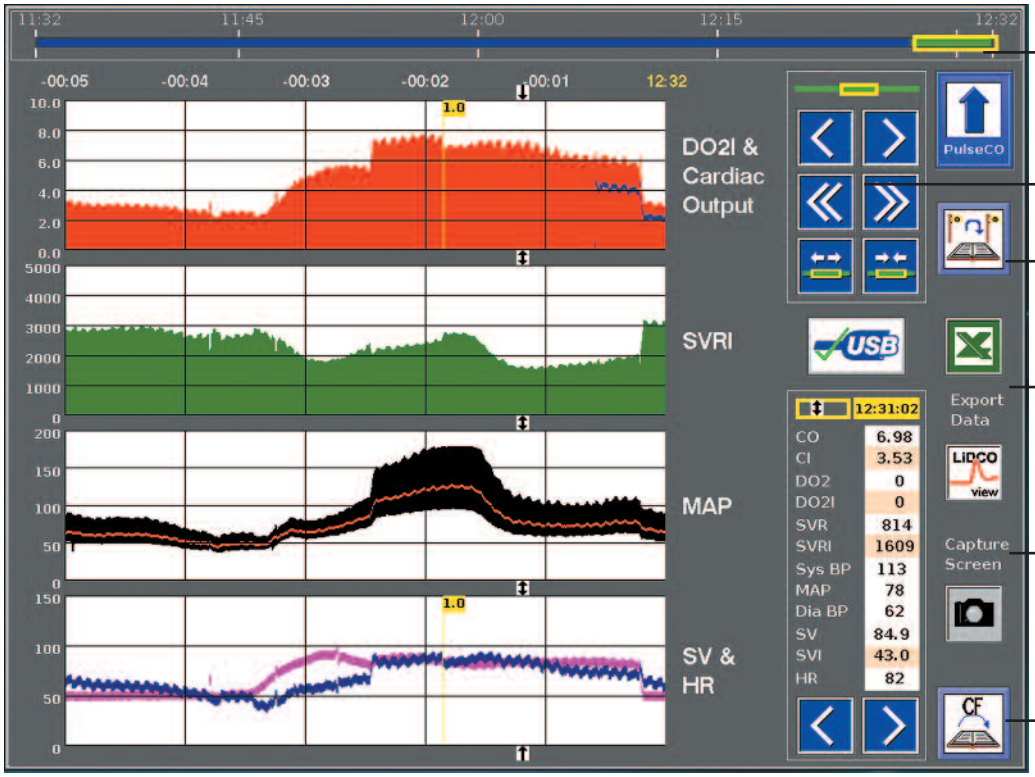
Patients current Hemodynamic status, presented as a series of 12 colour coded dots in real-time updated for every heart beat.

Allows easy assessment of the patients status at a glance and from a distance from the Monitor - useful in busy ICU's or high dependency units, as an early warning system to avoid adverse events. The graph screen is also ideal for the implementation of goal directed protocols that target oxygen delivery. The graph screen is the ideal "bedside" mode providing clear, easy-to-read feedback on changes to pressure, flow, and resistance. A patient specific "target zone" for Cardiac Output or Oxygen Delivery, Mean Arterial Pressure and thereby Systemic Vascular Resistance is defined specifically for each patient. The continuous display of the patient's last 12 heartbeats provides a ready reference to how well the therapeutic/hemodynamic targets are being maintained. The LiDCO*plus* Monitor provides point of care information, not just more patient data.

CONTINUOUS, REAL-TIME MONITORING OF CARDIAC OUTPUT

The History Screen

KEEPING PATIENT RECORDS, FOR AUDIT, TEACHING, ANALYSIS AND RESEARCH



The History Screen can be used to look back over the last 24 hours of the patient's hemodynamic data. The display is similar to the display of the Trend Screen. Touch anywhere on the screen to see the parameter readings, at that time, or track back through the hours of data as required.

This screen is designed to aid in data collection: for clinical studies or simply to have a complete record of the patient's treatment you can record the patient's critical parameters at the touch of a button. The beat-to-beat patient data, event markers and calibrations are recorded either as a file for LiDCO*view* or as an Excel file on a USB memory stick. This powerful tool for data collection provides you with the ability to review, research and train using Historical data. Record several patients or several days of a single patient onto one easy to use USB memory stick.

A picture can be taken of the entire history screen. This can be stored on the hard drive or immediately downloaded to a USB memory stick as a JPEG file.

PulseCO Validation

A number of studies have been completed in various centres in Europe and the USA demonstrating the accuracy and precision of the PulseCO software (hosted within the LiDCO*plus* Hemodynamic Monitor) when used in cardiothoracic surgery, major surgery and the ICU [2-6, 79, 80, 94].

INTRA OPERATIVE PERFORMANCE

One study at the University of Texas evaluated the change/drift in calibration factor across a post operative period of 8 hours in a group of 20 cardiac surgery patients [80].

The results of the study found:

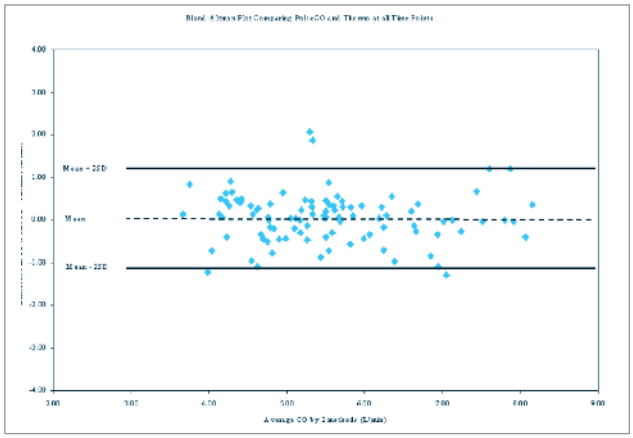
- that the range of cardiac outputs was 3.33 to 8.47 litres per minute;
- that, once calibrated, the PulseCO tracked the cardiac output continuously through the post surgery period without changes in calibration factor;
- that no significant differences were noted between the LiDCO, the thermodilution control and the PulseCO reading.

Differences in CO measurements by technique (Liters/min).

	0hours	2hours	4hours	6hours	8hours	all times
TLdiff	-0.1±0.1	0.0±0.1	0.1±0.1	0.0±0.2	-0.2±0.2	0.0±0.1
PLdiff	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
PTdiff	0.1±0.1	0.0±0.1	0.0±0.1	0.0±0.2	0.2±0.2	0.0±0.1

Conclusion:

'This technique appears to offer a safe, reliable and less invasive alternative to the traditional PA catheter for cardiac output monitoring in the immediate post-operative period after surgery.'



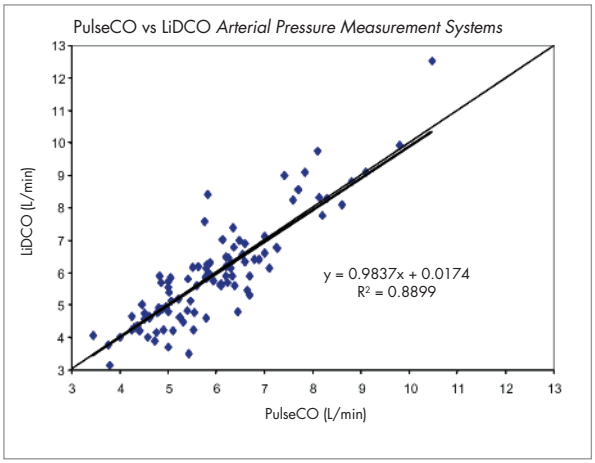
A study in intensive care patients [94] has shown good correlation of LiDCO and PulseCO without recalibration over 24hrs.

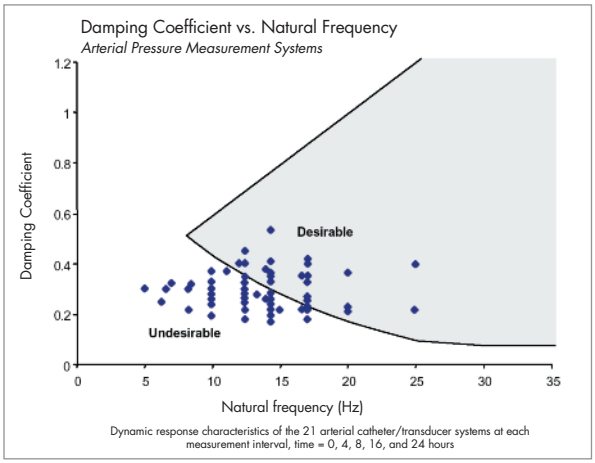
POST OPERATIVE PERFORMANCE AND THE EFFECT OF DAMPING

A further study was undertaken at Duke University to examine the effects of arterial damping in a group of 22 patients in a surgical intensive care unit[2]. The study was designed to evaluate the change/drift in calibration factor across a 24 hour period and in addition to examine whether the dynamic response (damping) of the arterial pressure monitoring system has an effect on the accuracy of the PulseCO software.

The results of the study found:

- that the range of cardiac outputs was 3.45 to 10.47 litres per minute;
- that there were acceptable bias and limits of agreement throughout the study with a correlation of $r^2 = 0.89$;
- that 68% of catheters had an undesirable dynamic response but that this did not affect the agreement between the measurements of cardiac output obtained by the PulseCO software and the Lithium dilution (p = 0.976)





Dynamic response characteristics of the 21 arterial catheter/transducer systems at each measurement interval, time = 0, 4, 8, 16, and 24 hours

Conclusion:

'Technical limitations of arterial catheter monitoring systems, such as low natural frequency or under or over damping, do not appear to influence the accuracy of the PulseCO measurement.'

'The pulse contour algorithm appears accurate despite a wide variety of arterial pressure waveform contours that are seen in clinical practice.'

'Re-calibration of the PulseCO software is recommended every four hours, but we have extended the period between calibrations to eight hours and demonstrated that the PulseCO software is still accurate after this time.'

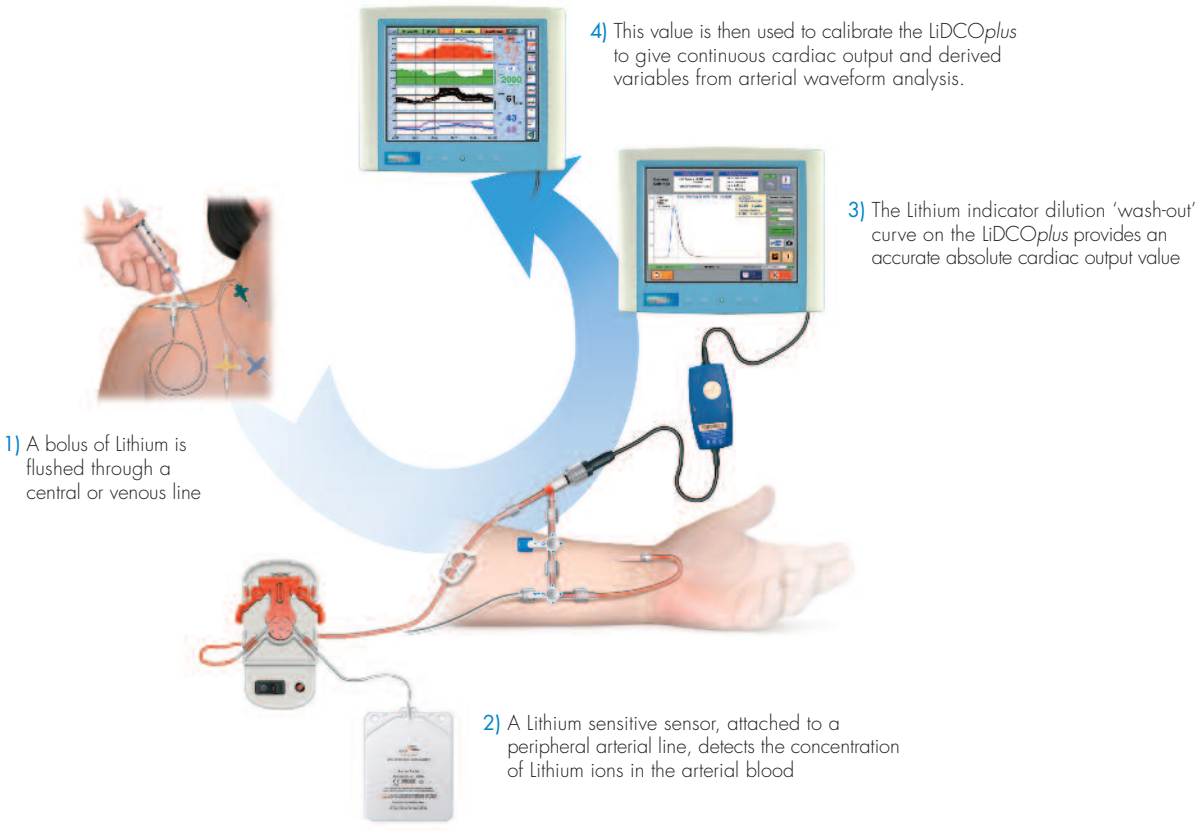
The LiDCO*plus* - Lithium Indicator Dilution

The LiDCO*plus* bolus lithium indicator dilution method is used to provide an accurate actual cardiac output value for the patient. The lithium indicator dilution method is a very accurate and minimally invasive indicator dilution cardiac output measurement method. This is used to calibrate the PulseCO arterial waveform stroke volume value. It can also be used to calculate intra thoracic blood volume (ITBV).

THE PRINCIPLE

The bolus indicator dilution method of measuring cardiac output was first described by Henriques and developed by Hamilton et al in 1932[71]. This became widely adopted - the original technique using indocyanine green (ICG) as the marker. However, as this technique required frequent blood sampling and manual analysis of the dilution curve, it proved to be technically difficult and time consuming. The use of Lithium as an indicator of cardiac output was first described in 1993[72] and has since been extensively validated[73]. Lithium like ICG, is a non-diffusible indicator[92]. The method of using bolus indicator dilution to measure volume was described by Stewart[93] and the method of ITBV calculation is simply ITBV=C0xMTt. MTt is the mean transit time of the lithium indicator from injection to detection.

The LiDCO*plus* Monitor provides a lithium bolus indicator dilution method of measuring cardiac output. A small dose of lithium chloride is injected via a central or peripheral venous line; the resulting arterial lithium concentration-time curve is recorded by withdrawing blood past a lithium sensor.



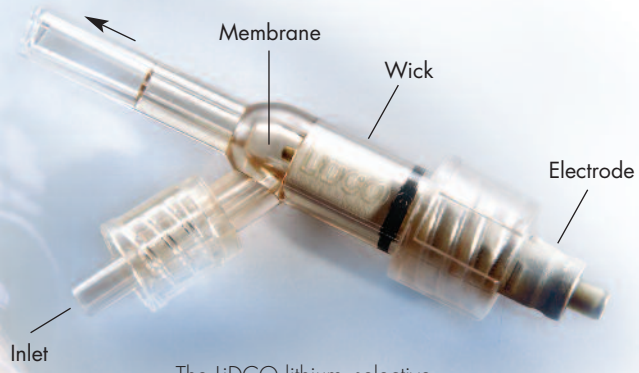
ADVANTAGES OF THE LiDCO*plus* LITHIUM INDICATOR DILUTION METHOD

The advantages of the LiDCO*plus* method are that it is safe, accurate and simple to use:

- Safe - Central/peripheral venous and arterial catheters are usually already in place in patients needing cardiac output measurements. No further catheter is needed, so the method avoids the risks associated with pulmonary artery catheterisation. The method requires withdrawal of approximately 5 ml blood per determination; for an adult this is an insignificant amount. The injectate is a solution of lithium chloride. The dose needed (0.15 - 0.30 mmol for an average adult) is very small and has no known pharmacological effect [74]. The dosage regimen recommended is very conservative, making worst case assumptions on volume of distribution of lithium, patient weight (assumes 40kg) and absence of renal function.
- Accurate - Clinical trials have been completed that demonstrate that the LiDCO System is at least as accurate as thermodilution [11,12].
- Simple to use - The method is simple and quick to use. It has the advantage that there is no unpleasant procedure for a conscious patient to undergo (such as insertion of a pulmonary artery catheter) and the time taken to set up and apply is between 5 and 10 minutes [68].

THE SENSOR

The sensor consists of a lithium-selective electrode in a flow-through cell. It is disposable, sterilised by gamma irradiation and foil packed. The sensor is connected to a three-way tap on the arterial line and a small peristaltic pump restricts the flow through it to 4.5 ml/min. The flow-through cell is made of polycarbonate and designed with an eccentric inlet so that the blood swirls past the tip of the electrode.

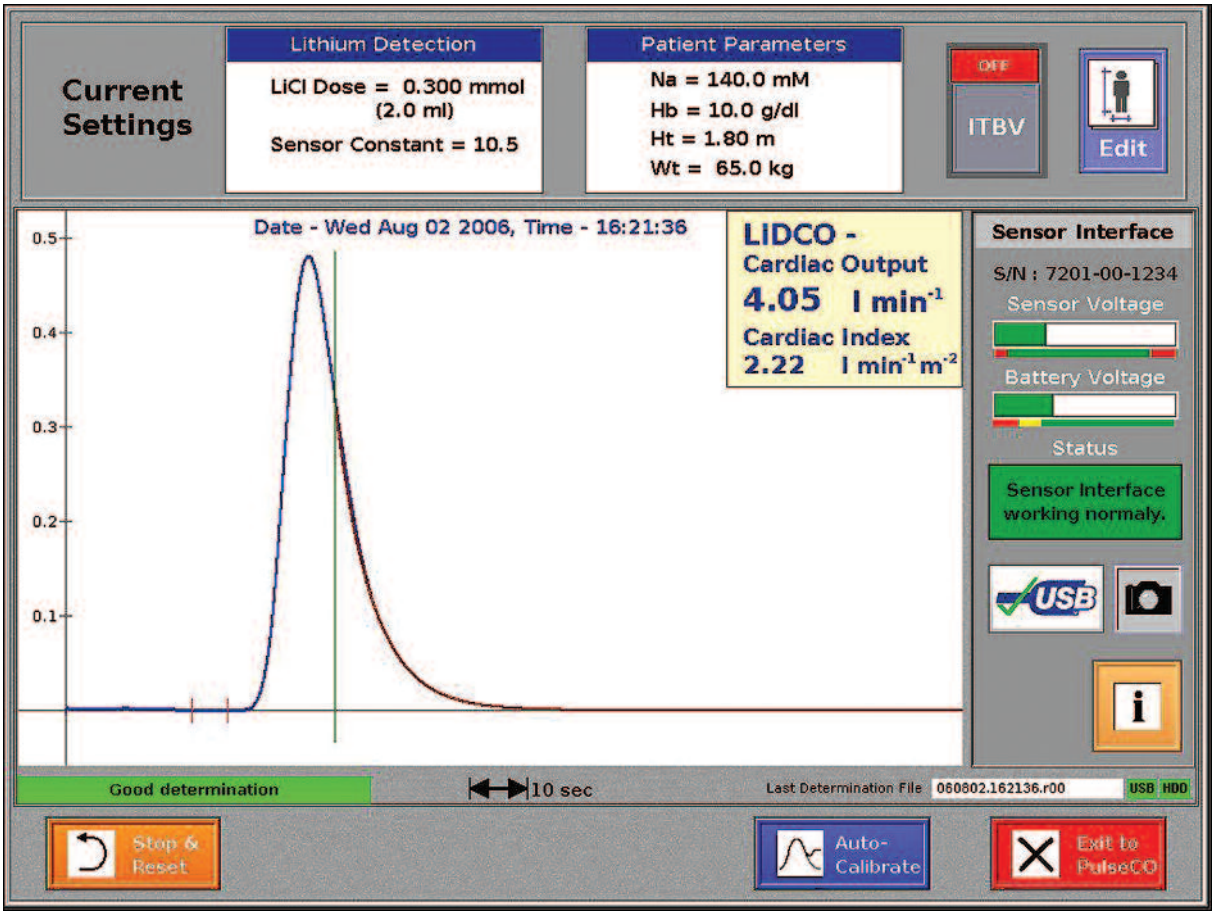


The LiDCO lithium- selective electrode in a flow through cell.

The lithium-selective electrode is made of polyurethane with a central lumen. Silver chloride paint coats the inside and the outside. A wick, which is soaked in saline when the cell is first primed, makes the electrical connection between the blood in the cell in the vicinity of the tip of the electrode and the remote reference. This arrangement ensures adequate constancy of the voltage of the reference which is far enough from the blood to avoid a significant temperature effect. The electrode is filled with a reference material which provides a constant ionic environment and supports the membrane which is dip cast. The membrane is made of polyvinyl chloride and contains a lithium ionophore to make it selectively permeable to lithium ions.

Indicator Dilution Screen

GREATER PRECISION THAN A SINGLE BOLUS THERMODILUTION



DERIVATION OF ABSOLUTE CARDIAC OUTPUT VALUE

The voltage across the sensor membrane is related via the Nernst equation to the plasma [Li^+.] A correction is applied for plasma sodium concentration because in the absence of lithium the baseline voltage is determined by the sodium concentration. The voltage is measured using an amplifier optically isolated from the patient, then digitised on-line and analysed by the LiDCO*plus* Monitor software.

Indicator dilution curves recorded in arterial blood consist of primary and secondary curves due to the initial circulation and then re-circulation of the indicator. Cardiac output is calculated as:

Cardiac Output = (Lithium Dose x 60)/(Area x (1-PCV))

Where lithium dose is in mmol; Area is the integral of the primary curve (mM.s); PCV is packed cell volume which may be calculated as hemoglobin concentration (g/dl) / 34: this correction is needed because lithium is distributed in the plasma and not into the red or white cells on the first pass to the arterial circulation.

VALIDATION

Validation comparing the LiDCO System with bolus pulmonary artery catheter thermodilution technique (Figure 8) demonstrated a good overall agreement between the two methods (see Figure 8 r^2= 0.94) [11]. The conclusions were that a single bolus of lithium was at least as accurate as meaned triplicate bolus thermodilution. In another study where thermodilution and lithium dilution were compared to an aortic electromagnetic flow probe the LiDCO results showed less variability and therefore the LiDCO System was found to have a greater precision than single bolus thermodilution [12].

Larger animals (horses) and paediatric subjects have also been studied to ensure that the lithium dilution technique remained valid at extremes of flows (Figure 9). The body weight studied ranged from as small as a 2kg baby* up to a 550kg horse [10 95].

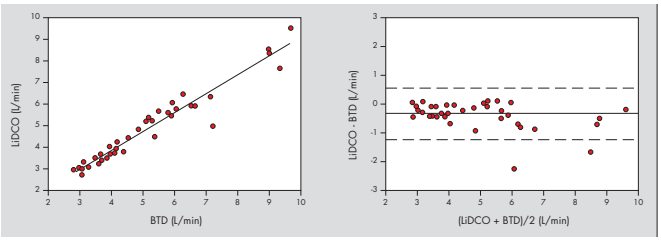


Figure 8. X-Y plot and Bland-Altman plot of 40 patients comparing LiDCO (average of 5 measurements) with bolus thermodilution (BTD) in 40 patients. X-Y plot: LiDCO = 0.31 + 0.89 BTD (L/minute) r^2 = 0.94. Bland-Altman plot: Mean differences BTD -LiDCO 0.25 L/minute, SD of the difference was 0.46 L/minute.

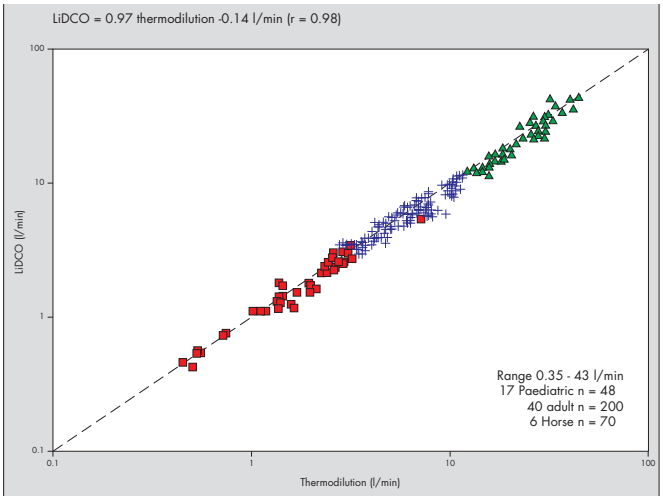


Figure 9. Comparisons (n = 318) of LiDCO vs bolus thermodilution in adults, paediatrics and horses.

*The use of LiDCO*plus* is unlicensed in patients <40kg (88lb).

LITHIUM CHLORIDE: THE FACTS

Multiple dosages of Lithium have been extensively investigated and the safety profile is well established. The pharmacokinetics of intravenous lithium chloride in man (and animals) has been documented [74], Lithium chloride has been used extensively in medicine for prophylactic and therapeutic treatment of unipolar and bipolar manic-depressive disorders [75, 76]. The lithium chloride is distributed throughout the total body water and excreted almost entirely by the kidneys. The half-life of lithium chloride in humans is 19.8 - 41.3 hrs [77, 78]. The recommended maximum total dose for a Lithium indicator dilution would have to be exceeded many times before toxic levels are reached. In fact, a single lithium chloride LiDCO indicator dilution determination at 0.3mmol is the equivalent to a steady state plasma lithium concentration of 1/240th of the therapeutic level. Lithium has been used for the measurement of cardiac output in thousands of patients over many years without a single side effect being reported.

(For warnings, contraindications and side-effect please refer to LiDCO Ltd Lithium Chloride Data Sheet and/or LiDCOplus manual)

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