# ASSESSMENT OF LITHIUM DILUTION CARDIAC OUTPUT AS

# A MEASURE OF CARDIAC OUTPUT IN THE DOG

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# ABSTRACT

## ASSESSMENT OF LITHIUM DILUTION CARDIAC OUTPUT AS
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This study is the investigation of lithium dilution cardiac output (LiDCO) for the measurement of cardiac output in the dog. The objectives of this study were to determine the agreement between LiDCO and thermodilution cardiac output (TDCO); the agreement of low-dose LiDCO and high-dose LiDCO, with TDCO; the effect of an increasing serum lithium concentration on subsequent LiDCO measurements; the ability to predict the serum lithium concentration from the cumulative lithium chloride dose; and the agreement between LiDCO obtained from the injection of lithium chloride through a central and a peripheral venous catheter.

To assess the agreements between LiDCO and TDCO, and between low- and high-dose LiDCO and TDCO, 92 comparisons were analyzed. Intraclass correlation coefficients (ICC) between low- and high-dose LiDCO with TDCO were 0.9898 and 0.9896, respectively. When both LiDCO doses were pooled and compared with TDCO, the ICC was 0.9894. The mean bias and precision ($\pm$ 1 SD) for LiDCO minus TDCO was $0.084 \pm 0.465$ L/min.

To assess the effect of an increasing serum lithium concentration on subsequent LiDCO measurements 44 observations were analyzed. The linear regression analysis for the effect of the serum lithium concentration on the agreement between TDCO and LiDCO revealed a slope of -1.530 [95% confidence interval of (-2.388, -0.671)] and a y-intercept of 0.011 (r = -0.485).

To assess the ability to predict the serum lithium concentration from the cumulative lithium chloride dose 74 paired observations were analyzed. The linear regression analysis revealed a slope of 2.291 [95% confidence interval of (2.153, 2.429)] and a y-intercept of 0.008 (r = 0.969).

To assess the agreement between LiDCO determined using a central and a peripheral venous catheter 50 comparisons were analyzed. The mean bias and precision for central minus peripheral LiDCO determinations was 0.098 ± 0.336 L/min (mean ± 2SD). The linear regression analysis demonstrated a slope of 1.050 [95% confidence interval of (0.904, 1.196)] and a y-intercept of 0.005 (r = 0.902).

This study provides insight into the usage of LiDCO in dogs and addresses some of the key issues with this indicator dilution method for measuring cardiac output.

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# DECLARATION OF WORK PERFORMED

I declare that, with the exception of the items below, all work reported in this thesis was performed by Dr. Doug Mason.

Anesthesia was performed by Amanda Hathway, Debbie Kingston, and Deb McWade. The placement of the peripheral arterial catheters was performed by Ingrid Danylyk, Melissa Sinclair, and Robert Cook. The measurement of serum lithium concentration was performed by the laboratory at the Homewood Health Center, Guelph, Ontario. The recording of the data during the studies was performed by Dr. Micheal O'Grady.

All studies were conducted in accordance with the guidelines of the Animals for Research Act and the University of Guelph Animal Care Committee.

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## 1.0    INTRODUCTION

The main function of the heart is to supply sufficient oxygen to the tissues of the body for the current metabolic state (Davidson et al.1997). The measurements of cardiac output and ventricular filling pressure have historically been used to assess the function of the heart. Cardiac output is a useful measurement of the pumping ability of the heart. However, because cardiac output is a dynamic process based on heart rate, preload, afterload, and myocardial contractility, it provides a limited assessment of ventricular function or myocardial contractility (Davidson et al. 1997).

Cardiac output by definition is the amount of blood that is pumped out of the heart over a given period of time and is usually expressed in liters/minute. Its value is derived from the product of heart rate and stroke volume. Its normal value is quite variable, and changes with age, body temperature, anxiety, environmental heat and humidity, and posture (Grossman 1991). These parameters must be considered when assessing cardiac output in the clinical situation. It is well known that the metabolic rate of young animals is much higher than that of geriatric animals (Davidson et al. 1997; Grossman 1991). Since cardiac output is based on the metabolic need for oxygen, it will decrease as an animal gets older. Thus, there is a wide range of what is considered as normal cardiac output.

Stroke volume is defined as the volume of blood that is pumped out of the heart with each contraction of the myocardium. Stroke volume is controlled by three factors: preload, afterload, and myocardial contractility. Preload is defined as the proportional

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stretch of the myocardium prior to stimulation and reflects the initial sarcomere length (Davidson et al. 1997). Preload usually refers to the amount of blood returning to the heart. This in turn depends on the time for ventricular filling (heart rate), circulatory volume, and amount of tone in the venous tree. Afterload is defined as the load that the myocardium must bear to contract and move blood in a forward direction. The factors that influence afterload are defined by the Law of Laplace, which states that wall stress is proportional to the product of pressure and radius, and is inversely proportional to 2 times wall thickness (Davidson et al. 1997). Myocardial contractility is defined as the fundamental property of cardiac tissue reflecting its level of activation, and the formation and cycling of the cross bridges between actin and myosin filaments. These are simplified definitions, since the true relationship between these variables is overlapping and are much more complicated than can be discussed in this chapter.

The measure of cardiac output has long been used in veterinary medicine as a research tool, but it has not been used extensively in the clinical setting. For many years cardiac output, along with arterial blood pressure, has become an integral part of both anesthetic and cardiovascular monitoring in human medicine. This information has been quintessential for therapeutic decision making in many critical patients. Currently in veterinary medicine the monitoring of blood pressure, pulse oximetry, and central venous pressure, as well as a multitude of diagnostic tests are used to evaluate critical patients. These are useful tests, however only cardiac output provides an assessment of global cardiovascular function. Unfortunately, there are no suitable surrogates for cardiac output. Cardiac output has not been routinely used in the management of the veterinary patient perhaps in large part due to the invasive nature of the procedure, the expertise

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required to position catheters, and the cost of equipment needed to monitor the catheter position. However, cardiac output along with blood pressure may be the most useful aids to manage the critical cardiovascular patient. Therefore, measurement of cardiac output in clinical veterinary medicine requires development of an easily performed, inexpensive method with acceptable accuracy and precision.

## 1.1   GOALS AND HYPOTHESES

The objective of this study was to assess lithium dilution cardiac output (LiDCO) as a method of measuring cardiac output in the dog. Multiple goals were developed in an attempt to address the key issues with the LiDCO system. To achieve some of these goals LiDCO was compared to the current clinical standard for cardiac output measurement, thermodilution cardiac output (TDCO). The goals of this study included:

1) To evaluate the accuracy of LiDCO determinations.

2) To evaluate the repeatability of LiDCO determinations.

3) To evaluate LiDCO determinations with a low dose of lithium chloride as compared to the recommended dose (i.e. high dose).

4) To evaluate the effect of increasing background serum lithium concentration on subsequent LiDCO determinations.

5) To assess the effect of the cumulative lithium chloride dose on the serum lithium concentration.

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6)      To evaluate LiDCO performed through a peripheral venous catheter in the

cephalic vein as compared to through the recommended central venous

catheter.

Therefore, the hypothesis statement for the respectively numbered goal is:

1)      There is a strong agreement between LiDCO and TDCO in the dog.

2)      There is a strong agreement between repeated LiDCO determinations.

3)      There is a strong agreement between LiDCO performed with a low dose

and a high dose of lithium chloride.

4)      As the background serum lithium concentration increases, the agreement

between LiDCO and TDCO decreases.

5)      There is a direct correlation between the cumulative lithium chloride dose

and the serum lithium concentration.

6)      There is a strong agreement between LiDCO performed through a

peripheral venous catheter and a central venous catheter.

## 1.2    INTRODUCTION TO THE METHODS OF CARDIAC OUTPUT MEASUREMENT

Over the last 2 centuries, several invasive and non-invasive methods have been

developed to assess cardiac output. The main invasive methods of cardiac output

determination are the indicator dilution methods. All of these indicator dilution methods

require the placement of some type of intravenous catheter (invasive), but unfortunately none are considered a gold standard for cardiac output determination. The most commonly described methods are the Fick oxygen method and thermodilution cardiac output (TDCO), where oxygen and temperature, respectively, are the two indicators utilized (Davidson et al. 1997; Grossman 1991). However, in the last 2 decades, many new methods have been developed to measure cardiac output. This includes an indicator dilution method, lithium dilution cardiac output (LiDCO), which is based on the injection of lithium chloride (Linton et al. 1993). There are several possible benefits to using LiDCO over TDCO in the clinical setting of veterinary medicine; the most important of which is not having to place a pulmonary arterial catheter.

The most common non-invasive methods developed include electrical bioimpedance and echocardiography. Both of these methods, although not requiring intravenous catheter placement, are not as reliable as the invasive methods mentioned above. Further research and enhancement has been occurring with these methods in the last few years and their reliability has been continually improving.

## 1.2.1 ELECTICAL BIOIMPEDANCE

Thoracic electrical bioimpedance is a non-invasive technique to determine cardiac output that analyzes changes in the thoracic cavity's resistance to an alternating current (AC) during the cardiac cycle. This methodology has been reported in humans (Donovan et al. 1986; Thangathurai et al. 1997), but a description of this procedure in the dog could not be found. It requires the placement of 8 electrodes: 2 sensing electrodes in

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the lateral cervical region; 2 sensing electrodes on the lateral thoracic wall at the level of

the xiphoid process; and 4 transmitting electrodes positioned 5 cm above and below the

respective sensing electrodes. With the transmission of AC current through the

electrodes the thorax becomes a transducer whose area can be determined

mathematically. A baseline value can be determined from the balance of electrically

conductive blood and interstitial fluid, less conductive tissue, and nonconductive air.

The result of thoracic electrical bioimpedance can be erroneously altered by the

ventilatory cycle, body movement, and blood flow (Moore et al. 1991). Ventilation will

change the area of the thoracic cavity and venous return. These ventilatory changes

occur at a different rate than the cardiovascular changes and thus can be eliminated in the

computer analysis. Body movement causes the shape of the electrical field to change and

the computer analysis can correct for this in the calculation of cardiac output.

Although the cardiac output equations used have been continually modified over

the last 10 to 15 years, to try to improve its agreement with TDCO, this method has not

replaced TDCO as the standard measure of cardiac output. There is fair to good

agreement between these two methods (Donovan et al. 1986; Thangathurai et al. 1997),

but there is still a large standard deviation, that is clinically significant and so could affect

the management of a patient. Therefore, until the standard deviation can be reduced, this

technique should be used with caution in clinical patients since inaccurate data are

possible. In addition, one report attempted whole-body electrical bioimpedance

(electrodes on wrists and ankles), which had very poor agreement with TDCO (Imhoff et

al. 2000).

In conclusion, research is ongoing with this cardiac output measurement

technique. It has failed to become clinically accepted and remains in the group of non-

invasive cardiac output methods that have potential to reduce morbidity in clinical

patients. Furthermore, there is a need to assess the feasibility and accuracy of this

methodology in the array of veterinary patients.


## 1.2.2 ECHOCARDIOGRAPHY

The typical echocardiographic method of cardiac output measurement uses

Doppler to determine the velocity of systolic flow in the ascending aorta, but it can also

be determined across any valve in the heart, as long as the valve is not insufficient. The

principle of Doppler describes the change in frequency of sound from a moving object

(blood) as compared to a stationary object (transducer) (Moore et al. 1991).

This method has mainly been described as performed either from a suprasternal or

transesophageal position. Doppler echocardiography could also be performed from the

left parasternal transthoracic position. From the suprasternal position the transducer is

angled toward the ascending aorta, therefore making the blood flow and sound waves

parallel. The computer analyzes the changing blood flow velocity and calculates the

average systolic velocity. The assumption with this method is that the aorta is a circular

tube. The cross sectional area of the aorta is calculated from its diameter. This aortic

diameter is measured from another view of the heart from a parasternal position. The

stroke volume is the product of the average velocity and the cross sectional area of the

aorta. The stroke volume is multiplied by the heart rate to calculate the cardiac output.

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Potential sources of error include the assumption that the angle (incident angle) between the blood flow and sound waves is zero. Usually it is not possible to identify an imaging plane with an incident angle of zero degrees, but an angle up to 20 degrees only causes an error of 6% (Moore et al. 1991). Therefore the degree of error that is introduced by a small angle of incident is minimal. The second error involves the assumption that the aorta is circular and does not change in size. The aorta is a dynamic structure that is changing in size (diameter) and shape during the phases of cardiac cycle. Additionally, obtaining the measurement of the ascending aortic diameter is technically difficult and requires experience. An error in measurement here will result in a large error being introduced because the measurement is squared in the determination of the cross-sectional area (e.g. an error of 2 mm will result in a 16% error) (Moore et al. 1991). Finally, the velocity of blood within the aortic column is assumed to be consistent, which is incorrect as there are changing velocities, most noted at the vessel wall blood interface. These errors or assumptions with this method have restricted its clinical usage. The agreement between the suprasternal echocardiographic and TDCO methods has been poor in several studies and has been clinically disappointing. Thus this ultrasound method has not gained wide acceptance clinically (Moore et al. 1991). Also the equipment is expensive, tends not to be easily portable and requires a high level of expertise. On the positive side echocardiography is non-invasive.

The transesophageal echocardiographic method involves sedating human patients or anesthetizing veterinary patients. This modification to the previously described method provided excellent Doppler signals of the descending aorta. This method has demonstrated fair to good agreement with TDCO (Axler et al. 1996; Tibby et al. 2000).

It must be remembered that the same errors/assumptions for suprasternal echocardiography apply to transesophageal echocardiography. This method has the advantage of being able to determine cardiac output serially, which clinically would be of benefit in decision making. It has the disadvantage of being operator dependent and experience improves the result achieved with this method (Moore et al. 1991).

There have been several other methods utilizing echocardiographically determined measures. Most involve attempting to calculate the internal area of the left ventricle so as to derive stroke volume. The measurements are complicated and difficult to perform without computer assistance. In the last few years many cardiac ultrasound machines have been equipped with these equations. Many of these methods correlate fairly well with standard cardiac output measurement methods, but again there is much operator dependency involved with these methods. Poor operator function can lead to significant errors with these methods.

## 1.2.3  INDICATOR DILUTION METHODS

### 1.2.3.1 GENERAL PRINCIPLES

The indicator dilution method is based on Fick's general principle. It states that if a measurable substance is continuously added to or removed from the blood by an organ, then the blood flow through the organ equals the amount of substance added or removed per unit time divided by the arteriovenous difference in the concentration of the substance (Grossman 1991).

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The indicator dilution method can be performed using either continuous infusion or a single bolus method. The single bolus method is used most frequently. The first description of an indicator dilution method, by Stewart in 1897, utilized the injection of an artificial indicator in the vascular system and then measured the mean concentration downstream along with its transit time. In 1932, Hamilton and Remington further modified this method, which improved both its accuracy and reliability (Davidson et al. 1997). This resulted in the development of the Stewart-Hamilton equation that is used today and is expressed as:

$$\text{Cardiac output (L/min)} = \frac{\text{amount of indicator injected (mg)} \times 60 \text{ sec/min}}{\text{mean indicator concentration (mg/ml)} \times \text{curve duration (s)} \times 1000 \text{ ml/L}}$$

The assumption made with the indicator dilution method is that the time for the injectate to appear and disappear from a point down stream is associated with the cardiac output. In general, the injectate is administered into the systemic venous circulation and is monitored in either the pulmonary artery or the systemic arterial circulation to form the indicator dilution curve. The normal indicator dilution curve is represented by a rapid upstroke that is then followed with a slower down stroke that tails off. The tailing off of the indicator dilution curve can occur due to recirculation of the indicator through the cardiovascular circuit, thus allowing it to be measured on its second pass through the heart. This is one of the inherent errors of the indicator dilution method.

The area under the indicator dilution curve is determined and is the product of the mean indicator concentration and the total duration of the first pass dilution curve. This result is used as the denominator of the Stewart-Hamilton equation. In most indicator dilution methods a computer calculates the area under the curve. This is accomplished by

modifying the curve to remove the tailing-off effect. This modification is based on using

the initial 1/3 to 1/2 of the down side of the curve with computer assisted extrapolation

determining the best line to continue the curve to baseline removing effects of tailing-off.

The length of time required for the indicator dilution curve to pass the monitoring site is

determined and is used in the denominator of the Stewart-Hamilton cardiac output

equation (i.e. curve duration).

In an indicator dilution method the fundamental requirements for the indicator

include: being non-toxic; mixes completely with blood; can be accurately measured;

remains in the blood stream during its passage from the injection site to the measurement

site; is measurable prior to the onset of recirculation; and must go through some of the

chambers of the heart (Grossman 1991). The ideal indicator would also dissipate

immediately after first passage through the heart.

With all of the indicator dilution methods there are several common sources of

error which must be controlled in order to achieve accurate cardiac output measurement.

These errors will be discussed within each of the separate indicator dilution methods.


### 1.2.3.2 FICK METHOD


The Fick oxygen method measures the difference in blood oxygen content across

the lungs and the rate of oxygen uptake by blood from the lungs (Davidson et al. 1997).

Therefore, cardiac output equals oxygen consumption divided by the arteriovenous

oxygen difference. In reality, the measurement of oxygen uptake by the lungs is

extrapolated from oxygen removal from the inspired air. In the steady state, these two

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measurements are considered equal (Grossman 1991). Pulmonary venous blood is not measured with this method, but peripheral arterial oxygen is measured and assumed to be representative of the pulmonary venous blood leaving the pulmonary capillary beds (Davidson et al. 1997; Grossman 1991).

The Fick method is considered to be the best of the indicator dilution methods available, with an average error of only 10% (Davidson et al. 1997; Grossman 1991). In human medicine, the patient is advised to breathe into a facemask, a bag, or a chamber. Unfortunately in veterinary medicine, these methods would result in changes in breathing rate, which would lead to errors in cardiac output measurement. Therefore, this method would be best performed with the animal under general anesthesia. This method employs the measurement of inspired and expired oxygen content, and the measure of blood gases, which require expensive equipment. Therefore, this method is only available for use in veterinary colleges and a few clinical practices for research purposes, and restricts its use in a general clinical setting.

There are several sources of error in the Fick method that can increase the standard error above 10% (Grossman 1991). This method is based on the assumption that the patient is at steady state and that both oxygen consumption and cardiac output remain constant while the test is being completed. Therefore, any change in these factors is a potential source of error. Error can also occur if there is an incomplete collection of all of the expired air (Grossman 1991). This would result in a low estimation of oxygen consumption and therefore decreased estimation of cardiac output. Another potential source of error is a change in the mean pulmonary volume (Grossman 1991), which could result in either an over-estimation or under-estimation of cardiac output by a clinically

significant amount. In animals, this can be controlled by the use of a ventilator.

Unfortunately, by using the ventilator and anesthesia, the metabolic drive of respiration

may be over-ridden and affect the results of the true cardiac output of the patient

(Davidson et al. 1997). There are several potential errors that can develop with the blood

gas analyses such as instrument inaccuracy and air bubbles remaining in the sample

(Grossman 1991). The combination of these potential errors can make this method

fraught with variability and therefore difficult to assess. The potential sources of error

coupled with the equipment expense are likely reasons why this method is not used as

much as the others for cardiac output measurement.


### 1.2.3.3 INDOCYANINE GREEN


This was the first indicator dilution method used regularly in clinical practice.

The method and potential errors that can occur with this diagnostic test are described

subsequently (Grossman 1991).

Indocyanine green dye is light sensitive and breaks down over time; therefore, a

fresh preparation of indocyanine green is necessary for each cardiac output

determination. A second potential source of error is the measurement of the amount of

dye to be injected because the volume is small requiring a tuberculin syringe for accurate

measurement. A third potential error could occur due to the loss of injectate during

administration, as could occur in a 3-way valve. This is primarily a problem when a very

small volume of any indicator is used. The volume of indocyanine green is injected as a

single bolus, usually into the pulmonary artery. A fourth potential error could occur with

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the time period over which the dye is injected, as it must be injected over as short a period as possible. This is common to all indicator methods. The indicator must mix well with the patient's blood prior to reaching the sampling site. This mixing occurs mainly as it passes through the ventricles of the heart. Blood sampling is collected from a peripheral systemic artery and is performed as a continuous process. A fifth potential error could occur if the blood sample is not withdrawn at a constant rate. The collected blood is continuously passed through a densitometer cuvette. The densitometer measures the concentration of indocyanine green in the blood sample and produces a concentration versus time curve (indicator dilution curve). The indicator dilution curve plotted from these results must have some component of decay so that extrapolation of the curve can be performed. This leads to a sixth potential error. Without any component of decay in the indicator dilution curve the down slope of the curve cannot be determined; this results in an erroneous estimation of cardiac output. For example, if there is recirculation of the indicator the indicator dilution curve is prolonged (e.g. an intracardiac shunt), which will result in overestimation of the indocyanine green concentration and thus reduced estimation of cardiac output. With these factors taken into account, the indocyanine green method is most accurate at high cardiac output states and least accurate at low cardiac output states.

In human patients, this method was associated with allergic reactions to the dye (Benya et al. 1989; Speich et al. 1988), especially in patients with renal disease, and has lost favour except in a research setting. This method was used until the development of the TDCO method. However, in dogs, it never really became a clinically useful diagnostic test, as its use tended to be restricted to research applications.

## 1.2.3.4 THERMODILUTION

Thermodilution (TDCO) is the most commonly used method of measuring cardiac output (Jansen 1995). It has become the accepted standard to which other methods of cardiac output determination are compared (Jansen 1995). There has been a great deal of research on the methodology of TDCO in an attempt to reduce the standard error of approximately 15%. Basically, this method uses temperature as the indicator across the heart to determine cardiac output. An aliquot of iced dextrose solution is injected into the cranial vena cava or right atrium. The solution mixes with blood in the right side of the heart and the change in temperature is detected at the level of the pulmonary artery. A temperature versus time graph is created by a thermodilution computer and the area under the curve is inversely proportionate to the cardiac output.

The TDCO method requires placement of a Swan-Ganz catheter into the jugular vein, with the tip, containing the temperature thermistor, advanced into the pulmonary artery. The catheter can be difficult to position correctly unless animals are anesthetized. The temperature change is produced by the injection of iced 5% dextrose in water. The Swan-Ganz catheter has two injection ports (proximal and distal). The indicator is injected into the proximal port, positioned in the cranial vena cava or the right atrium. The Swan-Ganz catheter, with its thermistor at the distal tip, is attached via a cable to a TDCO computer. The TDCO computer gathers the information from the thermistor regarding the change in temperature at the tip of the catheter over time, generates a temperature versus time graph (indicator dilution curve), and calculates the cardiac output.

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The injectate is inert within the body and can safely be injected repeatedly allowing determination of serial measurements. One of the most important advantages of this method is that there is virtually no long-term recirculation of the indicator. This increases the accuracy of the analysis of the temperature versus time curve when repeated measurements are made within a short time span.

There are several sources of error that can occur with the TDCO method. The first is that significant tricuspid regurgitation will cause under-estimation of the cardiac output (Konishi et al. 1992). Note that in the case of indocyanine green significant mitral regurgitation or aortic insufficiency would have the same effect. A second potential error is that under normal conditions, there are temperature fluctuations that coincide with the respiratory and cardiac cycles. If the temperature fluctuations are large enough, they may reach a magnitude equal to the temperature change associated with the iced injectate (Grossman 1991). The temperature change in the pulmonary artery increases at end expiration and during spontaneous respiration but decreases during intermittent positive pressure ventilation (IPPV). Therefore the temperature versus time graph would be overestimated with spontaneous breathing thus producing an underestimated cardiac output, while the opposite would be true for IPPV patients (Nishikawa et al. 1993). A third source of error is a change in temperature of the iced dextrose injectate (i.e. rewarming) during its passage through the catheter resulting in a decrease in the temperature curve and therefore overestimation of the cardiac output (Grossman 1991; Nishikawa et al. 1993; Taylor et al. 1990). The last major source of error relates to the warming of the injectate in the hand of the clinician before injecting it into the catheter. This will increase the injectate temperature before it reaches the pulmonary artery and

reduce the height of the temperature versus time graph, thus overestimating the cardiac output. When TDCO is performed carefully, the error rate can be as low as 5 to 10%, which is comparable to the Fick method (Grossman 1991).

Several reports have discussed modifications aimed at decreasing the error associated with TDCO. The effect of the timing of iced dextrose injection within the respiratory cycle has been studied extensively (McMilan et al. 1988; Nishikawa et al. 1993; Stevens et al. 1985). In the standard protocol, the solution is injected at end expiration. It was shown that injecting the solution at 4 equally spaced times within the respiratory cycle and averaging cardiac output measures improved correlation with the Fick method (Jansen et al. 1996; McMilan et al. 1988; Somers et al. 1993). Other studies compared the injection of iced versus room temperature solutions (Bourdillon et al. 1989; Daily et al. 1987; Groom et al. 1990). The room temperature injectate produced smaller temperature deflections which are more difficult to interpret unless the cardiac output computer is sensitive enough to register deflections of this magnitude (Groban et al. 1993). In one case report, the solution was accidentally injected at the level of the catheter introducer instead of the cranial vena cava, which produced a longer temperature curve thus underestimating cardiac output (Allen et al. 1992). In another report, the solution was injected while rapid fluid administration was occurring. Do to the decrease in the mean blood temperature the cardiac output computer underestimated the true cardiac output (Griffin et al. 1997; Wetzel et al. 1985). The duration of the injection of the solution has also been studied (Somers et al. 1993). If the injection occurs over a longer period of time, then the temperature curve will be prolonged, and the cardiac output measurement will be decreased (Nishikawa et al. 1993; Somers et al. 1993).

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Sources of error must be considered during the analysis of cardiac output by TDCO. If the clinician is not careful when using the method, the resulting data may be inaccurate and may result in an inappropriate clinical decisions.

The TDCO method has several advantages including not requiring the withdrawal of blood or an arterial puncture to perform a determination. The indicator is inert, inexpensive, and readily available. The virtual lack of recirculation or buildup of the indicator in the blood allow the computer to analyze the dilution curve easily and repeatedly.

A major disadvantage of the TDCO method is the requirement for placement of a pulmonary artery catheter (Swan-Ganz catheter). It is technically difficult to position and requires assistance of either pressure wave analysis or fluoroscopy. The Swan-Ganz catheter has been associated with both increased morbidity and mortality, and over the past decade there has been a great deal of controversy about its usage (Brown et al. 1997; Connors et al. 1996; Fink 1997; Nishimura 1989; Rackow 1997; Reinhart et al. 1997; Soni 1996; Tuman et al. 1997). In addition, there is the expense of the Swan-Ganz catheter and computer.

### 1.2.3.5 LITHIUM DILUTION CARDIAC OUTPUT

Linton first reported lithium dilution cardiac output (LiDCO) as an indicator-dilution method for cardiac output measurement in 1993. This method was developed to fill a need for a less invasive method that did not require a Swan-Ganz catheter and had accuracy comparable to thermodilution. A small volume of lithium chloride is injected

through a central venous catheter and the lithium concentration is subsequently measured from an arterial site. The concentration versus time graph is generated by the LiDCO computer (indicator dilution curve).

Prior to performing a LiDCO measurement both a hemoglobin and sodium determination must be performed and recorded in the LiDCO computer. The function of the hemoglobin value is to determine the fraction of blood in which there will be no lithium (i.e. red cells). The function of the sodium determination is to enable differentiation between the sodium and the lithium concentration, since the sensor measures both lithium and sodium.

The lithium sensor is attached to a catheter placed in a peripheral artery, monitors the lithium concentration, and sends this information to the LiDCO computer. As the injected dose of lithium chloride passes through the right side of the heart, lungs, and then the left side of the heart, there is complete mixing of the lithium chloride with the plasma. Arterial blood is withdrawn from the peripheral arterial catheter at a constant rate by a flow regulator pump. The blood is drawn past the lithium sensor and then through the pump, which pushes the blood into a collection bag. The LiDCO computer creates a lithium concentration versus time graph (indicator dilution curve). The computer calculates the area under the curve, which is used in the denominator of the LiDCO equation. The computer then calculates the cardiac output, and displays it along with the LiDCO curve.

Lithium is not normally present in blood, is not bound to plasma proteins, and thus is easily analyzed within blood (Linton et al. 1993). However, there is recirculation with this method requiring the computer to produce a correction curve. In low cardiac

output states, the area under the curve is already prolonged, which will then potentially make it difficult to determine the end of the initial curve. As previously stated, the true curve is extrapolated from 1/2 to 2/3 of the down slope of the indicator dilution curve (Band et al. 1997; Grossman 1991). This was not a problem with the initial reports presented by Linton that used patients of large body size. However, this may be a problem for the smaller veterinary patient, although this methodology has been successfully studied in the rat (O'Brien 2000).

Furthermore, there is a build up of serum lithium concentration when multiple determinations are performed. This can interfere with subsequent measurements, as the sensor is less able to differentiate the next injection of lithium from the background serum lithium concentration. This will lead to an erroneous reduction in the height of the measured dilution curve, thus producing a smaller area under the curve resulting in an increased cardiac output measurement. The manufacturer theoretically determined that this error would become significant at a serum lithium concentration of 0.2 mmol/L (O'Brien 2000).

The benefits of this method are that it is inexpensive compared to other methods, easy to perform, safe, and associated with few potential technical problems (Linton et al. 1997). It avoids the use of a pulmonary artery Swan-Ganz catheter, which has lately been shown to be associated with increased mortality (Brown et al. 1997; Connors et al. 1996; Fink 1997; Nishimura 1989; Rackow 1997; Reinhart et al. 1997; Soni 1996; Tuman et al 1997). In human medicine Swan-Ganz catheters have been associated with a great deal of debate about their overall utility. The LiDCO method should be easier to

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perform in the clinical setting because the catheter placement requires only standard intensive care nursing skills.

The disadvantages with the LiDCO method are that it requires using both a central venous catheter and a peripheral arterial catheter. However, the patient generally will not require sedation for the placement of these catheters, unlike with TDCO. Another disadvantage is the withdrawal of blood from the patient during a determination (at a rate of 4 ml/minute). The length of time required for a determination depends on the cardiac output value, and the time prior to a determination of cardiac output for the sensor to attain a steady baseline lithium value. This time to attain a steady baseline prior to a LiDCO determination is variable but requires about 15 to 60 seconds. This time period in which the sensor must be bathed in blood does not require the continual withdrawal of blood, only that the sensor be bathed completely by blood until a steady lithium baseline concentration is determined. And finally, this method could potentially be limited by the size of the patient due to the inability to place a peripheral arterial catheter in the very small patient.

Lithium dilution cardiac output has been compared to TDCO in humans (Linton et al. 1993; Linton et al. 1997), horses (Linton et al. 2000b), pigs (Kurita et al. 1997), and dogs (Mason et al. 2001). In these species the agreement between the two methods was excellent. In the study by Kurita et al., LiDCO and TDCO were both compared with an electromagnetic flowmeter, which revealed that LiDCO had a better agreement with the electromagnetic flowmeter than TDCO. The original human studies used adult patients. Recently a study conducted in a pediatric intensive care unit demonstrated excellent

agreement between TDCO and LiDCO (Linton et al. 2000a). The use of LiDCO has also been described in the giraffe (Linton et al. 1999).

## 1.2.4   FUTURE METHODS TO MEASURE CARDIAC OUTPUT

Future methods to measure cardiac output include 3-dimensional echocardiography, cine-magnetic resonance imaging (cine-MRI), and pulse-wave contour analysis (Goedje et al. 1999; Hibbard et al. 2000). At present, the most extensively studied method is the pulse-wave contour analysis, since this method is non-invasive and inexpensive compared to the other two methods. Pulse-wave contour analysis has very good agreement with TDCO although this method has had a tendency to develop inaccurate results (Goedje et al. 1999). In the report by Goedje et al. after the initial calibration the pulse contour method remained stable for 24 hours. The pulse contour wave method is being integrated with a standard method of cardiac output (i.e. TDCO) so that it can be initially calibrated and then, as needed, intermittently recalibrated. The major benefit of the pulse contour wave method is that it provides continuous cardiac output measurement.

Both 3-dimensional echocardiography and cine-MRI (high-speed MRI), although not currently widely available in veterinary medicine due to their costs, may be utilized more in the future as the cost of these methods is reduced. A recent study compared the two methods and found that there was excellent agreement (Hibberd et al. 2000). It also demonstrated that 3-dimensional echocardiography was much more accurate than the 2-dimensional methods described, and that interobserver variability was reduced 3-fold

with the 3-dimensional method (Hibberd et al. 2000). These two methods may require increased technical expertise and experience.

## 1.3    PHARMACOKINETICS OF LITHIUM IN THE DOG

Pharmacokinetics of lithium has been determined in dogs (Rosenthal et al. 1986; Rosenthal et al. 1989). Lithium has a narrow therapeutic range in dogs, similar to that in humans. Its distribution is similar to that of sodium and can be explained by a 2- or 3-compartment model. It has a half-life in mixed-breed dogs of 21.6 hours, whereas the half-life in Beagles is 13.5 hours (Rosenthal et al. 1986; Rosenthal et al. 1989). It is possible that different dog breeds may have varying lithium half-life values. Lithium competes for binding sites with other ions, including sodium, potassium, and phosphorus. It is excreted unchanged in the urine and, similar to sodium, is mostly reabsorbed in the renal tubules.

Lithium toxicosis is usually associated with long-term administration although it can occur with large single dosages. In humans, lithium has a narrow therapeutic range. When toxic amounts of lithium are reached, the most common effects include fine tremors followed by spastic tremors or seizures (Davies 1991). Gastrointestinal tract signs, cardiovascular signs, neutrophilia, lymphopenia, skin lesions, and signs of renal dysfunction may be evident (Davies 1991).

These signs mainly have been reported in humans, but there have been two reported cases of lithium toxicosis in dogs (Davies 1991). The only source of drinking water for these 2 dogs, for a period of 3 months, was from a swimming pool that had

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been chlorinated with lithium hypochlorite. Both dogs presented for polyuria, polydipsia, and weight loss. One dog also exhibited intermittent diarrhea, muscle tremors, and general weakness, while the other dog had 2 seizures during the exposure period. The initial serum lithium concentrations of the two dogs were 1.5 and 1.1 mmol/L. In humans, these values would be within the therapeutic reference range, but toxicity can occur with chronic therapy even when the serum lithium concentration is within the therapeutic range. The serum lithium concentrations of these two dogs, after a 2-month period without exposure to lithium, were 0.13 and 0.41 mmol/L respectively. The reason for the long washout period is that lithium competes for intracellular binding sites and can displace sodium ions in nerves and other tissues. Therefore with chronic therapy it can build up in the body tissues.

Treatment for lithium intoxication involves removing the exposure to the drug and intravenous infusion of saline to restore fluid and electrolyte balance. In 10% of human cases of lithium toxicity permanent renal and neurological deficits have been noted (Davies 1991).

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# ASSESSMENT OF LITHIUM DILUTION CARDIAC OUTPUT AS A

# TECHNIQUE FOR MEASUREMENT OF CARDIAC OUTPUT IN DOGS

## 2.0 ABSTRACT

**Objectives**—To determine agreement of cardiac output measured by lithium dilution cardiac output (LiDCO) and thermodilution cardiac output (TDCO) in dogs and to determine agreement of low- and high-dose LiDCO with TDCO.

**Animals**—10 dogs (7 males, 3 females).

**Procedure**—Cardiac output was measured in anesthetized dogs by use of LiDCO and TDCO. Four rates of cardiac output were induced by occlusion of the caudal vena cava, changes in depth of anesthesia, or administration of dobutamine. Lithium dilution cardiac output was performed using 2 doses of lithium chloride (low and high dose). Each rate of cardiac output allowed 4 comparisons between LiDCO and TDCO.

**Results**—160 comparisons were determined of which 68 were excluded. The remaining 92 comparisons had values ranging from 1.10 to 12.80 L/min. Intraclass correlation coefficient (ICC) between low-dose LiDCO and TDCO was 0.9898 and between high-dose LiDCO and TDCO was 0.9896. When all LiDCO determinations were pooled, ICC was 0.9894. For determinations of cardiac output $< 5.0$ L/min, ICC was 0.9730. Mean $\pm$ SD of the differences of TDCO minus LiDCO for all measurements was $-0.084 \pm 0.465$ L/min, and mean of TDCO minus LiDCO for cardiac outputs $< 5.0$ L/min was $-0.002 \pm 0.245$ L/min.

**Conclusions and Clinical Relevance**—The LiDCO technique is a suitable substitute for TDCO to measure cardiac output in dogs. Use of LiDCO eliminates the need for catheterization of a pulmonary artery. Use of LiDCO could increase use of cardiac output monitoring, which may improve management of cardiovascularly unstable animals.

## 2.1 INTRODUCTION

Measurement of cardiac output has been used in veterinary medicine as a research tool, but it has not been used extensively in clinical settings. In human medicine, cardiac output has become an integral part of anesthetic and cardiovascular monitoring. This information is quintessential for making therapeutic decisions in many critical patients. Currently in veterinary medicine, monitoring of blood pressure, pulse oximetry, and central venous pressure as well as evaluation of results for a multitude of diagnostic tests are used to assess critical patients. These are all useful tests; however, only cardiac output provides an assessment of global cardiovascular function. Monitoring of cardiac output has not been used routinely in the management of animals perhaps in large part because of the invasive nature and expertise required to position catheters and the cost of equipment needed to monitor catheter position. However, monitoring of cardiac output along with blood pressure may be the most useful aids to manage critical cardiovascular patients. A solution to this problem is the development of the lithium dilution cardiac output (LiDCO) method.

The LiDCO technique is a new method of measuring cardiac output that has been used in people.[1] It belongs to the group of cardiac output measurements known as

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indicator dilution methods. The other two most commonly used methods in this group are thermodilution cardiac output (TDCO) and administration of indocyanine green. All of these methods measure cardiac output by the use of a technique whereby an indicator substance is injected into the venous blood and the dilution of this indicator in blood is measured over time, using samples obtained from an arterial site that is distant from the site of injection.

The TDCO and indocyanine green indicator-dilution methods have drawbacks that limit their widespread use in animals in clinical settings. The TDCO method requires the placement of a Swan-Ganz catheter into a pulmonary artery, which usually requires use of fluoroscopy or pressure-wave analysis as well as a degree of expertise in catheterizing a pulmonary artery. In addition, safety of the technique of pulmonary arterial catheterization has been questioned in humans in clinical settings.[2-4] Indocyanine green is not currently used in humans because of the potential for allergic reactions to the indicator.[5] Other noninvasive methods of measuring cardiac output have not proven to be as accurate, reliable, simple, or inexpensive as TDCO.[6-8] Hence, there is a need for a method to measure cardiac output that is simple, safe, reliable, and inexpensive. For these reasons, the LiDCO method was developed for use in humans. This method involves injecting lithium chloride into a catheter inserted into a central vein and measuring the diluted concentration of lithium in blood samples obtained from a peripheral arterial site, using a sensor that is selective for lithium. The lithium sensor is monitored by a LiDCO computer that analyzes the dilution curve and determines cardiac output. The LiDCO method has been validated as being accurate, compared with values for TDCO, in humans,[9] horses,[10] and pigs.[11] In the study involving pigs, LiDCO and TDCO were

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compared with cardiac output measured by use of an electromagnetic flow meter. The

investigators found that LiDCO compared more closely than TDCO to the

electromagnetic flow meter estimation of cardiac output.[11] In each study TDCO was used

as the criterion-referenced standard. However, studies consistently have documented

inherent errors when the TDCO method is used to determine cardiac output.[12-15] Thus,

TDCO has become an accepted clinical standard but should not be considered as a

criterion-referenced standard.

The objective of the study reported here was to compare cardiac output measured

by use of LiDCO and TDCO in dogs and to determine the agreement between these

techniques. Another objective was to compare high and low dose lithium chloride cardiac

output determinations with TDCO.


## 2.2 MATERIALS AND METHODS


**Animals**—Ten crossbred dogs were used in the study. All dogs were anesthetized, and

instrumentation was accomplished. Dogs were given preanesthetic medication consisting

of butorphanol tartrate[a] (0.4 mg/kg of body weight, IM). Anesthetic induction was

accomplished by use of thiopental[b] (20 mg/kg, IV), dogs were intubated, and were

initially maintained on halothane[c] at 1.5%. Dogs were ventilated[d] at a rate of

approximately 10 breaths/min and to a volume calculated at 10 to 15 ml/kg.

**Instrumentation**—Instrumentation consisted of a 20-gauge 1.5-inch arterial catheter[e]

placed percutaneously in the dorsal pedal artery; a 22-F 80-cm occlusion catheter[f] placed

in a femoral vein by use of a cutdown technique and advanced to the level of the thoracic

portion of the caudal vena cava; a 7-F 110-cm Swan-Ganz thermodilution catheter[g] inserted into a jugular vein and advanced to the level of the pulmonary artery; and a 6-F 65-cm straight flush catheter[h] inserted in the same jugular vein and advanced to the level of the right atrium. Positions of the occlusion, Swan-Ganz, and straight flush catheters were confirmed by use of fluoroscopy.

**Measurement of cardiac output**—A thermodilution cardiac computer[i] was used to determine TDCO measurements. The unit performed a self-testing system check after being powered up. Prior to placement, the Swan-Ganz catheter was attached to the computer to validate that the thermistor was operational. The injection temperature probe attached to the computer was maintained in a 12-ml syringe with 5% dextrose in water (D5W); the temperature probe was positioned in an ice bath along with numerous 6- and 12-ml syringes filled with D5W. These syringes were maintained in the ice bath (approx 0 C) for at least 12 hours prior to each experiment. The computation constant for the computer was adjusted for a 7-F Swan-Ganz catheter, bath temperature of 0 to 5 C, and injection volume of 5 or 10 ml. Therefore, the computation constants used were 0.247 for a 5-ml injection and 0.542 for a 10-ml injection, as specified by the operation manual[j].

The TDCO measurements were determined as described in the operation manual[j]. The chilled syringes containing D5W were handled sparingly to avoid warming the solution prior to injection. All measurements were obtained at end-expiration by arresting the ventilator. Cardiac output measurements were repeated until 3 consecutive values with a difference of ≤10% were obtained. Mean of these 3 measurements was used for

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comparison. The smallest injection volume (5 or 10 ml of D5W) that produced a signal amplitude with a change of at least 0.5 C from baseline was used.

A LiDCO cardiac computer[k] was used to determine LiDCO (Appendix 1). The sensor for the lithium chloride measurements was attached to the side port of a 3-way valve that was connected to the catheter inserted in the dorsal pedal artery (Appendix 2). The sensor was prepared as described in the operation manual.[l] The housing for the sensor included inlet and outlet ports. The inlet port was attached to the catheter inserted in the dorsal pedal artery, and the outlet port was attached via tubing to a disposable blood collection bag. The tubing between the sensor and collection bag passed through a flow regulator pump. When the pump was activated, it withdrew blood from the dorsal pedal artery and forced the arterial blood across the sensor at a constant rate and into the collection bag. To measure cardiac output via this technique, the LiDCO cardiac computer required the input of the sensor constant, injection dose of lithium chloride, hemoglobin concentration of each dog, and serum sodium concentration. Injection of lithium chloride involved placing the injection dose into an extension set attached to the straight flush catheter and injecting the lithium chloride and a subsequent volume (10 ml) of heparinized saline (0.9% NaCl) solution to begin measurement of cardiac output.

The LiDCO was determined as described in the operation manual.[l] A manual count was instituted concomitant with activation of the injection button on the computer. At the 5-second mark, the ventilator was switched off (always at end-expiration). At the 7-second mark, the lithium chloride in the extension set was flushed into the right atrium. Two doses of lithium chloride were used to evaluate the accuracy of low- and high-signal amplitude in the LiDCO computer. The operating manual indicated that an ideal signal

should be in the amplitude range of 0.2 to 0.8 m$M$. The higher dose of lithium chloride

was used to generate an indicator dilution curve with a signal amplitude in the range of

0.5 to 0.7 m$M$ (Appendix 1), whereas the lower dose was used to generate an indicator

dilution curve with a signal amplitude in the range of 0.2 to 0.3 m$M$.

**Experimental protocol**—Four rates of cardiac output were studied. The highest rate of

cardiac output was produced by administration of a constant-rate infusion of dobutamine[m]

(5 to 10 μg/kg/min); the next highest rate of cardiac output was produced by inducing a

light plane of anesthesia; the third highest rate of cardiac output was produced by

inducing a moderately deep plane of anesthesia; and the lowest rate of cardiac output was

created by inducing an extremely deep plane of anesthesia or by inflation of the occlusion

catheter in the caudal vena cava. Order for the rates of cardiac output was determined

randomly for each dog. No attempt was made to ensure that the cardiac output was

identical for each rate in each dog, but 4 rates of cardiac output were produced in each

dog. Also, no attempt was made to ensure that the methods used to change cardiac output

were of equal magnitude for each dog. Thus, in some dogs, a deep plane of anesthesia

was used to create the lowest rate of cardiac output, whereas in other dogs, occlusion of

the caudal vena cava was used to create the lowest rate of cardiac output.

Cardiac output measurements were obtained only after a dog achieved a stable

hemodynamic plane following application of the preceding maneuver designed to alter

cardiac output. This stable plane was achieved by waiting for at least 15 minutes and

often as long as 60 minutes after changing the plane of anesthesia, infusing the

dobutamine, or occluding the caudal vena cava. In addition, an attempt was made to

maintain hemodynamic stability throughout the series of cardiac output measurements

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obtained within each rate of cardiac output. Hemodynamic and respiratory variables were recorded to document stability of the cardiovascular state during data collection. Variables recorded before and between each measurement of cardiac output were heart and respiratory rates; systolic, diastolic, and mean systemic arterial pressures; systolic, diastolic, and mean pulmonary arterial pressures; inspired and expired halothane concentrations; and end-tidal $CO_2$ concentration. All variables were recorded from an automated unit[n] that was calibrated prior to beginning the experiment on each dog. A disposable pressure transducer[o] attached to the distal port of the Swan-Ganz catheter provided systolic, diastolic, and mean pulmonary arterial pressures. A second disposable pressure transducer attached to the catheter inserted in the dorsal pedal artery provided continuous systolic, diastolic, and mean systemic arterial pressures. Body temperature was obtained from the pulmonary artery by the thermistor on the Swan-Ganz catheter and detected by the thermodilution cardiac computer. The $P_{CO_2}$ was maintained within the range of 30 to 45 mm Hg. To accomplish this, ventilation rate was increased when $P_{CO_2}$ was > 45 mm Hg and decreased when $P_{CO_2}$ was < 30 mm Hg.

At each rate of cardiac output, a 15-step protocol for data collection (Appendix 3) was followed. Prior to creating a specific cardiac output rate, a blood sample was obtained from the catheter inserted in the dorsal pedal artery. An aliquot of the sample was used to determine hemoglobin and sodium concentrations; another aliquot of the sample was used for subsequent determination of the serum lithium concentration, using a flame photometer[p]. These values for hemoglobin and sodium concentrations were entered into the LiDCO cardiac computer. Steps 1, 3, 5, 7, 9, 11, 13, and 15 were to record hemodynamic and respiratory variables. Step 2 was to perform a TDCO

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determination (3 consecutive measurements of cardiac output; values differed by ≤10%).

Step 4 was to perform an initial LiDCO determination (LiDCO$_a$). The dose of lithium

chloride (low or high) used for LiDCO$_a$ was determined randomly. Step 6 was to perform

another LiDCO determination with the alternate dose of lithium chloride from step 4

(LiDCO$_b$). Step 8 was to perform another TDCO determination. Step 10 was to perform

another LiDCO determination; the dose used here was identical to that used in step 6.

Step 12 was to perform another LiDCO determination; the dose of lithium chloride used

here was identical to that used in step 4. Step 14 was to perform a final TDCO

determination.

**Statistical analysis**—All data from the 4 cardiac output rates for each dog were

considered for statistical analysis. The TDCO and LiDCO determinations performed at

the previously described steps were paired for comparison as follows: steps 2 and 4, 6 and

8, 8 and 10, and 12 and 14 (Appendix 3).

Three exclusion criteria were used to reject paired observations. The first criterion

involved errors in methods during the experiment, including procedural errors such as

failure to enter the correct hemoglobin concentration, sodium concentration, or dose of

lithium chloride. The second criterion involved all paired observations that had a

background serum lithium concentration > 0.2 mmol/L. The third exclusion criterion

consisted of all paired observations obtained during hemodynamic instability (i.e.,

hemodynamic stability was not maintained throughout the cardiac output measurements

within a rate of cardiac output). Hemodynamic instability was defined as a variation of

> 20% in the cardiac output measurements determined by use of TDCO from the

beginning to the end of a series of cardiac output determinations within 1 rate of cardiac output.

Resulting data were analyzed by use of a repeated-measures ANOVA with the Generalizability Theory, using a statistical software program.[a] Data analysis was used to develop an intraclass correlation coefficient (ICC) for the true reliability between LiDCO and TDCO.[16] The initial analyses examined agreement between low-dose LiDCO and TDCO and between high-dose LiDCO and TDCO. When agreement between TDCO and each of the doses of lithium chloride used for LiDCO determinations was high (ICC > 0.9), then our objective was to repeat the analysis by comparing pooled LiDCO with TDCO. Data also were analyzed graphically, using the Bland-Altman method to assess agreement between the 2 methods of cardiac output.[17] Because the clinically relevant range of cardiac output for dogs is < 5 L/min, data were analyzed separately to evaluate agreement between the 2 methods for measurement of cardiac output in this selected range (ie, cardiac output of < 5 L/min), using the ICC for reliability and Bland-Altman methods.

Data also were analyzed to determine ICC for repeatability of the LiDCO determinations, using the following criterion. When the low- and high-dose LiDCO each had a high degree of agreement with TDCO (ICC > 0.9), then LiDCO for the 2 doses of lithium chloride were compared with each other to determine repeatability.

## 2.3 RESULTS

Of the 10 dogs in the study, 7 were male, and 3 were female. Dogs ranged from 30.5 to 45.4 kg (mean, 36.2 kg). Cardiac output induced in these dogs ranged from 1.10 to 12.80 L/min. For 4 dogs, a single LiDCO sensor was used for each dog for all cardiac output measurements at all 4 rates of cardiac output. For the other 6 dogs, 1 LiDCO sensor was used for cardiac output measurements of only 2 rates of cardiac output (i.e. 2 sensors were used for all 4 rates of cardiac output). The occlusion catheter was used to create the lowest rate of cardiac output in 8 dogs, and an extremely deep plane of anesthesia was used in the other 2 dogs.

A total of 160 paired observations were collected (Appendix 4 and 5). Of these, 28 were excluded from analysis because of errors in methods (12 for input of incorrect sodium or hemoglobin concentrations, 12 for obstruction of the catheter in the dorsal pedal artery, and 4 for failure of the flow regulator pump during determinations). Eight paired observations were excluded because of hemodynamic instability throughout a rate of cardiac output, and 32 paired observations were excluded because of a problem with the sensor. None of the paired observations were excluded because of a background serum lithium concentration > 0.2 mmol/L. Thus, 92 paired observations were used for analysis (Appendix 4 and 5).

The ICC for comparisons of low-dose LiDCO to TDCO and high-dose LiDCO to TDCO were 0.9898 and 0.9896, respectively. The ICC for comparison of TDCO to pooled LiDCO was 0.9894. When the overall analysis was performed for 71 paired observations of the more clinically relevant data (cardiac output < 5.0 L/min), a pooled

ICC of 0.9730 was observed. Repeatability of LiDCO resulted in an ICC of 0.9940.

Bland-Altman representation of agreement between the 2 methods with all paired

observations was examined (Figure 2.1). Bias and precision (mean ± SD of LiDCO minus

TDCO) for this analysis was 0.084 ± 0.465 L/min. When data for the more clinically

relevant cardiac output (< 5.0 L/min) were analyzed, bias and precision was 0.002 ±

0.245 L/min (Figure 2.2).

In 3 of the initial 4 dogs, it was observed that LiDCO measurements progressively

exceeded TDCO measurements as the duration of use of the LiDCO sensor increased

(Figure 2.3). Paired observations for the first 4 dogs in which the LiDCO sensor was used

for measuring > 2 rates of cardiac output were excluded (32 observations). For the

remaining 6 dogs, a LiDCO sensor was used for only 2 rates of cardiac output. This

resulted in a pattern toward a reduced difference between LiDCO and TDCO values for

the first and third rates of cardiac output, compared with the difference between LiDCO

and TDCO values for the second and fourth rates of cardiac output (Figure 2.4).


## 2.4 DISCUSSION


Results of the ANOVA revealed that there is a high degree of agreement between

values for low-dose LiDCO and TDCO as well as between values for high-dose LiDCO

and TDCO. Therefore, the high- and low-dose LiDCO values were pooled, and analyzed

for agreement with TDCO. As expected, agreement for pooled LiDCO with TDCO also

was high. Bias determined from the Bland-Altman analysis revealed that on average,

there was little difference between the 2 methods but that precision can vary; most

determinations for precision were within a range of ± 0.930 L/min (± 2 SD; Figure 2.1).

When the data were analyzed for paired observations for cardiac output rates < 5.0 L/min,

ICC decreased from 0.9894 to 0.9730. Although this is less than the ICC for the full

range of data, there still was a high degree of agreement. This reduction in ICC does not

mean that the agreement is worse in this range, because this is an expected finding for

this statistical method when the range over which the observations were performed is

reduced.[16] The ICC is defined as the ratio of variance between dogs (this refers to all

variance except that attributable to the tests) compared with the total error variance. In

other words, if ICC were to be subtracted from 1, then the resulting difference would be

the variance between the tests compared with the total error variance.[16]

Bias and precision determined from Bland-Altman analysis revealed that the

agreement between both methods improved for cardiac output that ranged from 1.10 to

4.91 L/min, compared with cardiac output that ranged from 1.10 to 12.80 L/min (Figure

2.1 and 2.2). Therefore, within the clinically relevant range of cardiac outputs, LiDCO

has a high degree of agreement with TDCO. This analysis leads to the important clinical

question of whether LiDCO can be substituted for TDCO. To determine the answer, it

needs to be determined whether a difference between these 2 methods of determining

cardiac output (± 0.49 L/min for the range of < 5 L/min) is acceptable. Neither method of

determining cardiac output is a true criterion-referenced standard; hence, the real

difference between LiDCO and actual cardiac output may be within ± 0.49 L/min. Also, a

study performed on pigs[11] revealed that LiDCO had more reliability than TDCO when

compared with results from the electromagnetic flowmeter, which could be considered to

be a better criterion-referenced standard. Nevertheless, a difference of ± 0.49 L/min, the

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worst-case scenario for 95% of all evaluations, can be acceptable for cardiac output measurements within the range for cardiac output < 5 L/min. This study does not reveal whether LiDCO is better than TDCO, or vice versa, for measurement of cardiac output. As mentioned previously, TDCO is not a criterion-referenced standard; therefore, this analysis indicates only that LiDCO can be substituted for TDCO in clinical settings. Repeatability of LiDCO was excellent.

A number of paired observations (n = 68) were not used for analysis on the basis of exclusion criteria. One criterion was elimination of paired observations when background serum lithium concentration was > 0.2 mmol/L; however, none of the observations were excluded on the basis of this criterion. This value was theoretically determined by the manufacturer to be the point at which LiDCO would differ significantly from true cardiac output as a result of background concentrations of serum lithium.[r] This increased serum lithium concentration could interfere with subsequent determinations, because of reduced ability of LiDCO to differentiate between a background serum lithium concentration and a concentration attributable to the lithium chloride injection. This is a problem inherent to all indicator dilution methods and is not specific to LiDCO. Thus, as the serum lithium concentration gradually increases, LiDCO theoretically becomes less accurate. Therefore, we expect that there is a cutoff value for background lithium chloride concentration; above this value, substantial error is introduced, and below this value, substantial error is not detected. We are not aware of published data that establishes the value of 0.2 mmol/L for serum concentration of lithium as the optimal cutoff value.

Twenty-eight paired observations were excluded because of errors in methods, which were mainly the result of errors by the investigators (12 paired observations), thrombosis or kinking of the catheter in the dorsal pedal artery (12 paired observations), or equipment failure (4 paired observations). In 1 dog, the arterial catheter became obstructed because of a positioning problem within the artery, which required placement of a second catheter. Rates of cardiac output that were excluded because of errors in methods were not repeated because of the concern that the background threshold serum lithium concentration of 0.2 mmol/L would be surpassed as a result of additional LiDCO measurements that would need to be performed.

Eight paired observations were excluded because of an inability to maintain hemodynamic stability within a rate of cardiac output. Exclusion was based on a difference of > 20% between TDCO measurements within a rate of cardiac output. By excluding these observations, this eliminated the differences in cardiac output measured as a result of actual changes in true cardiac output, as opposed to differences between the methods.

A new exclusion criterion was identified after data from the first 4 dogs were analyzed. It was observed that in 3 dogs, LiDCO measurements progressively exceeded TDCO measurements, apparently associated with increasing duration of use of the LiDCO sensor (Figure 2.3). The reasons may have been multifactorial, including damage by excess pressure during the flushing process, blood clots on the sensor, binding of lithium to the surface of the sensor, or an inherent problem of the sensors that became apparent during progressive use. Therefore, the LiDCO sensor was changed after completion of data collection for 2 rates of cardiac output for the remaining 6 dogs.

Hence, all paired observations for the first 4 dogs in which the LiDCO sensor was used

for measuring > 2 rates of cardiac output (32 paired observations) were retrospectively

excluded. For the remaining 6 dogs, a pattern toward a reduced difference between

LiDCO and TDCO values for the first and third rates of cardiac output was observed

(Figure 2.4). A new sensor was used for the first and third rates of cardiac output only.

The manufacturer of the LiDCO system subsequently changed the sensors by increasing

the thickness of the sensor membrane, which the manufacturer believes will increase the

life of the sensors.[r] Hence, this may no longer be an issue but should be kept in mind for

sensors used for long periods or used repetitively during a short period.

The LiDCO differs from TDCO, because it does not require use of a Swan-Ganz

catheter. However, it does require that a central venous catheter and a catheter in a

peripheral artery be used, both of which are common in the management of critically ill

animals and would allow for easy monitoring of these patients with LiDCO. The LiDCO

does require that blood be withdrawn from a patient at a rate of 4 ml/min; the duration of

measurement could be 1 to 2 minutes. The actual cardiac output measurement can require

15 to 30 seconds, depending on the cardiac output. The residual time for measurement of

cardiac output primarily involves bathing the sensor in lithium chloride to establish a

stable baseline. During this time, blood is withdrawn to bathe the sensor. However, the

amount of blood withdrawn can be reduced, which could be useful in smaller animals. A

much smaller volume of blood would be withdrawn if only enough blood were allowed to

reach the sensor and bathe it to stabilize the sensor prior to starting the pump. This is an

important issue for extremely small animals; however, the system has been used

successfully in rats.[r] Thus, there is not a limitation of animal size for the LiDCO, but a

technical limitation exists in the ability of clinicians or researchers to place a catheter in a

peripheral artery of small animals.

Another technical issue to be considered is the battery-powered pump used for

LiDCO measurements. It is conceivable that as the battery starts to expire, the amount of

blood being withdrawn may decrease to < 4 ml/min. If this assumption were true, then the

cardiac output measurement calculated by the computer analysis of the dilution curve

would overestimate the real cardiac output. Finally, we believe that it is important to keep

the arterial catheter patent by flushing it at regular intervals with heparinized saline

solution to avoid thrombi obstructing the catheter, thereby slowing the rate of blood flow

across the sensor and affecting the cardiac output measurement.

Pharmacokinetics of lithium have been determined in dogs.[18,19] Lithium has a

narrow therapeutic range in dogs, similar to that in humans. Its distribution is similar to

that of sodium and can be explained by a 2- or 3-compartment model. It has a half-life in

mixed-breed dogs of 21.6 hours, whereas the half-life in Beagles is 13.5 hours.[18,19]

Lithium competes for binding sites with other ions, including sodium, potassium, and

phosphorus. It is excreted unchanged in the urine and, similar to sodium, is mostly

reabsorbed in the renal tubules. Lithium toxicosis usually is associated with long-term

administration. When toxic amounts of lithium are reached, the most common effects

include fine tremors followed by spastic tremors or seizures.[20] Gastrointestinal tract signs,

cardiovascular signs, neutrophilia, lymphopenia, skin lesions, and signs of renal

dysfunction may be evident.[20] These signs mainly have been reported in humans, but

there have been 2 reported cases of lithium toxicosis in dogs.[20] Both of these dogs had

been drinking water from a swimming pool that had been chlorinated with lithium

hypochlorite. There was no evidence of lithium toxicosis in any of the dogs in the study reported here.

The manufacturer recommended use of a dose of lithium chloride that would create a signal amplitude of 0.5 to 0.7 m$M$ for the LiDCO.[r] However, we are not aware of any reports of inadequacy for lesser doses of lithium chloride that generate a lower signal amplitude. The advantage for use of a lower dose of lithium chloride is the ability to perform more serial repetitions before the background serum lithium concentration increases substantially. This probably is not an issue in humans, because they are much larger than most dogs and cats. However, it is possible that the theoretic limit of a serum lithium concentration of 0.2 mmol/L set by the manufacturer may become an issue in smaller animals. There is a reasonable safety margin with LiDCO, because the toxic dose of lithium is approximately 1 mmol/L, and the theoretic upper limit for serum lithium concentration is 0.2 mmol/L. None of the 10 dogs reported here reached a serum lithium concentration of 0.2 mmol/L after a minimum of 16 LiDCO measurements. This investigation of 2 doses of lithium chloride revealed that values for the low- and high-dose LiDCO were both in strong agreement with values for TDCO. Thus, we advocate use of a lower dosage of lithium chloride for LiDCO measurement to allow the potential for additional serial repetitions in an animal when clinically indicated.

Future studies of LiDCO could address important issues. One could be to determine whether an injection of lithium chloride could be performed through a catheter inserted in a peripheral vein, rather than a central venous catheter. This could be a considerable saving in cost and patient morbidity if the need for a central catheter could be eliminated. Another area of investigation could be to determine the effect of an

increase in background serum lithium concentration on the agreement between LiDCO and TDCO values, which may result in development of a correction factor to compensate for a high serum lithium concentration.

The LiDCO measurements provided a reliable and acceptable method of cardiac output determination in dogs and can be used in lieu of TDCO, because agreement between LiDCO and TDCO values is high. In addition, repeatability of LiDCO is high. The LiDCO system is safe, because it does not require placement of a catheter in a pulmonary artery. Furthermore, there is a reasonable margin of drug safety. The LiDCO measurements are simple to obtain and reasonably cost effective when compared with TDCO measurements.

## 2.5 FOOTNOTES

[a] Torbugesic, Ayerst Veterinary Laboratories, Guelph, ON, Canada.

[b] Pentothal, Merial Ltd, Iselin, NJ.

[c] Halothane BP, Bimeda-MTC Animal Health Inc, Cambridge, ON, Canada.

[d] Air-Shields ventimeter ventilator, Air-Shields Inc, Hatboro, Pa.

[e] Insyte-W, Becton-Dickinson, Sandy, Utah.

[f] Fogarty occlusion catheter, Baxter Healthcare Corp, Irvine, Calif.

[g] Swan-Ganz thermodilution catheter, Baxter Healthcare Corp, Irvine, Calif.

[h] Straight flush catheter, Medi-tech, Watertown, Mass.

[i] Edwards thermodilution cardiac output computer model COM-2, Baxter Healthcare

Corp, Santa Ana, Calif.

[j] Edwards thermodilution cardiac output computer model COM-2 operation manual,

Baxter Healthcare Corp, Santa Ana, Calif.

[k] LiDCO cardiac monitor CM 31-01 computer, LiDCO Limited, London, UK.

[l] LiDCO operation manual, LiDCO Limited, London, UK.

[m] Dobutrex, Eli Lilly, Toronto, ON, Canada.

[n] Criticare model 1100, Criticare Systems Inc, Waukesha, Wis.

[o] DTX plus DT-36, Becton-Dickinson, Sandy, Utah.

[p] IL 943 flame photometer, Instrumentation Laboratories, Lexington, Mass.

[q] SPSS software, SPSS Inc, Chicago, Ill.

[r] O'Brien T, LiDCO Limited, London, UK: Personal communication, 2000.

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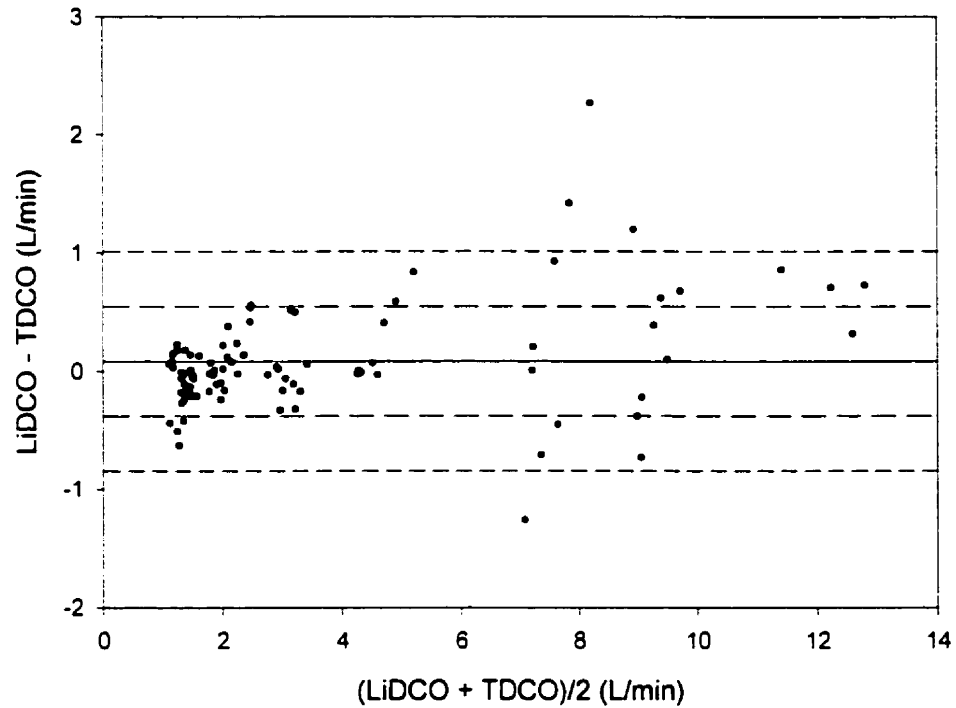
**Figure 2.1**—Bland-Altman plot of cardiac output measurements obtained in 10 dogs by
use of lithium dilution cardiac output (LiDCO) and thermodilution cardiac output
(TDCO). Each symbol represents a paired observation (n = 92 data points). Range for
cardiac output values is 1.10 to 12.80 L/min. Mean ± SD bias for the comparison of
LiDCO minus TDCO is 0.084 ± 0.465 L/min. Horizontal lines indicate the mean ( — ),
mean ± 1 SD (— — —), and mean ± 2 SD (- - -).
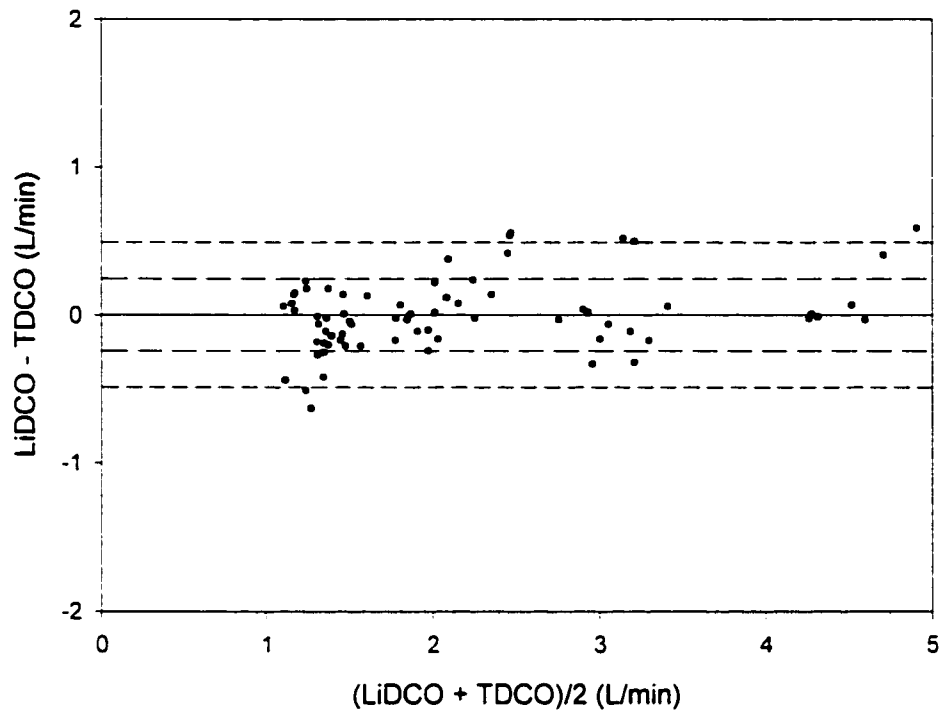
**Figure 2.2**—Bland-Altman plot of cardiac output measurements obtained in 10 dogs by

use of lithium dilution cardiac output (LiDCO) and thermodilution cardiac output

(TDCO) for the clinically relevant range of cardiac output (< 5 L/min). Each symbol

represents a paired observation for LiDCO and TDCO (n = 71 data points). Range for

cardiac output values is 1.10 to 4.91 L/min. Mean ± SD bias for the comparison of

LiDCO minus TDCO is 0.002 ± 0.245 L/min. Horizontal lines indicate the mean ( — ),

mean ± 1 SD (— — —), and mean ± 2 SD (- - -).
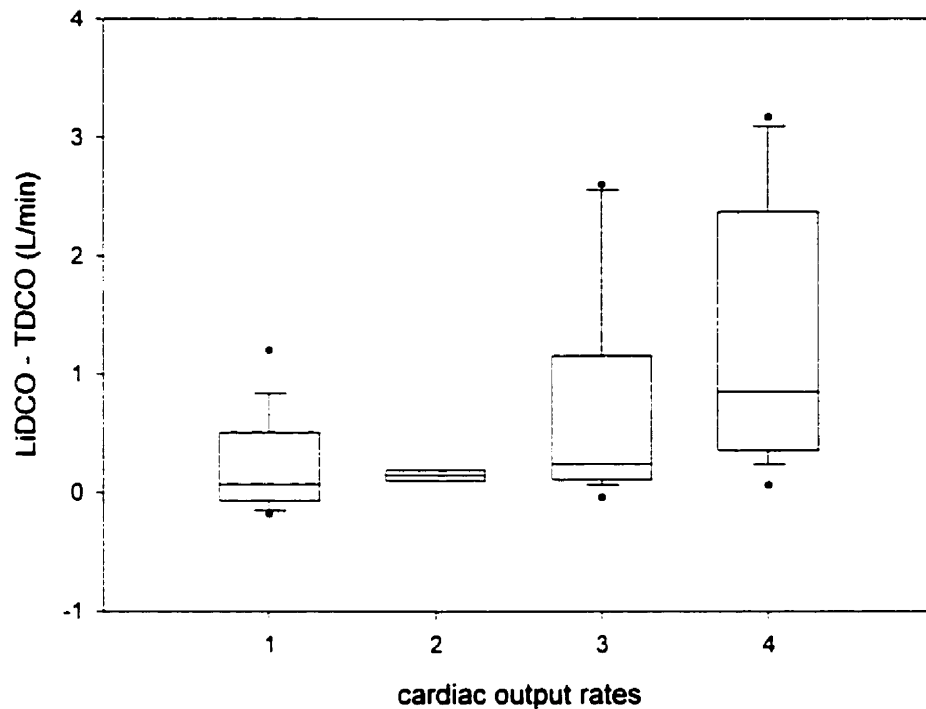
**Figure 2.3**—Box plots of 4 rates of cardiac output for 3 of the initial 4 dogs obtained by use of lithium dilution cardiac output (LiDCO) in which a single LiDCO sensor was used to measure all 4 rates in each dog. Notice the disagreement that developed between LiDCO and thermodilution cardiac output (TDCO) values starting with the third rate of cardiac output that was measured and progressing with the fourth rate of cardiac output that was measured. The boxes represent the 25th to 75th percentile values. Horizontal lines within boxes represent median values. T-bars on boxes represent 10th and 90th percentile values. Solid circles represent values outside the 10th to 90th percentiles.
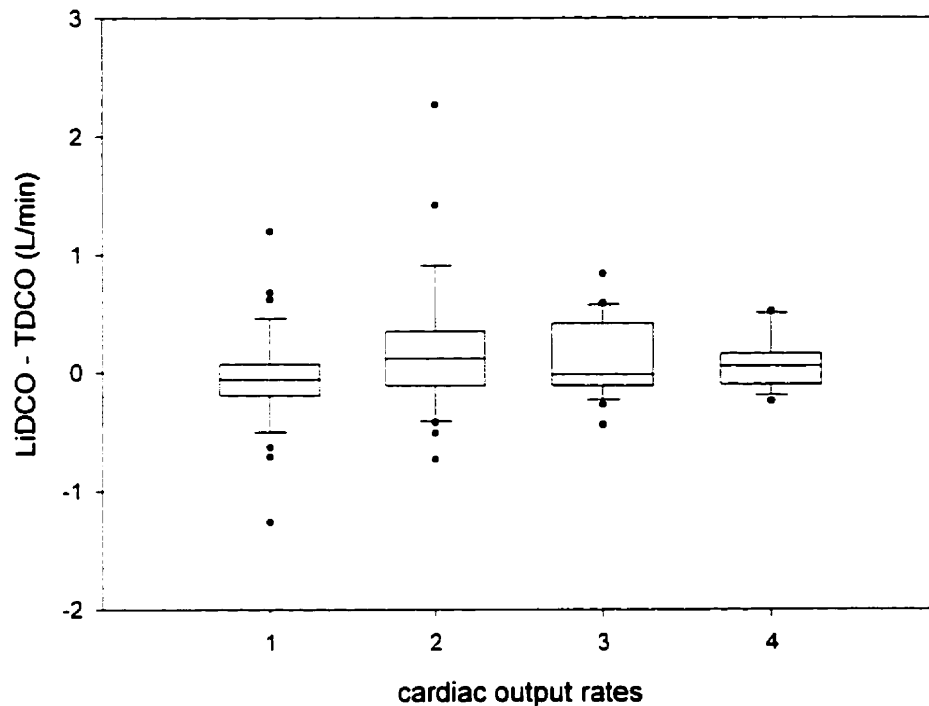
**Figure 2.4**—Box plots of 4 rates of cardiac output for 10 dogs obtained by use of lithium dilution cardiac output (LiDCO). Values for some rates of cardiac output obtained by use of a single sensor from 4 dogs were excluded. Therefore, cardiac output rates 1 and 2 represent values for all 10 dogs, whereas cardiac output rates 3 and 4 represent values obtained for only 6 dogs. Notice the pattern toward a reduced difference between LiDCO and thermodilution cardiac output (TDCO) for cardiac output of rates 1 and 3, compared with the difference for rates 2 and 4. The boxes represent the 25th to 75th percentile values. Horizontal lines within boxes represent median values. T-bars on boxes represent 10th and 90th percentile values. Solid circles represent values outside the 10th to 90th percentiles.

# LITHIUM DILUTION CARDIAC OUTPUT IN THE DOG: EFFECT OF BACKGROUND SERUM LITHIUM CONCENTRATION ON ACCURACY AND THE EFFECT OF CUMULATIVE LITHIUM CHLORIDE DOSE ON SERUM LITHIUM CONCENTRATION.

## 3.0 ABSTRACT

**Objectives**–The primary objective was to assess the effect of increasing serum lithium concentration on lithium dilution cardiac output (LiDCO) determinations. A secondary objective was to determine the ability to predict the serum lithium concentration from the cumulative lithium chloride dose used in a short period of time.

**Animals**–10 dogs (7 males, 3 females).

**Procedure**–Cardiac output was measured in anesthetized dogs by LiDCO and thermodilution cardiac output (TDCO). The effect of the serum lithium concentration on LiDCO was assessed by observing the agreement between TDCO and LiDCO at various serum lithium concentrations, for the clinically relevant range of cardiac outputs (< 5 L/min). Cumulative lithium chloride dose was compared with the corresponding serum lithium concentrations to evaluate the secondary objective.

**Results**–44 paired observations were used. The background serum lithium concentrations ranged from 0.02 to 0.40 mmol/L. The linear regression analysis for the effect of the serum lithium concentration on the agreement between TDCO and LiDCO revealed a slope of -1.530 [95% confidence interval of (-2.388, -0.671)] and a y-intercept of 0.011 (r = -0.485).

The linear regression analysis for the effect of the cumulative lithium chloride

dose on the serum lithium concentration, revealed a slope of 2.291 [95% confidence

interval of (2.153, 2.429)] and a y-intercept of 0.008 (r = 0.969).

**Conclusions and Clinical Relevance**–The LiDCO measure increased slightly as the

serum lithium concentration increased. This error that developed in LiDCO, as the serum

lithium concentration increased, was not clinically significant, was minimal at a serum

lithium concentration of 0.1 mmol/L, and modest at a concentration of 0.4 mmol/L. The

serum lithium concentration can be reliably predicted from the cumulative lithium dosage

if lithium chloride is administered frequently within a short period of time.


## 3.1 INTRODUCTION

The measure of cardiac output has long been used in veterinary medicine as a

research tool, but it has not been used extensively in the clinical setting. In human

medicine, cardiac output has become an integral part of both anesthetic and

cardiovascular monitoring for many years. This information has been quintessential to

therapeutic decision making in many critical patients. Currently in veterinary medicine

the monitoring of blood pressure, pulse oximetry, central venous pressure, as well as a

multitude of diagnostic tests are used to evaluate critical patients. These are all useful

tests, however only cardiac output provides an assessment of global cardiovascular

function. Cardiac output has not been routinely used in the management of the veterinary

patient perhaps in large part due to the invasive nature of the procedure, expertise

required to position catheters, and the cost of equipment needed to monitor the catheter

position. However, cardiac output along with blood pressure may be the most useful aids

to manage the critical cardiovascular patient. A solution to this problem is the

development of the lithium dilution cardiac output (LiDCO) methodology.

Lithium dilution cardiac output is a method of measuring cardiac output, which

has been utilized in people[1] and has recently been validated in the dog.[2] It belongs to the

group of cardiac output measurements known as indicator dilution methods. The other

two most commonly used indicators in this group are thermodilution cardiac output

(TDCO) and indocyanine green. All of these methods measure cardiac output by

injecting an indicator substance into the venous blood and measuring the amount of

dilution of this indicator over time, as detected from an arterial site.

The two previous indicator dilution methods have drawbacks that limit their use

in the veterinary clinical setting. The TDCO method requires the placement of a Swan-

Ganz catheter into the pulmonary artery, which requires either fluoroscopy or pressure

wave analysis, as well as a level of expertise in pulmonary arterial catheterization. In

addition, the safety of pulmonary arterial catheterization has recently been questioned in

the human clinical setting.[3-5] The indocyanine green method is not currently used

clinically in human medicine due to the potential for allergic reactions to the indicator.[6]

Other non-invasive methods of measuring cardiac output have not proven to be as

accurate, reliable, simple, or inexpensive as TDCO.[7-9] Hence there is a need for a method

to measure cardiac output that is simple, safe, reliable, and inexpensive.

For these reasons the LiDCO method was developed for human medicine. This

method involves injecting lithium chloride into a central venous catheter, and measuring

the diluted lithium concentration at a peripheral arterial catheter site with a sensor that is

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selective for lithium. The lithium sensor is monitored by the LiDCO computer that analyzes the dilution curve and determines the cardiac output. Recent work has validated this method as being accurate compared to TDCO in humans,[10] horses,[11] pigs,[12] and dogs.[2] In the dog study, two doses of LiDCO were assessed, a high dose and low dose. Excellent agreement was demonstrated between the two doses.[2] In all these reports, TDCO was used as the "gold standard". However, studies consistently demonstrate the inherent errors with the TDCO method.[13-16] Thus, TDCO is not a "gold standard" but rather has become an accepted clinical standard. Similarly, lithium dilution cardiac output is also not a "gold standard" for the measurement of cardiac output. A recent study in the dog has demonstrated that LiDCO agrees quite favorably with TDCO.[2]

The manufacturer of the LiDCO system has stated that an increase in the serum lithium concentration will decrease the accuracy of the system. They have determined a theoretical serum lithium concentration of 0.2 mmol/L to be the value beyond which the LiDCO system would significantly differ from the true cardiac output due to the background build up of serum lithium[3]. The elevated background serum lithium concentration would reduce the ability of the LiDCO system to differentiate the next lithium chloride injection from the prevailing serum lithium concentration. This is a problem inherent to all indicator dilution methods and not just LiDCO. Thus, as the serum lithium concentration gradually rises, as a result of previous LiDCO determinations, the LiDCO system theoretically becomes less accurate. The ability to use a low dose of lithium chloride to perform LiDCO should delay the accumulation of lithium within the circulation.[2] Nevertheless, with the frequent assessment of cardiac output by LiDCO within a short time period, it may be possible for the background serum

lithium concentration to rise substantially. Therefore, a cut-off value would be expected for the background lithium chloride concentration, above which significant error is introduced. The authors are unaware of published data that establishes this cut off value to be optimal at 0.2 mmol/L.

The primary objective of this study was to determine the effect of increasing serum lithium concentration on the LiDCO measurement, and in particular when the serum lithium concentration reaches or exceeds the 0.2 mmol/L value. A secondary objective was to determine if the cumulative lithium chloride dose could be used to predict the serum lithium concentration.

The experimental design that follows was previously used to demonstrate the agreement between cardiac output measurements obtained by LiDCO and TDCO.[2] In addition, that study also demonstrated a strong agreement between LiDCO performed by the injection of a high and low dose of lithium chloride. The current study involves the analysis of additional data that utilized the previous experimental design.

## 3.2 MATERIALS AND METHODS

**Animals** – Ten crossbred dogs were used in the study. All dogs were anesthetized, and instrumented. The dogs were given preanesthetic medication consisting of butorphanol[b] (0.4 mg/kg of body weight, IM). Anesthetic induction was accomplished by the use of thiopental[c] (20 mg/kg, IV), the dogs were intubated and initially maintained on halothane[d] at 1.5%. The dogs were ventilated[e] at a rate of approximately 10 breaths/min and to a volume calculated at 10 to 15 ml/kg.

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**Instrumentation** – Instrumentation consisted of a 20-gauge 1.5-inch arterial catheter[f]

placed percutaneously in the dorsal pedal artery; a 22-F 80-cm occlusion catheter[g] placed

in a femoral vein by use of a cutdown technique and advanced to the level of the thoracic

portion of the caudal vena cava; a 7-F 110-cm Swan-Ganz thermodilution catheter[h]

inserted in a jugular vein and advanced to the level of the pulmonary artery; and a 6-F 65-

cm straight flush catheter[i] inserted in the same jugular vein and advanced to the level of

the right atrium. The positions of the occlusion, Swan-Ganz, and straight flush catheters

were confirmed by fluoroscopy.

**Measurement of cardiac output** – A thermodilution cardiac computer[j] was used to

determine the TDCO measurements. The unit performed a self-testing system check after

being powered up. Prior to placement, the Swan-Ganz catheter was attached to the

computer to validate that the thermistor was operational. The injectate temperature probe

attached to the computer was maintained in 5% dextrose in water (D5W) in a 12-ml

syringe without the plunger; the syringe was positioned in an ice bath along with

numerous 6- and 12-ml syringes filled with D5W. These syringes were maintained in the

ice bath (approx. 0 C) for at least 12 hours prior to each experiment. The computation

constant for the computer was adjusted for a 7-F Swan-Ganz catheter, bath temperature of

0 to 5 C, and injection volume of 5 or 10 ml. Therefore, the computation constants used

were 0.247 for a 5-ml injection and 0.542 for a 10-ml injection, as specified by the

operation manual.[k] The TDCO measurements were determined as described in the

operation manual.[k] The chilled syringes containing D5W were handled sparingly to

avoid warming the solution prior to injection. All measurements were obtained at end-

expiration by arresting the ventilator. Cardiac output measurements were repeated until 3

consecutive values with a difference of ≤10% were obtained. The mean of these 3

measurements was used for comparison. The smallest injection volume (5 or 10 ml of

D5W) that produced a signal amplitude with a change of at least 0.5 C from baseline was

used.

A LiDCO cardiac computer[i] was used to determine LiDCO (Appendix 1). The

sensor for the lithium chloride measurements was attached to the side port of a 3-way

valve that was connected to the catheter inserted in the dorsal pedal artery (Appendix 2).

The sensor was prepared as described in the operation manual.[m] The housing for the

sensor included an inlet and outlet port. The inlet port was attached to the catheter

inserted in the dorsal pedal artery, and the outlet port was attached via tubing to a

disposable blood collection bag. This tubing between the sensor and collection bag

passed through a flow regulator pump. When the pump was activated, it withdrew blood

from the dorsal pedal artery and forced the arterial blood across the sensor at a constant

rate and into the collection bag. To measure cardiac output via this technique, the LiDCO

cardiac computer required the input of the sensor constant, injection dose of lithium

chloride, hemoglobin concentration, and serum sodium concentration for each dog.

Injection of lithium chloride involved placing the injection dose into an extension set

attached to the straight flush catheter and injecting it with a subsequent volume (10 ml) of

heparinized saline (0.9% NaCl) solution to begin measurement of cardiac output.

The LiDCO was determined as described in the operation manual.[m] A manual

count was instituted coincident with activation of the injection button on the computer.

At the 5-second mark, the ventilator was switched off (always at end-expiration). At the

7-second mark, the lithium chloride in the extension set was flushed into the right atrium. The operating manual indicates that an ideal signal should be in the amplitude range of 0.2 to 0.8 mM. Two doses of lithium chloride were used. The higher dose of lithium chloride was used to generate an indicator dilution curve with a signal amplitude in the range of 0.5 to 0.7 mM (Appendix 1), the lower dose was used to generate an indicator dilution curve with a signal amplitude in the range of 0.2 to 0.3 mM.

**Experimental protocol** – Four to 10 rates of cardiac output were studied in each dog. The initial 4 rates consisted of various cardiac outputs. The highest rate of cardiac output was produced by the administration of a constant-rate infusion of dobutamine[n] (5-10 ug/kg/min); the next to highest rate of cardiac output was produced by inducing a light plane of anesthesia; the third highest rate of cardiac output was produced by inducing a moderately deep plane of anesthesia; and the lowest rate of cardiac output was created by inducing an extremely deep plane of anesthesia or by inflation of the occlusion catheter in the caudal vena cava. The order for the first 4 rates of cardiac output was determined randomly for each dog. No attempt was made to ensure that the cardiac output was identical for each rate in each dog, but that 4 different rates of cardiac output were produced in each dog. Also, no attempt was made to ensure that the methods used to change cardiac output were of equal magnitude for each dog. Thus, in some dogs, a deep plane of anesthesia was used to create the lowest rate of cardiac output, whereas in other dogs, occlusion of the caudal vena cava was used to create the lowest rate of cardiac output. After these initial four rates of cardiac output were studied, additional rates of cardiac output (up to 6) were created for each dog, using a light plane of anesthesia. No attempt was made to vary the cardiac output among these additional cardiac output rates.

Cardiac output determinations were obtained only after a dog achieved a stable

hemodynamic plane following application of the preceding maneuver designed to alter

cardiac output. This stable plane was achieved by waiting for at least 15 minutes and

often as long as 60 minutes after changing the plane of anesthesia, infusion of

dobutamine, or occluding the caudal vena cava. In addition, an attempt was made to

maintain hemodynamic stability throughout the series of cardiac output measurements

obtained within each rate of cardiac output. Hemodynamic and respiratory variables were

recorded to document stability of the cardiovascular state during data collection.

Variables recorded before and after each measurement of cardiac output were heart and

respiratory rates; systolic, diastolic, and mean systemic arterial pressures; systolic,

diastolic, and mean pulmonary arterial pressures; inspired and expired halothane

concentrations; and end-tidal $CO_2$ concentration. All variables were recorded with an

automated unit[o] that was calibrated prior to beginning the experiment on each dog. A

disposable pressure transducer[p] attached to the distal port of the Swan-Ganz catheter

provided systolic, diastolic, and mean pulmonary arterial pressures. A second disposable

pressure transducer attached to the catheter inserted in the dorsal pedal artery provided

continuous systolic, diastolic, and mean systemic arterial pressures. Body temperature

was obtained from the pulmonary artery by the thermistor on the Swan-Ganz catheter and

detected by the thermodilution cardiac computer. The $Pco_2$ was maintained within the

range of 30 to 45 mmHg. To accomplish this, the ventilation rate was increased when

$Pco_2$ was > 45 mmHg and decreased when $Pco_2$ was < 30 mmHg.

At each rate of cardiac output, a 15-step protocol for data collection was followed

(Appendix 6). Prior to inducing a specific cardiac output rate, a blood sample was

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obtained from the catheter inserted in the dorsal pedal artery. An aliquot of the sample

was used to determine hemoglobin and sodium concentrations; another aliquot of the

sample was used for subsequent determination of the serum lithium concentration, using

a flame photometer.[4] A blood sample for serum lithium concentration was also obtained

after the last cardiac output determination. These values for hemoglobin and sodium

were entered into the LiDCO cardiac computer. Steps 1, 3, 5, 7, 9, 11, 13, and 15 were to

record hemodynamic and respiratory variables. Step 2 was to perform a TDCO

determination (3 consecutive measurements of cardiac output; values differed by $\leq 10\%$).

Step 4 was to perform a LiDCO determination (LiDCO$_a$). The dose of lithium chloride

(low or high) used for LiDCO$_a$ was determined randomly. Step 6 was to perform another

LiDCO determination with the alternate dose of lithium chloride from step 4 (LiDCO$_b$).

Step 8 was to perform another TDCO determination. Step 10 was to perform another

LiDCO determination; the dose used here was identical to that used in step 6. Step 12

was to perform another LiDCO determination; the dose of lithium chloride used here was

identical to that used in step 4. Step 14 was to perform a final TDCO determination.

**Statistical Analysis** – To determine the effect of increasing background serum lithium

concentration on the LiDCO measurement, an analysis of the effect of increasing

background serum lithium concentration on the agreement between TDCO and LiDCO

was undertaken. All data from each dog were considered for statistical analysis. LiDCO,

in this experimental design, included both low and high dose lithium chloride. Since a

previous study[2] demonstrated that high dose and low dose LiDCO are equivalent, the data

was pooled for all cardiac output rates. The TDCO and LiDCO (steps 14 and 12

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respectively (Appendix 6)) obtained closest to the time of the collection of the serum lithium sample were used to determine the variability in the agreement between TDCO and LiDCO as a function of the background serum lithium concentration.

Four exclusion criteria were used to reject LiDCO determinations. The first criterion limited this study to the clinically relevant range of cardiac outputs (< 5 L/min), and all LiDCO measurements above this limit were removed from the analysis. The second criterion involved errors in methods during the experiment, including procedural errors such as failure to enter the correct hemoglobin concentration, sodium concentration, or dose of lithium chloride into the LiDCO computer. The third criterion involved all paired observations obtained during hemodynamic instability (i.e. hemodynamic stability was not maintained throughout the cardiac output measurements within a rate of cardiac output). Hemodynamic instability was defined as a variation of >20% in the cardiac output measurements determined by TDCO from the beginning to the end of a series of cardiac output determinations within a rate of cardiac output. The fourth criterion excluded all paired observations for which the lithium sensor had been used for more than 2 cardiac output rates. The effect of persistent use of a lithium sensor has been previously discussed.[2]

For the analysis of the effect of the cumulative lithium chloride dose on the serum lithium concentration, all data from each dog were considered for statistical analysis. There were no exclusion criteria placed on the data for this analysis, since TDCO and LiDCO measurements were not relevant to this objective. The serum lithium concentration that was determined at the end of each cardiac output rate was compared with the cumulative dose of lithium chloride that had been administered up to that point

in time. The cumulative lithium chloride dose was expressed as dose divided by the weight of the dog in kilograms.

Linear regression analysis[r] was used to assess the effect of increasing serum lithium concentration on the agreement between TDCO and LiDCO (primary objective). Linear regression analysis[r] was also used to assess the effect of the cumulative lithium chloride dose on the serum lithium concentration (secondary objective), to enable the estimation of the background serum lithium concentration from the cumulative dosage of lithium chloride administered.

## 3.3 RESULTS

Ten dogs were used (7 male, 3 female), with an average weight of 36.2 kg, and range of 30.5 to 45.4 kg. The range of cardiac outputs induced in these dogs was 1.10 to 12.80 L/min. The average number of injections of lithium chloride used was 32.1, with a range of 12 to 44. This included both low and high dose lithium chloride injections. The range of serum lithium concentrations measured in these dogs was 0.02 to 0.47 mmol/L, with an average of 0.17 mmol/L. The average amount of time from the first to the last cardiac output determination for each dog was 5.5 hours, with a range of 3 to 7 hours.

Coefficient of variation for the serum lithium measurements were determined for two controls, each performed 10 times on separate days (Appendix 7).[q] The low control had a mean value of 0.69 mmol/L, standard deviation of 0.1, and a coefficient of variation

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of 2%. The high control had a mean value of 2.12 mmol/L, standard deviation of 0.03, and a coefficient of variation of 1%.

A total of 74 paired observations of TDCO - LiDCO and the corresponding serum lithium concentration were collected from the protocol (Appendix 4 and 5). Implementation of exclusion criteria resulted in the following paired observations being removed from the analysis. Six observations were excluded for lithium dilution cardiac output > 5 L/min. Methodological errors resulted in 7 observations being excluded, these included: 3 for incorrect input of sodium and hemoglobin values; 3 for obstruction of the dorsal pedal arterial catheter; and 1 for failure of the flow regulator pump battery during determinations. Hemodynamic instability resulted in 3 observations being excluded. Lithium sensors used for greater than 2 cardiac output rates resulted in 14 observations being excluded. Thus, a total of 44 paired observations were used for the analysis of the effect of increasing background serum lithium concentration on the agreement between LiDCO and TDCO (Appendix 4 and 5). Thus, the range of LiDCO measurements used in the analysis was 1.13 to 4.55 L/min. The range of corresponding serum lithium concentrations used in the analysis was 0.02 to 0.40 mmol/L.

As the background serum lithium concentration increased there was a trend for a LiDCO determination to increase in value. The linear regression analysis of the effect of the serum lithium concentration on the agreement between TDCO and LiDCO demonstrated a slope of -1.530 [95% confidence interval of (-2.388, -0.671)] and a y-intercept of 0.011 (Figure 3.1). The linear regression equation therefore is expressed as y = -1.530x + 0.011 (r = -0.485). Using this equation, the estimated mean difference between TDCO and LiDCO determinations (with 95% confidence intervals) when a

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serum lithium concentration is measured at 0.1, 0.2, 0.3 or 0.4 mmol/L is -0.142 (-0.787, 0.503), -0.295 (-0.940, 0.350), -0.448 (-1.093, 0.197), or -0.601 (-1.246, 0.044) L/min respectively.

The linear regression analysis of the effect of the cumulative lithium chloride dose on the serum lithium concentration demonstrated a slope of 2.291 [95% confidence interval of (2.153, 2.429)] and a y-intercept of 0.008 (Figure 3.2). The linear regression equation therefore is expressed as $y = 2.291x + 0.008$ (r = 0.969). Using this equation, the estimated serum lithium concentration (with 95% confidence intervals) when a cumulative dosage of lithium chloride is calculated at 0, 0.05, 0.10, 0.15, or 0.20 mmol/kg is 0.008 (-0.047, 0.062), 0.122 (0.067, 0.177), 0.237 (0.182, 0.291), 0.351 (0.296, 0.406), or 0.466 (0.411, 0.521) mmol/L respectively.

## 3.4 DISCUSSION

The linear regression analysis of the effect of increasing background serum lithium concentration on the agreement between TDCO and LiDCO revealed an expected trend in which the average difference between TDCO and LiDCO became greater as the serum lithium concentration increased. This occurred because the LiDCO measurement increased as the background serum lithium concentration increased. Accumulation of the indicator represents a problem with all indicator dilution methods for measuring cardiac output. As the background serum lithium concentration increases, the lithium sensor and computer have greater difficulty differentiating the next dose of lithium chloride from the background concentration. The resulting indicator dilution curves become smaller, which

results in a smaller area under the curve, used in the denominator of the cardiac output

equation. Thus, the LiDCO determinations begin to overestimate the cardiac output as

the serum lithium concentration increases. Remember that neither TDCO nor LiDCO are

gold standard tests but rather have become clinically accepted standards.

The critical level beyond which the measure of cardiac output is no longer reliable

has been set by the manufacturer of LiDCO at 0.2 mmol/L. The resulting linear

regression analysis (Figure 3.1) revealed the expected negative slope (-1.530) due to the

gradually increasing serum lithium concentration. The y-intercept was nearly zero, which

would indicate that there is no error present when the serum lithium concentration is zero.

This would be expected, and supports the view that it is the background serum lithium

concentration that is creating the error that develops in a LiDCO determination as the

background serum lithium increases. However the r value for the linear regression

analysis was -0.485, indicating a weak association. The low r value may be due to

several reasons including other uncontrolled variables within the two tests. For example,

LiDCO was performed as a single determination, whereas TDCO was repetitively

performed until 3 consecutive observations were within ≤10 % that were then averaged

into one determination. This would reduce the error with the TDCO measurement. Had

the reported LiDCO value been similarly determined, as the average of 3 consecutive

observations within ≤10%, the resultant cardiac output measurement may have been

closer to the TDCO. Therefore, on average this may have resulted in less variability in

LiDCO. However, this was not possible with the experimental design that was

employed.[2] The average error introduced into the LiDCO system when the serum lithium

concentration increased was not clinically significant, but the 95% confidence intervals observed were wide, which could achieve clinical significance. No attempt was made from the analysis to create a cut-off value to suggest a serum lithium concentration beyond which a clinically significant degree of error would be introduced. Clinical significance can be expected to vary with the individual clinician and clinical situation. Clinical significance may be defined as a difference between the measured value and the real value that is of such a magnitude as to change one's clinical decision.[17]

The data demonstrates that the cumulative lithium chloride dose can predict the serum lithium concentration, when multiple injections are performed over a short time period (Figure 3.2). This is important information since it allows the operator to estimate the serum lithium concentration that has been introduced from previous lithium chloride injections, when the injections occurred over a short period of time. It could then allow the operator to estimate the "real cardiac output" based on the observed LiDCO measurement and the estimated error introduced by the estimated serum lithium concentration. If the determinations are performed over a long period of time (e.g. days) then the estimated serum lithium concentration will be greater than the true serum lithium concentration.

The pharmokinetics of lithium have been determined in the dog.[18,19] Lithium has a narrow therapeutic range in dogs, similar to people. Its distribution is similar to sodium and can be explained by either a two- or three-compartment model. It has a half-life in mixed breed dogs of 21.6 hours, while in the beagle it is 13.5 hours.[18,19] Lithium competes for binding sites with other ions, including sodium, potassium, and phosphorus. It is excreted unchanged in the urine and like sodium is mostly reabsorbed in the renal

tubule. Lithium toxicity is usually associated with chronic administration. When toxic levels of lithium are reached, the most common effects include fine motor tremors, followed by spastic tremors and/or seizures.[20] Other signs include gastrointestinal signs, cardiovascular signs, neutrophilia, lymphopenia, skin lesions and renal signs.[20] These toxic signs are mainly reported in the human literature but there have been two reported cases of lithium toxicity in the dog.[20] Both of these dogs had been drinking pool water that had been chlorinated with lithium hypochlorite. There was no evidence of lithium toxicity noted in any of the dogs in this study despite achieving levels of up to 0.47 mmol/L.

An earlier study demonstrated that LiDCO could be performed with either a low or high dose lithium chloride injection[2]. In light of the current study, if one is anticipating performing multiple determinations, the low dose of lithium chloride will cause a lesser rise in the background serum lithium concentration. This in turn will result in less of an over estimation of the actual cardiac output with a LiDCO measurement. Therefore the low dose of lithium chloride should be used when performing multiple LiDCO determinations, particularly within a short time period.

The background serum lithium concentration increased rapidly in the dogs with this experimental design, with some dogs receiving as many as 30 to 40 injections of lithium chloride. Recall that these injections included both low and high doses of lithium chloride. Only a small degree of biological elimination of lithium would have occurred during the time course of this experiment (3 to 7 hours), since the half-life of lithium in dogs is reported to be 13.5 to 21.6 hours.[18,19] In the clinical setting it is very unlikely that multiple LiDCO determinations would be performed, similar to this study, thus reaching

these serum lithium concentrations, particularly if the low dose is used. Using the regression equation that relates the cumulative lithium chloride dose to the serum lithium concentration and using the low dose of lithium chloride injection, the number of injections that could be performed to reach a serum lithium concentration of 0.1, 0.2, 0.3 and 0.4 mmol/L are 16, 34, 51, and 68 respectively within the short time period of 3 to 7 hours. It is unlikely that more than 16 determinations would be performed in a clinical setting over a given 7 hour period, therefore the background serum lithium concentration is unlikely to exceed 0.1 mmol/L.

Determinations on successive days would allow time for a greater amount of the lithium to be biologically eliminated from the dog. For cases where multiple determinations are performed in a day, the average degree of error could be estimated by either measuring the serum lithium concentration or estimating it from the cumulative lithium chloride dosage (Figure 3.2). The manufacturer may also be able to integrate this information into the LiDCO computer. However, if the estimated average number of LiDCO determinations in a day were 6 (low dose injections), then a mean error, after the $5^{th}$ determination, would be -0.045 L/min with 95% confidence intervals of (-0.690, 0.600). This mean error could be introduced into the $6^{th}$ LiDCO determination, if it were performed shortly thereafter; i.e. that is this $6^{th}$ LiDCO determination would be expected to overestimate a TDCO measurement by 0.045 L/min on average.

Knowing or estimating the serum lithium concentration enables the estimation of the error introduced by a high background serum lithium concentration. However, these linear relationships, that allow the estimation of the serum lithium concentration, are based on multiple LiDCO determinations over a short period of time. Therefore if

multiple determinations occur in a patient over a longer period of time (12 to 24+ hours) then these linear relationships will overestimate the error introduced into LiDCO.

There are several potential errors that could occur during a LiDCO determination, which would affect its measured result. These include some of the errors that were encountered in the process of performing this experiment and include: failure to input the correct sodium and hemoglobin values in the LiDCO computer; obstruction of dorsal pedal arterial catheter; and failure of the flow regulator pump battery. A previous study demonstrated a trend for the accuracy of the LiDCO determinations to fall as a lithium sensor underwent repeated use, thus all data analyzed in this study are the result of a lithium sensor used for only two cardiac output rates (approximately 8 determinations).[2] The manufacturer of the LiDCO system has since modified the membrane of the sensor to improve its functional life-span.[4]

This study represents a further analysis of data collected utilizing an experimental design that was developed to demonstrate the agreement between cardiac output measurements obtained by LiDCO (two different doses) and TDCO at various cardiac outputs.[2] Therefore the current design was not specific for the objectives of this study. A different experimental design could have been used to only address the objectives of this study. This could have included evaluating one rate of cardiac output throughout the study, instead of varying the rates, and utilizing only one dose of lithium chloride instead of two doses. Such a design may have improved the level of agreement observed with the present design.

In conclusion, when the background serum lithium concentration increases there is a reduction in the accuracy of the LiDCO system, but it does not appear to be clinically

significant when a small number of determinations are performed, but may become

clinically significant if a large number of determinations are performed in a short period

of time. However the use of a low dose of lithium chloride reduces the amount of error in

the LiDCO with multiple determinations. In addition, the linear regression equations that

have been produced will allow users of the LiDCO system to estimate the error that will

be introduced into a determination following multiple determinations. The LiDCO

system has been previously shown to be accurate, easy, and inexpensive in the dog.

These results should increase the use of LiDCO in the general clinical setting.

## 3.5 FOOTNOTES

a O'Brien T. LiDCO Limited. Personal communication May, 2000

b Torbugesic, Ayerst Veterinary Laboratories, Guelph, Ontario, Canada

c Pentothal, Merial Limited, Iselin, New Jersey

d Halothane B.P., Bimeda-MTC Animal Health Inc., Cambridge, Ontario, Canada

e Air-Shields ventimeter ventilator, Air-Shields Inc., Hatboro, Pennsylvania

f Insyte-W, Becton Dickinson, Sandy, Utah

g Fogarty occlusion catheter, Baxter Healthcare Corporation, Irvine, California

h Swan-Ganz thermodilution catheter, Baxter Healthcare Corporation, Irvine, California

i Straight flush catheter, Medi-tech, Watertown, MA

j Edwards thermodilution cardiac output computer model COM-2, Baxter Healthcare

      Corporation, Santa Ana, California

k Edwards thermodilution cardiac output computer model COM-2 operation manual,

      Baxter Healthcare Corporation, Santa Ana, California

l LiDCO cardiac monitor CM 31-01 computer, LiDCO Limited, London, UK

m LiDCO operation manual, LiDCO Limited, London, UK

n Dobutrex, Eli Lilly, Toronto, Ontario, Canada

o Criticare model 1100, Criticare Systems Inc., Waukesha, Wisconsin

p DTX plus DT-36, Becton Dickinson, Sandy, Utah

q IL 943 flame photometer, Instrumentation Laboratories, Lexington, MA

r SPSS software, SPSS Inc., Chicago, Illinois

## 3.6 ACKNOWLEDGEMENTS

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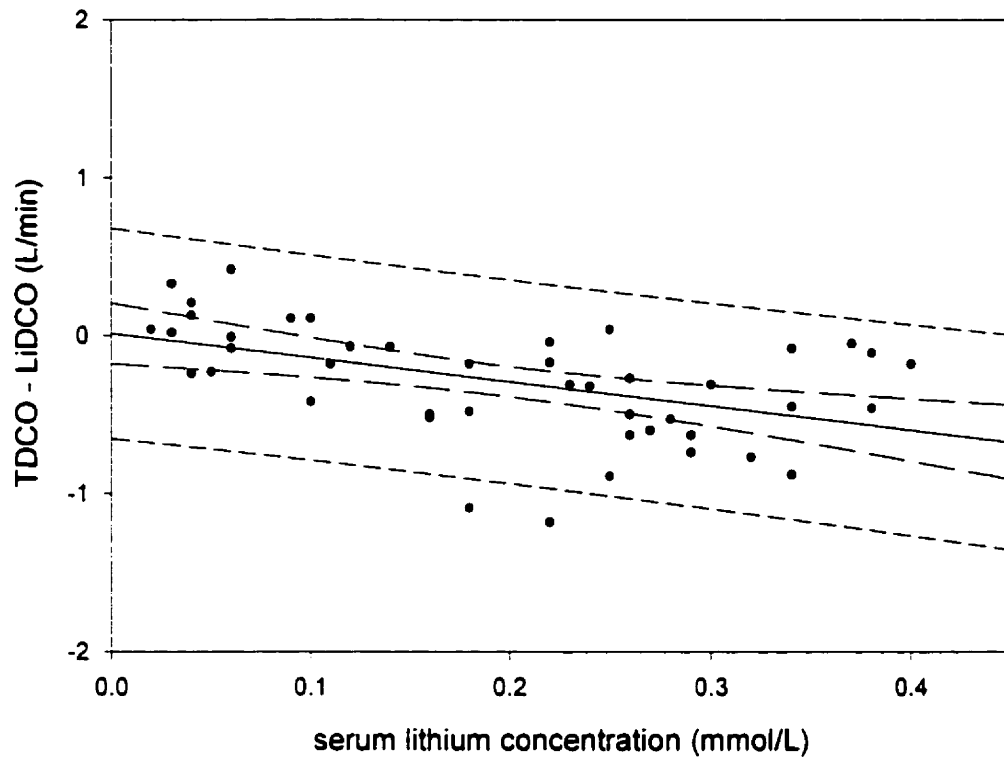
**Figure 3.1** – Linear regression plot of the difference between thermodilution cardiac

output (TDCO) and lithium dilution cardiac output (LiDCO) versus the serum lithium

concentration in 10 dogs, for cardiac output range of 1.13 to 4.55 L/min. There are 44

paired observations representing a serum lithium concentration of 0.02 to 0.40 mmol/L.

The analysis resulted in a slope (——) of -1.530 [95% confidence interval (— —) of (-2.388,

-0.671)] and a y-intercept of 0.011. The linear regression equation is y = -1.530x + 0.011

(r = -0.485). The 95% confidence intervals of the predictive values for the regression

equation are displayed (- - -).
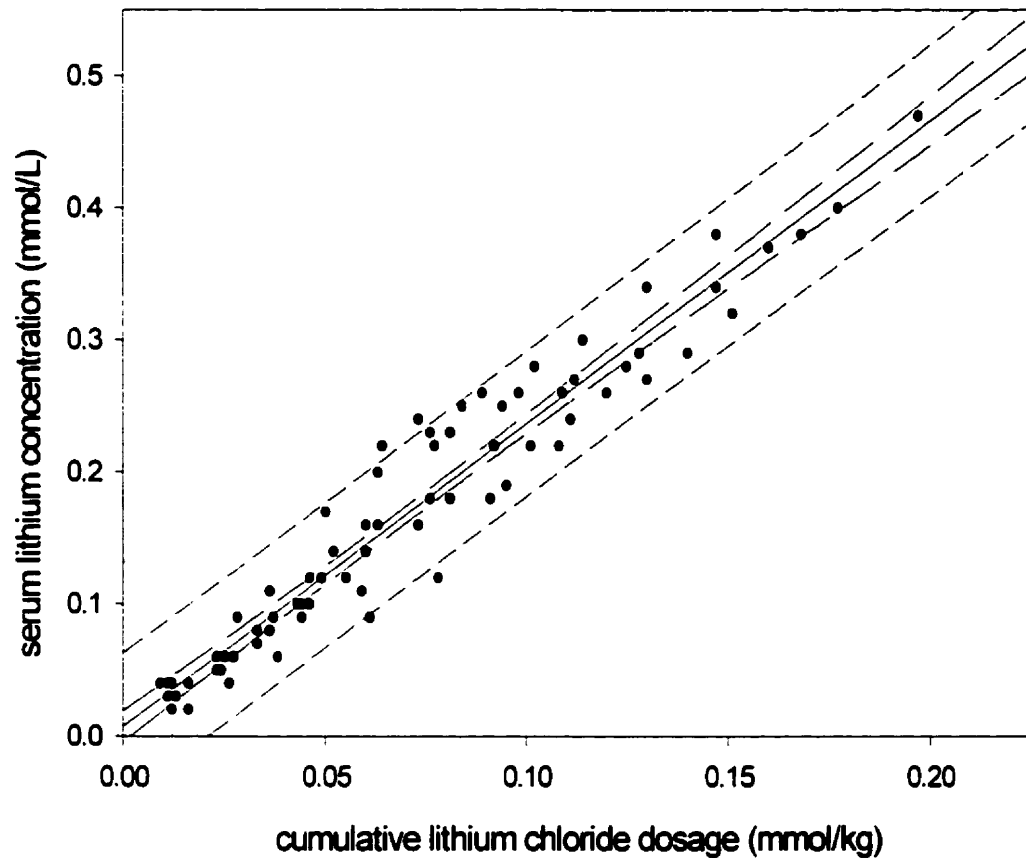
**Figure 3.2** – Linear regression plot of the serum lithium concentration versus the cumulative dosage of lithium chloride in 10 dogs. There are 74 paired observations representing a serum lithium concentration of 0.02 to 0.47 mmol/L. The analysis resulted in a slope (——) of 2.291 [95% confidence interval (– –) of (2.153, 2.429)] and a y-intercept of 0.008. The linear regression equation is $y = 2.291x + 0.008$ ($r = 0.969$). The 95% confidence intervals of the predictive values for the regression equation are displayed (- - -).

# COMPARISON OF LITHIUM DILUTION CARDIAC OUTPUT BY THE INJECTION OF LITHIUM CHLORIDE THROUGH A CENTRAL AND A PERIPHERAL VENOUS CATHETER IN THE DOG

## 4.0 ABSTRACT

**Objectives** – To determine the agreement between cardiac output measured by a peripheral and a central venous injection of lithium chloride for lithium dilution cardiac output (LiDCO) determination.

**Animals** – 5 dogs (2 males, 3 females).

**Procedure** – LiDCO was compared in anesthetized dogs using central venous and peripheral venous injections of lithium chloride. Twelve alternating central and peripheral LiDCO determinations were made for each dog, resulting in 10 paired comparisons.

**Results** – 50 comparisons were determined with cardiac outputs ranging from 1.11 to 2.76 L/min. The LiDCO determination from the peripheral venous site was virtually identical to that obtained from the recommended central venous site. The mean of the difference between the central and peripheral LiDCO determinations for all measurements was $0.098 \pm 0.336$ L/min (mean $\pm$ 2SD). The linear regression analysis demonstrated a slope of 1.050 [95% confidence interval of (0.904, 1.196)] and a y-intercept of 0.005 (r = 0.902).

**Conclusions and Clinical Relevance** – Although the central venous site for LiDCO is recommended by the manufacturer, the peripheral venous site is a suitable substitute for

the central venous injection to determine LiDCO in the dog. Peripheral venous LiDCO

eliminates the need for central venous catheterization, which reduces patient morbidity,

as well as time and cost.


## 4.1 INTRODUCTION


Lithium dilution cardiac output (LiDCO) is a new method of measuring cardiac

output, which has been utilized in people.(1) In addition, it has recently been

demonstrated to strongly agree with thermodilution cardiac output in the horse,(2) pig,(3)

and dog.(4) It belongs to the group of cardiac output measurements known as indicator

dilution methods. The other two most commonly used indicators in this group are

thermodilution cardiac output and indocyanine green. All of these methods measure

cardiac output by injecting an indicator substance into the venous blood and measuring

the amount of dilution of this indicator over time, as detected from an arterial site.

The LiDCO method involves injecting lithium chloride into a central venous

catheter and measuring the diluted lithium concentration at a peripheral arterial catheter

site with a sensor that is selective for lithium. The lithium sensor is monitored by the

LiDCO computer, which analyzes the dilution curve and determines the cardiac output.

The manufacturer recommends the use of a central venous catheter for LiDCO

determinations, with the catheter tip in the right atrium or cranial vena cava.(1) However,

the use of a peripheral venous site for lithium chloride injections has several advantages.

These include less morbidity to the patient, less time for the catheter placement, and less

cost associated with the catheter. In addition, there may be situations in which it may be contraindicated to place a central venous catheter.

Presently, cardiac output is infrequently measured in a general clinical setting in veterinary medicine, therefore continued efforts to simplify LiDCO should result in its enhanced clinical usage. Compared with thermodilution cardiac output, LiDCO measurement is already a simpler method of measuring cardiac output because it does not require the placement of a Swan-Ganz catheter. The ability to perform LiDCO from a peripheral venous site represents a further technical simplification that again should favour further clinical usage of the LiDCO system.

This study set out to determine the feasibility of performing LiDCO from a peripheral venous site. It was anticipated that LiDCO performed through a peripheral venous site would have a lower measured cardiac output than LiDCO performed through a central venous catheter due to the greater time for the lithium chloride to disperse prior to passing the lithium sensor.

Thus, the objective of this study was to determine the degree of agreement between LiDCO determined by centrally and peripherally injected lithium chloride in the dog.

## 4.2 MATERIALS AND METHODS

**Cardiac Output Measurement** – LiDCO measurements have been recently described in the dog.(4) The following is a brief description of the operation of the LiDCO system. The LiDCO cardiac computer (LiDCO cardiac monitor CM 31-01 computer, LiDCO

Limited, London, UK) was used to determine the cardiac output with the lithium chloride indicator (Appendix 1). The sensor for the lithium chloride determinations was attached to the side port of a 3-way valve that was connected to a catheter in the dorsal pedal artery (Appendix 2). The sensor was prepared as described in the LiDCO operation manual (LiDCO operation manual, LiDCO Limited, London, UK). The housing for the sensor included an inlet port and outlet port. As described, the inlet port was attached to the dorsal pedal arterial catheter. The outlet port was attached via tubing to a disposable blood collection bag. This tubing between the sensor and collection bag was passed through a flow regulator pump. When the pump was activated, it withdrew blood from the dorsal pedal artery and forced the arterial blood across the sensor at a constant rate and into the collection bag. For each cardiac output determination the LiDCO cardiac computer required the input of the sensor constant, the injectate dose of lithium chloride, the patient's hemoglobin concentration, and serum sodium concentration. The injection of the lithium chloride indicator involved the park and ride feature described in the LiDCO operation manual. This required placing the injectate dose into an extension set attached to a catheter in a venous injection site and advancing the injectate into the patient with a bolus of 10 ml of heparinized saline to begin a cardiac output determination.

Lithium dilution cardiac output was determined as described in the LiDCO operation manual. A manual count, in seconds, began with the activation of the inject button on the computer. At the 7-second mark, the lithium chloride parked in the extension set was flushed into the right atrium for a central injection and into the cephalic vein for a peripheral injection. The operating manual indicates that an ideal sensor signal

should lie in the amplitude range of 0.2 to 0.8 mM. One ml of lithium chloride (0.15 mmol) was used for each cardiac output determination. This resulted in a sensor signal amplitude of 0.6 to 0.8 mM (Appendix 1).

**Experimental Design** – Five beagle dogs were used in the study. All dogs were instrumented under general anesthesia. The premedication regimen consisted of butorphanol (Torbugesic, Ayerst Veterinary Laboratories, Guelph, Ontario, Canada) (0.4 mg/kg, IM). A peripheral venous catheter (Insyte-W, Becton Dickinson, Sandy, Utah) (22 gauge, 1") was percutaneously placed in the cephalic vein, to facilitate anesthetic induction as well as peripheral venous LiDCO determinations. Anesthetic induction consisted of thiopental (Pentothal, Merial Limited, Iselin, New Jersey) (20 mg/kg, IV), and the dogs were intubated and maintained on halothane (Halothane B.P., Bimeda-MTC Animal Health Inc., Cambridge, Ontario, Canada) at 1.5%. Instrumentation consisted of a peripheral arterial catheter (Insyte-W, Becton Dickinson, Sandy, Utah) (20 gauge, 1 ½") percutaneously placed in the dorsal pedal artery and a straight flush catheter (Straight flush catheter, Medi-tech, Watertown, MA) (6 fr, 65 cm) introduced via a jugular venous cutdown that was advanced to the level of the 7th intercostal space (estimated level of the right atrium).

All dogs were maintained at a normal depth of anesthesia. Cardiac output determinations were obtained only after the dog achieved a stable anesthetic plane. This steady state was accomplished by waiting for at least 30 minutes after beginning anesthesia.

A total of 12 cardiac output determinations were performed (Appendix 8). This consisted of six LiDCO determinations utilizing the central venous catheter, which were

designated as central LiDCO, and six utilizing the cephalic venous catheter, which were designated as peripheral LiDCO. The first cardiac output determination for each dog used central LiDCO. The choice of injection site for all subsequent LiDCO determinations was alternately selected. The LiDCO sensor was changed after six cardiac output determinations; thus two lithium sensors were used for each dog. Prior to starting cardiac output measurements in a dog, a blood sample was taken from the dorsal pedal arterial catheter to determine hemoglobin and sodium concentrations. These values for the hemoglobin and sodium were input into the LiDCO cardiac computer.

**Statistical Analysis** – Data from the 12 cardiac output determinations from each dog were considered for statistical analysis. Pairing observations obtained consecutively resulted in five pairs per sensor and 10 pairs per dog (Appendix 8). Thus, each pair consisted of a peripheral and a central LiDCO measurement.

The data were analyzed using both the Bland Altman graphical (5) and linear regression (SPSS software, SPSS Inc., Chicago, Illinois) methods to assess the agreement between the two methods of performing LiDCO.

## 4.3 RESULTS

Five dogs (two male, three female) were used with an average weight of 10.76 kg, and range of 9.8 to 11.8 kg. The cardiac outputs observed in these dogs ranged from 1.11 to 2.76 L/min. A total of 50 paired observations were collected (Appendix 9).

Overall, there was excellent agreement between the two sites of lithium chloride injection for the LiDCO determinations. The Bland Altman graphical representation of

the agreement between the two methods is presented in Figure 4.1. The bias and

precision (mean of the difference between central LiDCO and peripheral LiDCO ($\pm$

2SD)) was $0.098 \pm 0.336$ L/min (Figure 4.1).

The linear regression analysis of the central versus peripheral site for LiDCO

measurement demonstrated a slope of 1.050 [95% confidence interval of (0.904, 1.196)]

and a y-intercept of 0.005 (Figure 4.2). The linear regression equation therefore is

expressed as $y = 1.050x + 0.005$ ($r = 0.902$). Using this equation, the estimated LiDCO

values (with 95% confidence intervals) calculated for a central venous injection when a

LiDCO value was obtained from the peripheral venous site with a value of 1, 2, or 3

L/min is 1.055 (-0.715, 1.395), 2.105 (1.765, 2.445), or 3.155 (2.815, 3.495) L/min

respectively.

## 4.4 DISCUSSION

The bias from the Bland Altman analysis (Figure 4.1) demonstrates that there is

little difference between the two methods on average, but the precision can vary with

most determinations falling into a range of $\pm$ 0.336 L/min ($\pm$2 SD). Similarly, the linear

regression analysis (Figure 4.2) demonstrates a strong level of agreement with an r value

of 0.902. Thus, the cardiac output determinations from these two injection sites have

very good agreement.

The Bland Altman analysis revealed that the average difference between central

LiDCO and peripheral LiDCO was very slight, in the order of 0.098 L/min. This

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difference is not likely clinically significant for these dogs. Thus, as anticipated, peripheral LiDCO measurements were on average lower than central LiDCO measurements. The lower cardiac output with the peripheral venous injection likely occurred due to the greater dispersion of the lithium chloride indicator prior to entering the heart. The increased dispersion of the lithium chloride would result in a longer transit time across the lithium sensor attached to the arterial catheter and hence a longer indicator dilution curve (concentration versus time graph). The area under the curve (AUC) is inversely related to the cardiac output (cardiac output $\propto 1 / \text{AUC}$); therefore, any factor that results in an increase in the transit time of the indicator across its sensor (i.e. increased AUC), will cause a reduction in the cardiac output measurement. Peripheral LiDCO may be associated with several factors which could lead to this type of error. These may include the distance between the lithium chloride injection site and the sensor, the degree of vasodilation, and venous volume.

This experiment was performed on healthy dogs with a presumed normal cardiovascular system. Could a dispersion error with peripheral LiDCO become more clinically relevant in dogs with an abnormal cardiovascular system (e.g. venodilated dogs)? Future research will be needed to assess the accuracy of the peripheral venous site, for lithium chloride injections, in clinical cases in which there are abnormalities within the cardiovascular system. Cardiac valvular abnormalities will be expected to increase the dispersion of the indicator within the vascular system, thus causing decreased cardiac output determinations. Vasodilated patients such as those with septic shock should be studied.

The size of the dogs in this experiment were fairly uniform Beagles, but larger

dogs, with a greater distance from their peripheral venous catheter to the right side of the

their heart, may have greater dispersion of the lithium chloride and thus decreased

measured cardiac output. Only cephalic venous catheters were evaluated in this

experiment. Would a peripheral venous injection site from a rear limb result in further

and clinically significant discrepancies in cardiac output measurement? Future studies

will be necessary to answer this question.

As has been previously discussed, LiDCO is not a "gold standard" and therefore

any result will not likely be 100% accurate, but as a clinical standard LiDCO has been

shown to be as good as thermodilution cardiac output in the dog.(4) Furthermore, this

study demonstrates that LiDCO can be performed via a peripheral venous catheter with

similar results to LiDCO performed via a central venous catheter, which is the technique

recommended by the manufacturer. The use of a peripheral venous catheter will both

reduce the time and cost of placing a central venous catheter. Additionally, a peripheral

venous catheter will allow the assessment of cardiac output for those patients in which a

central venous catheter may be contraindicated.

The pharmacokinetics of lithium have been determined in dogs.(6,7) Lithium has

a narrow therapeutic range in dogs, which is similar to humans. Its distribution is similar

to sodium and it can compete for binding sites with several cations. Its toxicity is usually

associated with long-term administration, and there have only been two reported cases in

the dog.(8) These dogs had been drinking swimming pool water for 3 months, which had

been chlorinated with lithium hypochlorite, and the dogs had serum lithium

concentrations of 1.5 and 1.1 mmol/L.(8) The clinical signs of lithium toxicity have been

described previously.(8)  In a previous study multiple LiDCO determinations (up to 44) were performed in dogs over a period of 3 to 7 hours, and serum lithium concentrations never reached 0.5 mmol/L.(9)  It would be unlikely in a clinical setting to ever need to do that many LiDCO determinations.  In addition, another study found that a low dose and high dose of lithium chloride had excellent agreement.(4)  Thus, if many determinations were required in a short period of time, then the use of the low dose of lithium chloride would allow for more determinations prior to reaching a toxic level.

In conclusion, the LiDCO system is a reliable and accurate method of cardiac output measurement in the dog.(4)  The LiDCO method can either be performed via the recommended central venous catheter or via a peripheral venous catheter.  It is the authors' opinion that cardiac output measurement has been greatly underutilized in veterinary medicine.  It is anticipated that this study will encourage the assessment of cardiac output in the clinical setting by the LiDCO method.  The increased use of cardiac output measurement data could improve our knowledge of therapeutic responses and decrease the time that patients spend in the critical care setting.

## 4.5 ACKNOWLEDGEMENTS

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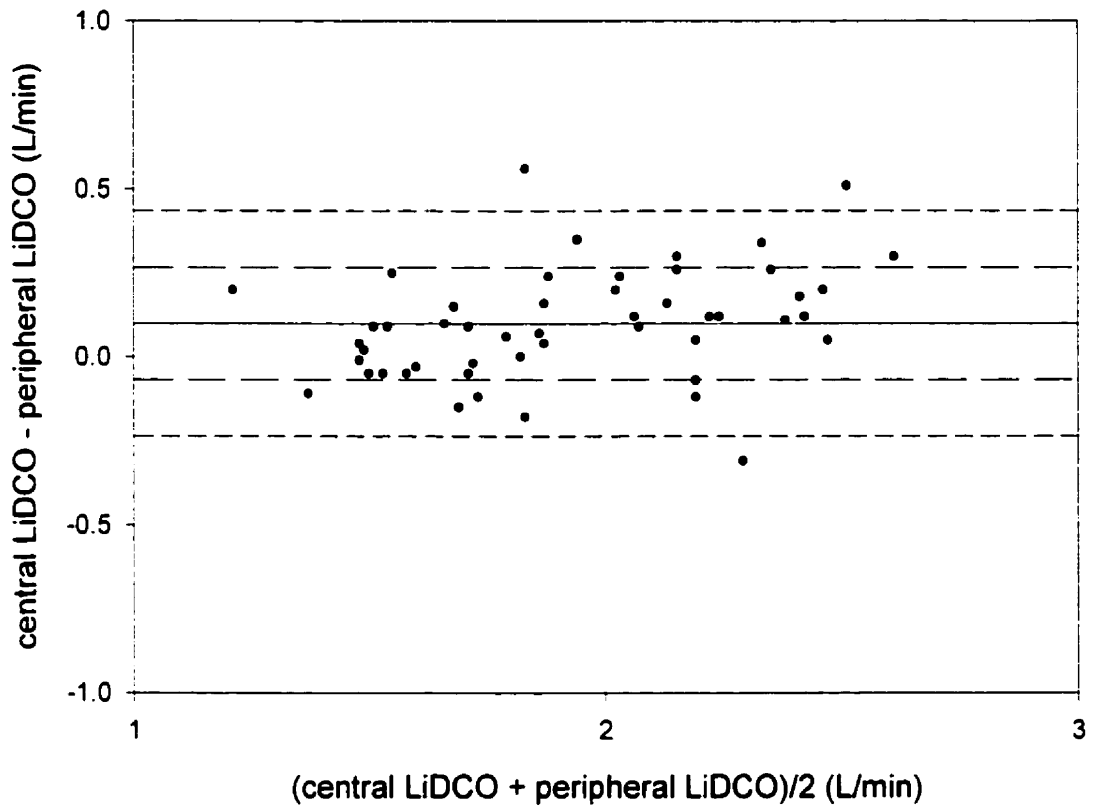
**Figure 4.1** – Bland Altman plot of cardiac output measurements by lithium dilution

cardiac output (LiDCO) through a central and a peripheral venous catheter in 5 dogs.

There are 50 data points representing a cardiac output range of 1.11 to 2.76 L/min. The

mean bias (——) ± 2SD (- - -) for the comparison of central – peripheral LiDCO is 0.098 ±

0.336 L/min. ±1SD is represented by (— —).
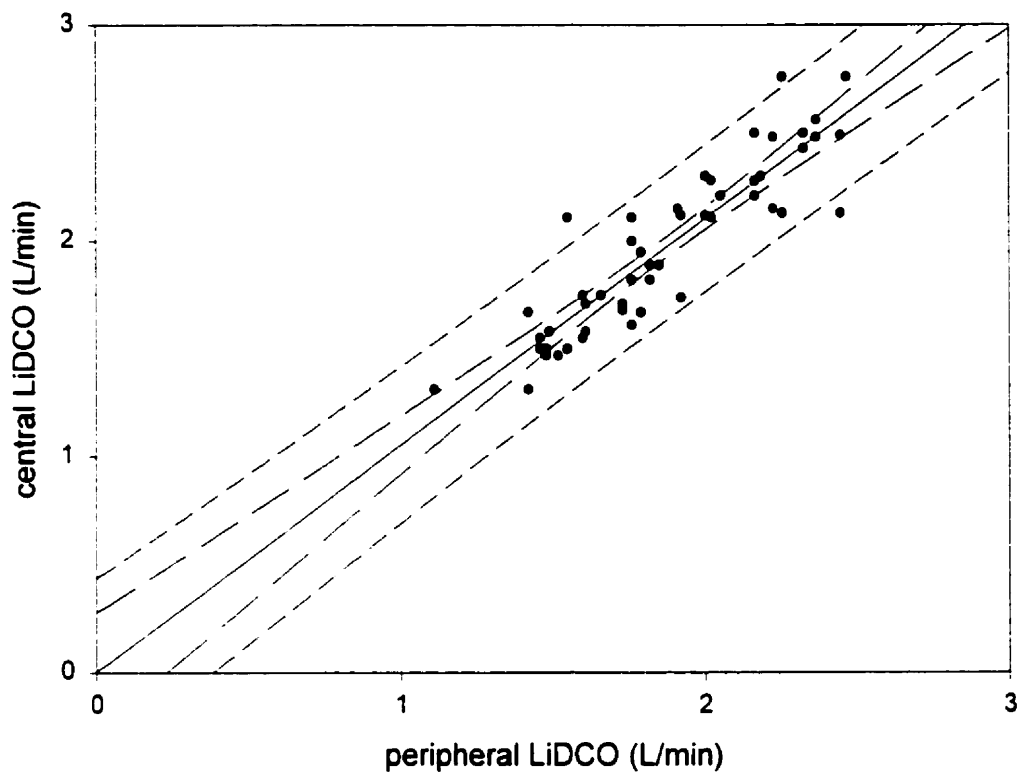
**Figure 4.2** – Linear regression plot of cardiac output measurements by lithium dilution

cardiac output (LiDCO) through a central versus a peripheral venous catheter in 5 dogs.

There are 50 data points representing a cardiac output range of 1.11 to 2.76 L/min. The

analysis demonstrates a slope of 1.050 (——) [95% confidence intervals of (0.904, 1.196)

(— —)] and a y-intercept of 0.005. The linear regression equation is y = 1.050x + 0.005

(r = 0.902). The 95% confidence intervals of the predictive values are displayed (- - -).

## 5.0 CONCLUSIONS AND FUTURE STUDIES

The measurement of cardiac output, in my opinion, has been underutilized in the clinical setting of veterinary medicine. As a test it provides unique information, for which no other test can be used as its surrogate. Thermodilution cardiac output (TDCO) has been the most commonly used method of measuring cardiac output in veterinary patients, but mainly in a research capacity. It has been the best available clinical measure of cardiac output.

We initially considered reasons why cardiac output measurement was not used more often in veterinary practice. These included: the time to place the catheters, the expertise to place the catheters, the cost of the equipment to help place the catheters, the cost of the catheters, and the risks of catheter placement. These same concerns have been cited in the human literature. A new method of cardiac output measurement called lithium dilution cardiac output (LiDCO) has recently been described that may resolve many of these concerns. However, before this method of performing cardiac output in the dog could be embraced, it was necessary to establish its accuracy, to assess the impact of increasing background serum lithium concentration, and to explore technical variations in the methodology.

To establish the accuracy of LiDCO, it was compared with TDCO, which was the best available clinical standard. This study demonstrated that LiDCO and TDCO had excellent agreement.

As with all indicator dilution methods, the indicator itself can be a source of concern. In the case of indocyanine green, the indicator was a cause of morbidity to a

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small percentage of people. With TDCO, the indicator is non-toxic and readily and rapidly reversed. As for LiDCO, the indicator has been demonstrated to be toxic. In addition, since lithium has a long half-life, its accumulation in the circulation should affect the ability to perform further measurements of LiDCO. Therefore it was necessary to determine the error introduced into the LiDCO measurement as a result of a high background serum lithium concentration, in a "worse case scenario", in which numerous injections of lithium chloride would be administered within a short period of time. The manufacturer of the LiDCO system recommended that a background serum lithium concentration of 0.2 mmol/L should be used as the point beyond which there would be significant error introduced into subsequent LiDCO determinations. In addition, this experiment would allow the assessment for a predictive value of the serum lithium concentration from the cumulative lithium chloride dose administered when multiple doses are injected in a short period of time. This experiment demonstrated that an increasing background serum lithium concentration had an effect on subsequent LiDCO determination, but this effect was not clinically significant until many determinations were performed over a short period of time. Furthermore, it was demonstrated that the serum lithium concentration can be predicted from the cumulative lithium chloride dose administered over a short period of time. Therefore, if multiple determinations of LiDCO are to be performed within a short time period, the background serum lithium concentration can be estimated and the error introduced into the subsequent LiDCO determination can be estimated.

Since lithium chloride is not a benign and inert substance, particularly as the serum levels rise, an experiment was designed to assess the utility of a low dose of

lithium chloride indicator on the accuracy of the LiDCO system. If a low dose of lithium chloride were shown to be effective to determine LiDCO, then many more LiDCO determinations could be performed within a short time period without causing a substantial rise in the serum lithium concentration. This study found that both a high dose and a low dose of lithium chloride had strong agreement with TDCO, as well as between the two doses. Therefore a low dose of lithium chloride should be used for LiDCO determinations particularly if one anticipates performing multiple injections within a short period of time.

And finally, with a view to further simplify the methodology of LiDCO, a study was designed to determine the accuracy of LiDCO performed from a peripheral venous site. We compared the LiDCO determinations obtained by the injection of lithium chloride through both peripheral and central venous catheters. This study found that there was strong agreement between the two methods, and that a peripheral venous catheter could be used to perform LiDCO. This modification of the LiDCO methodology should result in reducing patient morbidity associated with the placement of a central venous catheter and the cost of the catheter.

The characteristics of an ideal clinical test might be described as one that is accurate, repeatable, safe, simple, and inexpensive to perform. The ideal indicator dilution method of cardiac output measurement would involve an indicator that does not accumulate overtime and that is non-toxic. Overall, these studies demonstrated that LiDCO was accurate (compared to TDCO) and repeatable. Although the indicator lithium is potentially toxic and does accumulate in the body due to its long half-life, it was demonstrated that these features are not likely to be a concern if less than 16 to 34

LiDCO determinations are performed in a short period of time using the low dose of lithium chloride. We believe it is highly improbable that this limitation will be surpassed. With this in mind only a minimal effect on the accuracy of LiDCO due to an increasing serum lithium concentration occurs. Lithium dilution cardiac output is less invasive and easier to perform than TDCO, since it does not require a Swan-Ganz catheter and can be readily performed using a peripheral venous catheter. With respect to simplicity, the main limitation to the use of LiDCO lies in the ability to place a peripheral arterial catheter in certain patients (i.e. small patients or patients with low blood pressure). There are fewer costs associated with a LiDCO determination as compared with TDCO. Note that the cost for each of the cardiac output computers are approximately equal. In conclusion, LiDCO is an indicator dilution test to measure cardiac output that is accurate, repeatable, safe, simple, inexpensive to perform a determination, and multiple determinations have a minimal effect on its accuracy. Therefore, we believe that LiDCO is ideally suited to replace TDCO as the clinical standard measurement of cardiac output in the dog.

The limitation of this study is that the experimental protocol created for the assessment of the agreement between LiDCO and TDCO, was also utilized for the agreement between low dose and high dose lithium chloride injections, for the assessment of the effect of a rising background serum lithium concentration on the accuracy of LiDCO, and for the assessment of the ability of the cumulative lithium chloride dose to predict the serum lithium concentration. Of these other objectives that were addressed with this design, we feel that the assessment of the effect of an increasing serum lithium concentration on subsequent LiDCO determinations may have been better

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dealt with by using a different design. This multi-use protocol was utilized so as to reduce the number of dogs required for the overall study.

There are several future studies that should be considered to assess the breadth of use for this method of cardiac output measurement. These include:

1)   Assessing the life span of the sensor in a clinical setting (the manufacturer has developed a new sensor since this study was performed), and the factors that are responsible for the error in cardiac output when the sensor is over used, as was noted in this study.

2)   Assessing the effect of averaging 3 consecutive LiDCO determinations, within 10% of each other, on the accuracy of the LiDCO system.

3)   Assessing the difference between peripheral venous and central venous lithium dilution cardiac output when the distance between the peripheral venous catheter site and the right side of the heart is varied (e.g. differing sized dogs and catheter placement in a saphenous vein).

4)   Assessing the feasibility of performing LiDCO in clinical patients (i.e. patients with various cardiovascular disorders and placement of the peripheral arterial catheter).

5)   Assessing lithium dilution cardiac output in dogs that are vasodilated (i.e. septic shock).

6)   Evaluating the LiDCO system in the cat.

**Appendix 1:    Image of LiDCO Computer Screen with an Indicator Dilution Curve**
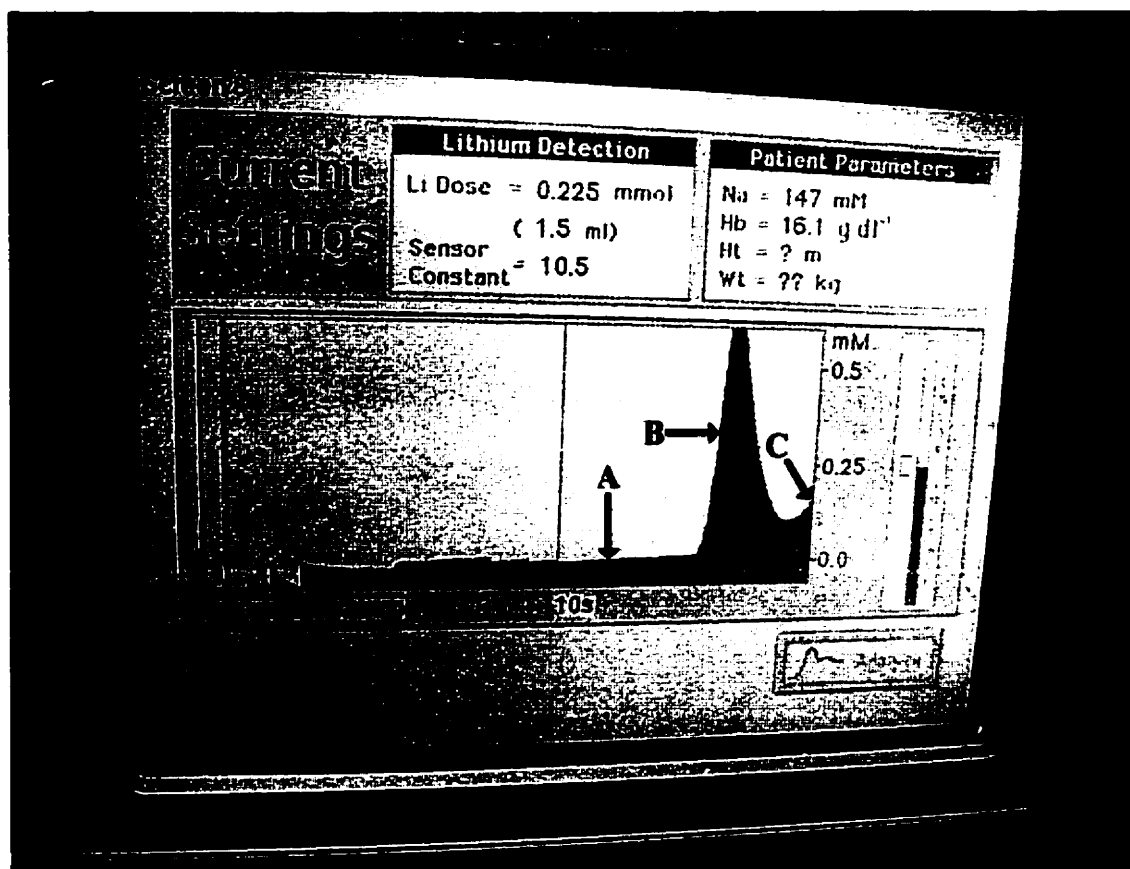


A -    Baseline serum lithium concentration

B -    Indicator dilution curve

C -    The start of the recirculation curve

**Appendix 2:** **Set-up of the Peripheral Arterial Catheter Site for LiDCO and Arterial Pressures**
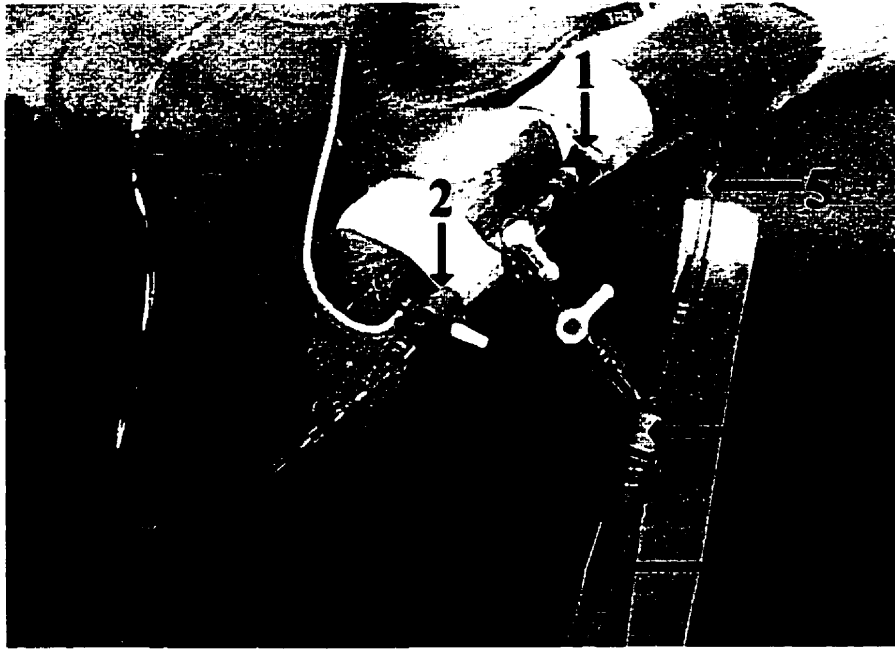


1 - Peripheral arterial catheter

2 - Arterial pressure transducer

3 - Lithium sensor

4 - Cable to LiDCO computer from lithium sensor

5 - Tubing from lithium sensor to roller pump

**Appendix 3:** **Experimental Protocol for a Rate of Cardiac Output in Chapter 2 with Paired Observations Indicated**


\* TDCO \* LiDCOa \* LiDCOb \* TDCO \* LiDCOb \* LiDCOa \* TDCO \*


⋃ - Encompasses the paired CO observations used for analysis

\* - Collect hemodynamic and respiratory parameters, which include heart rate, respiratory rate, systemic arterial systolic, diastolic and mean pressures, pulmonary arterial systolic, diastolic and mean pressures, inspired and expired halothane concentrations, end-tidal $CO_2$ and body temperature.


TDCO - thermodilution cardiac output, three observations within 10% of each other were collected and averaged

LiDCO - lithium dilution cardiac output

LiDCOa - was randomly selected to be either the high dose or the low dose of lithium chloride

LiDCOb - was determined to be the opposite dose to LiDCOa

# Appendix 4: Complete Data Collected from Assessment of Lithium Dilution Cardiac Output and Thermodilution Cardiac Output

## Appendix 4.0: Index of abbreviations

| | |
|---|---|
| CO | cardiac output |
| CO2 | carbon dioxide |
| CV | cardiovascular |
| E | exhaled |
| ET | end-tidal |
| Halo | halothane |
| Hb | hemoglobin (g/L) |
| HR | heart rate (beats per minute) |
| I | inhaled |
| I/E | inhaled/exhaled |
| IM | intramuscular |
| IV | intravenous |
| kg | kilogram |
| Li | lithium |
| LiCla | lithium dilution cardiac output (low or high dose) (L/min) |
| LiClb | lithium dilution cardiac output (low or high dose) (L/min) |
| Li [ ] | serum lithium concentration (mmol/L) |
| MAP | mean arterial pressure (mmHg) |
| ml | milliliters |
| Na++ | sodium (mmol/L) |

| | |
|---|---|
| PA | pulmonary artery |
| Press | pressure (mmHg) |
| RR | respiratory rate (breaths per minute) |
| S/D | systolic/diastolic |
| S/N | signal amplitude of indicator dilution curve |
| TD | thermodilution cardiac output (L/min) |
| Temp | temperature (C) |

**Appendix 4.1:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 1**

Date: Sept 28/99    Anesthetic Plane: Start:12:12 Finish: 12:41 Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 1    MAP Range: 41 to 43 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: mildly low - deep anesthesia

Weight: 33.4 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 12:12 | 12:15 | | 12:18 | 12:20 | 12:23 | 12:25 | 12:28 | 12:28 | | 12:31 | 12:33 | 12:34 | 12:36 | 12:38 | 12:39 | | 12:41 |
| Temp (C) | 35.2 | 1 1.42 | 1.2 | 35.1 | 1/3ml | 35.1 | 1 ml | 35.1 | 1 1.48 | 1.2 | 35.0 | 1 ml | 35.1 | 1/3ml | 35.1 | 1 1.52 | 1.2 | 35.0 |
| RR | 10 | 2 1.39 | 1.2 | 10 | 1.21 | 10 | 1.32 | 10 | 2 1.45 | 1.2 | 10 | 1.47 | 10 | 1.48 | 10 | 2 1.54 | 1.2 | 10 |
| HR | 86 | 3 1.36 | 1.2 | 86 | S/N 0.24* | 87 | S/N 0.6 | 87 | 3 1.46 | 1.2 | 85 | S/N 0.55 | 85 | S/N 0.2* | 85 | 3 1.51 | 1.2 | 83 |
| MAP | 43 | 4 | | 42 | | 42 | | 43 | 4 | | 42 | | 42 | | 41 | 4 | | 41 |
| S/D | 53/38 | 5 | | 52/37 | | 53/37 | | 54/37 | 5 | | 54/37 | | 52/36 | | 53/36 | 5 | | 53/35 |
| PA Press | 15 | 6 | | 14 | | 15 | | 15 | 6 | | 15 | | 16 | | 15 | 6 | | 14 |
| PA S/D | 17/14 | 7 | | 18/13 | | 18/14 | | 18/14 | 7 | | 18/14 | | 18/14 | | 18/14 | 7 | | 17/13 |
| Halo. I/E | I 2.8 E 2.4 | 8 | | I 2.8 E 2.3 | | I 2.8 E 2.4 | | I 2.8 E 2.4 | 8 | | I 2.9 E 2.3 | | I 2.8 E 2.4 | | I 2.8 E 2.4 | 8 | | I 2.9 E 2.3 |
| ET CO2 | 30 | 9 | | 32 | | 31 | | 32 | 9 | | 37 | | 36 | | 36 | 9 | | 36 |
| Hb | 14.6 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 141 | | | | | | | | | | | | | | | | | |
| Time | 12:00 | | | | | | | | | | | | | | | | | |
| Li[] | 0.01 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

Analyzed in chapters 2 and 3.

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**Appendix 4.1:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 1**

Date: Sept 28/99    Anesthetic Plane: Start: 1:26 Finish: 1:55    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 1    MAP Range: 103 to 117 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: high - dobutamine

Weight: 33.4 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1:26 | 1:28 | | 1:31 | 1:33 | 1:34 | 1:36 | 1:37 | 1:38 | | 1:40 | 1:47 | 1:48 | 1:49 | 1:52 | 1:53 | | 1:55 |
| Temp (C) | 35.5 | 1 / 5.52 | | 35.5 | 1/3ml | 35.5 | 1 ml | 35.6 | 1 / 5.62 | | 35.6 | 1 ml | 35.6 | 1/3ml | 35.7 | 1 / 5.32 | | 35.7 |
| RR | 10 | 2 / 5.41 | 0.6 | 10 | 5.63 | 10 | 5.75 | 10 | 2 / 5.51 | 0.65 | 10 | 5.77 | 10 | NR | 10 | 2 / 5.54 | 0.65 | 10 |
| HR | 119 | 3 / 5.69 | 0.65 | 118 | S/N 0.2 * | 118 | S/N 0.4 | 107 | 3 / 5.37 | 0.7 | 105 | S/N 0.4 | 93 | S/N 0.13* | 87 | 3 / 5.80 | 0.7 | 88 |
| MAP | 106 | 4 | | 108 | | 103 | | 105 | 4 | | 117 | | 109 | | 108 | 4 | | 110 |
| S/D | 160/90 | 5 | | 162/91 | | 155/86 | | 156/86 | 5 | | 128/112 | | 172/85 | | 168/85 | 5 | | 172/86 |
| PA Press | 20 | 6 | | 21 | | 21 | | 20 | 6 | | 21 | | 18 | | 19 | 6 | | 23 |
| PA S/D | 21/16 | 7 | | 23/17 | | 23/16 | | 22/16 | 7 | | 23/16 | | 21/15 | | 22/16 | 7 | | 25/18 |
| Halo. I/E | I 1.0 E 0.8 | 8 | | I 1.1 E 0.8 | | I 1.0 E 0.8 | | I 1.0 E 0.7 | 8 | | I 1.0 E 0.8 | | I 1.1 E 0.8 | | I 1.0 E 0.8 | 8 | | I 1.0 E 0.7 |
| ET CO2 | 45 | 9 | | 46 | | 45 | | 46 | 9 | | 46 | | 45 | | 44 | 9 | | 45 |
| Hb | 20.3 | 10 | | | | | | | | | | | | | | 10 | | |
| Na++ | 144 | | | | | | | | | | | | | | | | | |
| Time Li[ ] | 1:25 0.02 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

The Hb and Na++ values were not changed from the previous series

Not analyzed in chapter 2 and 3 (objective 1) – Incorrect Na and Hb

Analyzed in Chapter 3 (objective 2)

**Appendix 4.1:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 1**

Date: Sept 28/99    Anesthetic Plane: Start: 2:49 Finish: 3:14    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 1    MAP Range: 32 to 45 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: markedly low - occlusion

Weight: 33.4 kg    Volume of Iced Dextrose Used: 5 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.247

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:49 | 2:50 | | 2:52 | 2:55 | 2:56 | 2:57 | 2:59 | 3:00 | | 3:04 | 3:06 | 3:07 | 3:09 | 3:11 | | 3:14 |
| Temp (C) | 35.9 | 1 0.77 | 0.85 | 35.9 | 1/3ml | 35.9 | 1 ml | 35.9 | 1 0.76 | 0.9 | 35.9 | 1 ml | 35.9 | 1/3ml | 1 0.69 | 0.8 | 35.9 |
| RR | 16 | 2 0.76 | 0.9 | 19 | 0.70 | 19 | 0.81 | 19 | 2 0.67 | 0.8 # | 15 | 0.81 | 19 | 0.81 | 2 0.71 | 0.8 | 18 |
| HR | 110 | 3 0.70 | 0.8 | 108 | S/N 0.35* | 107 | S/N >0.6 | 108 | 3 0.67 | 0.8 | 104 | S/N >0.6 | 107 | S/N 0.35* | 3 0.69 | 0.8 | 112 |
| MAP | 36 | 4 | | 34 | | 45 | | 32 | 4 | | 32 | | 32 | | 4 | | 36 |
| S/D | 41/33 | 5 | | 38/31 | | 47/43 | | 36/30 | 5 | | 36/30 | | 35/30 | | 5 | | 39/33 |
| PA Press | 9 | 6 | | 9 | | 10 | | 7 | 6 | | 11 | | 9 | | 6 | | 11 |
| PA S/D | 9/7 | 7 | | 9/8 | | 11/9 | | 9/6 | 7 | | 12/10 | | 9/7 | | 7 | | 11/8 |
| Halo. I/E | I 1.4 E 1.3 | 8 | | I 1.5 E 1.4 | | I 1.5 E 1.4 | | I 1.5 E 1.4 | 8 | | I 1.5 E 1.4 | | I 1.4 E 1.4 | | 8 | | I 1.4 E 1.4 |
| ET CO2 | 22 | 9 | | 25 | | 21 | | 22 | 9 | | 20 | | 20 | | 9 | | 22 |
| Hb | 17.1 | 10 | | | | | | | 10 | | | | | | 10 | | |
| Na++ | 141 | | | | | | | | | | | | | | | | |
| Time Li[] | 2:23 0.05 | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device    Not analyzed in chapter 2 and 3 (objective 1) – Sensor exclusion

# alert – unsteady baseline    Analyzed in chapter 3 (objective 2)

**Appendix 4.1:** Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 1

Date: Sept 28/99    Anesthetic Plane: Start: 3:31 Finish: 4:01    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 1    MAP Range: 65 to 76 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 33.4 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:31 | 3:31 |  | 3:34 | 3:39 | 3:40 | 3:42 | 3:44 | 3:48 |  | 3:52 | 3:53 | 3:55 | 3:56 | 3:58 | 3:59 |  | 4:01 |
| Temp (C) | 36.2 | 1 / 4.57 | 0.8 | 36.1 | 1/3 ml | 36.2 | 1 ml | 36.2 | 1 / 4.13 | 0.75 | 36.1 | 2 ml | 36.1 | 1 ml | 36.1 | 1 / 3.75 | 0.7 | 36.0 |
| RR | 9 | 2 / 4.29 | 0.85 | 9 | NR | 10 | 6.65 | 9 | 2 / 3.88 | 0.8 | 9 | 7.06 | 9 | 6.91 | 9 | 2 / 3.77 | 0.7 | 9 |
| HR | 89 | 3 / 4.63 | 0.8 | 87 | S/N <0.1* | 85 | S/N 0.25 | 84 | 3 / 4.00 | 0.8 | 80 | S/N 0.49 | 79 | S/N 0.25 | 78 | 3 / 3.71 | 0.7 | 78 |
| MAP | 65 | 4 |  | 65 |  | 76 |  | 66 | 4 |  | 67 |  | 69 |  | 72 | 4 |  | 71 |
| S/D | 86/53 | 5 |  | 88/53 |  | 95/64 |  | 95/52 | 5 |  | 95/54 |  | 94/58 |  | 99/60 | 5 |  | 96/60 |
| PA Press | 21 | 6 |  | 21 |  | 20 |  | 19 | 6 |  | 19 |  | 18 |  | 18 | 6 |  | 18 |
| PA S/D | 21/16 | 7 |  | 21/16 |  | 21/16 |  | 20/15 | 7 |  | 19/14 |  | 19/14 |  | 19/14 | 7 |  | 18/14 |
| Halo. I/E | I 1.4 E 1.2 | 8 |  | I 1.4 E 1.2 |  | I 1.3 E 1.2 |  | I 1.4 E 1.2 | 8 |  | I 1.4 E 1.2 |  | I 1.3 E 1.2 |  | I 1.3 E 1.2 | 8 |  | I 1.4 E 1.2 |
| ET CO2 | 42 | 9 |  | 42 |  | 43 |  | 41 | 9 |  | 40 |  | 41 |  | 41 | 9 |  | 42 |
| Hb | 16.0 | 10 |  |  |  |  |  |  | 10 |  |  |  |  |  |  | 10 |  |  |
| Na++ | 138 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Time Li[] | 3:25 / 0.08 |  |  |  |  |  |  |  | 3:49 / 0.16 |  |  |  |  |  |  |  |  | 4:09 / 0.22 |

* peak concentration below recommended level for the device
3:52 – additional 2 ml of LiCl injected into PA catheter

Not analyzed in chapter 2 and 3 (objective 1) – Sensor exclusion
Analyzed in chapter 3 (objective 2)

**Appendix 4.2:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 2**

Date: Sept 29/99    LiCla: 0.6mM    LiClb: 0.2mM

Anesthetic Plane: Start: 10:29 Finish: 10:56 Premed: Butorphanol 0.4 mg/kg IM

Induction: Thiopental 10 mg/kg IV    Rate of CO: markedly low - occlusion

Animal # 2

MAP Range: 26 to 30 mmHg

Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.247

Weight: 45.4 kg

Volume of Iced Dextrose Used: 5 ml

| sensor | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 10:29 | 10:30 | | 10:33 | 10:35 | 10:36 | 10:38 | 10:40 | 10:41 | | 10:46 | 10:47 | 10:49 | 10:50 | 10:52 | 10:53 | | 10:56 |
| Temp (C) | 36.7 | 1 0.58 | 0.9 | 36.7 | 1 ml | 36.7 | 1/3ml | 36.7 | 1 0.66 | 0.9 | 36.6 | 1/3ml | 36.6 | 1 ml | 36.5 | 1 0.77 | 1.0 | 36.4 |
| RR | 10 | 2 0.57 | 0.9 | 10 | 0.44* | 10 | 0.49* | 10 | 2 0.56 | 1.0 | 10 | 0.52* | 10 | 0.63* | 10 | 2 0.75 | 1.0 | 10 |
| HR | 83 | 3 0.56 | 1.0 | 83 | S/N >0.6# | 87 | S/N 0.37 | 89 | 3 0.58 | 0.9 | 92 | S/N 0.45 | 94 | S/N >0.6# | 96 | 3 0.77 | 1.2 | 95 |
| MAP | 28 | 4 | | 27 | | 27 | | 26 | 4 0.62 | 1.0 | 28 | | 29 | | 29 | 4 | | 30 |
| S/D | 32/26 | 5 | | 31/26 | | 30/25 | | 30/25 | 5 | | 31/26 | | 33/27 | | 33/27 | 5 | | 35/28 |
| PA Press | 14 | 6 | | 14 | | 13 | | 16 | 6 | | 14 | | 15 | | 14 | 6 | | 14 |
| PA S/D | 15/13 | 7 | | 16/12 | | 14/12 | | 18/14 | 7 | | 16/14 | | 15/13 | | 14/12 | 7 | | 15/12 |
| Halo. I/E | I 1.7 E 1.5 | 8 | | I 1.6 E 1.5 | | I 1.7 E 1.6 | | I 1.7 E 1.6 | 8 | | I 1.7 E 1.6 | | I 1.7 E 1.6 | | I 1.7 E 1.6 | 8 | | I 1.7 E 1.6 |
| ET CO2 | 16 | 9 | | 17 | | 16 | | 16 | 9 | | 20 | | 19 | | 20 | 9 | | 21 |
| Hb | 14.2 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 146 | | | | | | | | | | | | | | | | | |
| Time Li[] | 10:17 0.01 | | | | | | | | | | | | | | | | | |

* cardiac output outside range of the device

# peak concentration above recommended level for the device

Not analyzed in chapter 2 and 3 (objective 1) – Hemodynamic stability

Analyzed in chapter 3 (objective 2)

**Appendix 4.2:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 2**

Date: Sept 29/99          Anesthetic Plane: Start: 11:27  Finish: 12:00  Premed: Butorphanol 0.4 mg/kg IM          LiCla: 0.2mM     LiClb: 0.6mM

Animal # 2          MAP Range: 78 to 98 mmHg          Induction: Thiopental 10 mg/kg IV          Rate of CO: high – dobutamine

Weight: 45.4 kg          Volume of Iced Dextrose Used: 10 ml          Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 11:27 | 11:28 | | 11:31 | 11:38 | 11:40 | 11:42 | 11:45 | 11:47 | | 11:48 | 11:50 | 11:52 | 11:54 | 11:57 | 11:58 | | 12:00 |
| Temp (C) | 36.3 | 1  10.7 | 0.4 | 36.3 | **  2/3ml | 36.2 | 2 ml | 36.1 | 1  12.3 | 0.4 | 36.1 | 2 ml | 36.1 | 2/3ml | 36.1 | 1  12.1 | 0.3 | 36.0 |
| RR | 10 | 2  11.1 | 0.4 | 11 | 11.83 | 11 | 12.75 | 11 | 2  12.2 | 0.4 | 11 | 13.16 | 11 | 12.58 | 11 | 2  12.0 | 0.4 | 11 |
| HR | 117 | 3  11.1 | 0.4 | 133 | S/N 0.22* | 151 | S/N 0.6 | 157 | 3  12.8 | 0.4 | 186 | S/N 0.55 | 190 | S/N 0.17* | 170 | 3  11.5 | 0.3 | 173 |
| MAP | 98 | 4 | | 87 | | 81 | | 80 | 4 | | 78 | | 79 | | 80 | 4 | | 78 |
| S/D | 167/73 | 5 | | 146/62 | | 129/60 | | 123/61 | 5 | | 114/62 | | 110/62 | | 112/63 | 5 | | 116/61 |
| PA Press | 32 | 6 | | 30 | | 31 | | 27 | 6 | | | | | | | 6 | | |
| PA S/D | 32/24 | 7 | | 41/22 | | 39/24 | | 33/20 | 7 | | | | | | | 7 | | |
| Halo. I/E | I 1.5 E 1.2 | 8 | | I 1.5 E 1.2 | | I 1.5 E 1.2 | | I 1.5 E 1.2 | 8 | | I 1.5 E 1.2 | | I 1.5 E 1.2 | | I 1.5 E 1.2 | 8 | | I 1.5 E 1.2 |
| ET CO2 | 46 | 9 | | 48 | | 50 | | 51 | 9 | | 39 | | 48 | | 48 | 9 | | 48 |
| Hb | 17.1 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 144 | | | | | | | | | | | | | | | | | |
| Time | 11:26 | | | | | | | | | | | | | | | | | |
| Li[ ] | 0.04 | | | | | | | | | | | | | | | | | |

** 1st dose of LiCl (1/3 ml) was too low for analysis by computer
all LiDCO curves had an unusual shape – due to strong recirculation curves

. Not analyzed in chapter 3 (objective 1) -- cardiac output > 5 L/min
Analyzed in chapters 2 and 3 (objective 2)

**Appendix 4.2:** Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 2

Date: Sept 29/99    Anesthetic Plane: Start: 12:35 Finish: 1:08 Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 2    MAP Range: 24 to 49 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: mildly low - deep anesthesia

Weight: 45.4 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 12:35 | 12:35 |  | 12:36 | 12:37 | 12:40 | 12:41 | 12:45 | 12:46 |  | 12:52 | 12:54 | 12:56 | 12:58 | 1:00 | 1:01 |  | 1:08 |
| Temp (C) | 35.7 | 1 1.24 | 1.25 | 35.5 | 1/3ml | 35.6 | 1 ml | 35.6 | 1 0.78 | 1.1 | 35.4 | 1 ml | 35.5 | 1/3ml | 35.5 | 1 0.72 | 1.0 | 35.3 |
| RR | 11 | 2 1.10 | 1.3 | 11 |  | 11 |  | 11 | 2 0.71 | 1.0 | 11 |  | 11 |  | 11 | 2 0.84 | 1.2 | 11 |
| HR | 92 | 3 0.96 | 1.3 | 88 | 1.02 | 94 | 0.92 | 96 | 3 0.67 | 1.0 | 91 | 0.68 | 89 | 0.49 | 89 | 3 1.03 | 1.3 | 98 |
| MAP | 39 | 4 0.97 | 1.3 | 30 | S/N 0.2 * | 30 | S/N 0.5 | 30 | 4 | 1.0 | 25 | S/N 0.5 | 24 | S/N 0.18* | 26 | 4 1.15 | 1.5 | 49 |
| S/D | 53/34 | 5 0.94 | 1.2 | 40/27 |  | 39/26 |  | 39/26 | 5 |  | 31/23 |  | 28/22 |  | 33/24 | 5 1.44 | 1.2 | 69/40 |
| PA Press | 20 | 6 |  | 20 |  | 19 |  | 18 | 6 |  | 18 |  | 18 |  | 19 | 6 1.85 | 1.2 | 25 |
| PA S/D | 22/16 | 7 |  | 22/17 |  | 21/16 |  | 20/16 | 7 |  | 20/16 |  | 21/17 |  | 21/17 | 7 |  | 27/22 |
| Halo. I/E | I 3.2 E 2.8 | 8 |  | I 3.3 E 2.8 |  | I 3.2 E 2.9 |  | I 3.3 E 3.0 | 8 |  | I 3.3 E 3.0 |  | I 3.3 E 2.9 |  | I 3.3 E 3.0 | 8 |  | I 3.2 E 2.6 |
| ET CO2 | 23 | 9 |  | 25 |  | 24 |  | 23 | 9 |  | 21 |  | 21 |  | 23 | 9 |  | 23 |
| Hb | 15.5 | 10 |  |  |  |  |  |  | 10 |  |  |  |  |  |  | 10 |  |  |
| Na++ | 145 |  |  |  |  |  |  |  |  |  |  |  |  |  | ** |  |  |  |
| Time Li[] | 12:23 0.09 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

** ran out of halothane

* peak concentration below recommended level for the device

Not analyzed in chapter 2 and 3 (objective 1) – Sensor exclusion

Analyzed in chapter 3 (objective 2)

**Appendix 4.2:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 2**

Date: Sept 29/99   Anesthetic Plane: Start: 1:37  Finish: 2:00   Premed: Butorphanol 0.4 mg/kg IM   LiCla: 0.2mM   LiClb: 0.6mM

Animal # 2   MAP Range: 76 to 80 mmHg   Induction: Thiopental 10 mg/kg IV   Rate of CO: normal

Weight: 45.4 kg   Volume of Iced Dextrose Used: 10 ml   Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1:37 | 1:38 | | 1:40 | 1:45 | 1:46 | 1:47 | 1:48 | 1:49 | | 1:52 | 1:53 | 1:54 | 1:56 | 1:58 | 1:59 | | 2:00 |
| Temp (C) | 34.8 | 1 / 4.53 | 0.8 | 34.7 | ½ ml | 34.7 | 1½ml | 34.7 | 1 / 4.54 | 0.75 | 34.5 | 1½ml | 34.5 | ½ ml | 34.5 | 1 / 4.54 | 0.8 | 34.4 |
| RR | 11 | 2 / 4.33 | 0.9 | 11 | 4.76 | 11 | 5.00 | 11 | 2 / 4.72 | 0.8 | 11 | 5.10 | 11 | 5.11 | 11 | 2 / 4.69 | 0.7 | 11 |
| HR | 99 | 3 / 4.35 | 0.8 | 96 | S/N 0.22* | 96 | S/N 0.6 | 96 | 3 / 4.46 | 0.75 | 94 | S/N 0.6 | 94 | S/N 0.2* | 94 | 3 / 4.48 | 0.75 | 93 |
| MAP | 76 | 4 | | 78 | | 78 | | 77 | 4 | | 78 | | 78 | | 78 | 4 | | 80 |
| S/D | 103/63 | 5 | | 108/66 | | 105/67 | | 104/66 | 5 | | 105/66 | | 105/67 | | 106/67 | 5 | | 108/68 |
| PA Press | 25 | 6 | | 23 | | 24 | | 23 | 6 | | 25 | | 22 | | 25 | 6 | | 24 |
| PA S/D | 29/21 | 7 | | 30/21 | | 28/20 | | 28/20 | 7 | | 29/21 | | 27/19 | | 28/20 | 7 | | 29/21 |
| Halo. I/E | 1 1.5 E 1.4 | 8 | | 1 1.5 E 1.4 | | 1 1.5 E 1.4 | | 1 1.5 E 1.4 | 8 | | 1 1.5 E 1.4 | | 1 1.5 E 1.3 | | 1 1.5 E 1.3 | 8 | | 1 1.4 E 1.3 |
| ET CO2 | 30 | 9 | | 34 | | 33 | | 33 | 9 | | 34 | | 33 | | 32 | 9 | | 35 |
| Hb | 13.8 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 141 | | | | | | | | | | | | | | | | | |
| Time | 1:35 | | | | | | | | | | | | | | | | | |
| Li [ ] | 0.11 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

Not analyzed in chapter 2 and 3 (objective 1) – Sensor exclusion
Analyzed in chapter 3 (objective 2)

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**Appendix 4.2:    Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 2**

Date: Sept 29/99    Anesthetic Plane: Start: 2:07  Finish: 2:27    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 2    MAP Range: 80 to 84 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 45.4 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:07 | 2:08 | | 2:10 | 2:12 | 2:14 | 2:15 | 2:16 | 2:16 | | 2:18 | 2:20 | 2:21 | 2:22 | 2:23 | 2:24 | | 2:27 |
| Temp (C) | 34.4 | 1  4.57 | 0.7 | 34.3 | ½ ml | 34.2 | 1½ml | 34.2 | 1  4.42 | 0.7 | 34.1 | 1½ml | 34.1 | ½ ml | 34.1 | 1  4.85 | 0.7 | 33.9 |
| RR | 11 | 2  4.48 | 0.8 | 11 | 4.66 | 11 | 5.01 | 11 | 2  4.39 | 0.75 | 11 | 5.09 | 11 | 4.97 | 11 | 2  4.35 | 0.8 | 11 |
| HR | 94 | 3  4.34 | 0.8 | 92 | S/N 0.22* | 88 | S/N 0.6 | 90 | 3  4.28 | 0.75 | 90 | S/N 0.6 | 90 | S/N 0.21* | 90 | 3  4.60 | 0.75 | 90 |
| MAP | 80 | 4 | | 82 | | 82 | | 84 | 4 | | 82 | | 83 | | 81 | 4  4.59 | 0.8 | 82 |
| S/D | 106/68 | 5 | | 110/69 | | 99/72 | | 99/73 | 5 | | 99/72 | | 98/71 | | 97/70 | 5 | | 97/70 |
| PA Press | 23 | 6 | | 24 | | 22 | | 24 | 6 | | 24 | | 22 | | 22 | 6 | | 23 |
| PA S/D | 27/19 | 7 | | 28/20 | | 27/19 | | 28/20 | 7 | | 28/20 | | 28/20 | | 28/20 | 7 | | 28/20 |
| Halo. I/E | I 1.5 E 1.3 | 8 | | I 1.5 E 1.3 | | I 1.5 E 1.3 | | I 1.5 E 1.3 | 8 | | I 1.4 E 1.3 | | I 1.5 E 1.3 | | I 1.4 E 1.3 | 8 | | I 1.5 E 1.3 |
| ET CO2 | 31 | 9 | | 32 | | 31 | | 32 | 9 | | 34 | | 33 | | 32 | 9 | | 33 |
| Hb | 12.9 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 142 | | | | | | | | | | | | | | | | | |
| Time Li[] | 2:02 0.17 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

Not analyzed in chapter 3 (objective 1) – Sensor exclusion
Analyzed in chapter 3 (objective 2)

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**Appendix 4.2:**  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 2

Date: Sept 29/99  Anesthetic Plane: Start: 2:29  Finish: 2:52  Premed: Butorphanol 0.4 mg/kg IM  LiCla: 0.2mM  LiClb: 0.6mM

Animal # 2  MAP Range: 81 to 84 mmHg  Induction: Thiopental 10 mg/kg IV  Rate of CO: normal

Weight: 45.4 kg  Volume of Iced Dextrose Used: 10 ml  Maintenance: Halothane  Li Sensor Constant: 10.5  Cardiac Output Constant: 0.542

| sensor | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | |
| Time | 2:29 | 2:31 | | 2:34 | 2:37 | 2:38 | 2:40 | 2:41 | 2:42 | | 2:44 | 2:45 | 2:46 | 2:48 | 2:50 | 2:51 | | 2:52 |
| Temp (C) | 34.0 | 1 / 4.85 | 0.75 | 33.9 | ½ ml | 33.8 | 1½ml | 33.8 | 1 / 5.07 | 0.7 | 33.7 | 1½ml | 33.7 | ½ ml | 33.7 | 1 / 4.96 | 0.75 | 33.6 |
| RR | 11 | 2 / 4.73 | 0.75 | 11 | 5.06 | 11 | 5.09 | 11 | 2 / 4.72 | 0.75 | 11 | 5.85 | 11 | 5.64 | 11 | 2 / 5.03 | 0.7 | 11 |
| HR | 91 | 3 / 4.63 | 0.75 | 90 | S/N 0.21* | 90 | S/N 0.6 | 90 | 3 / 4.69 | 0.75 | 90 | S/N 0.55 | 90 | S/N 0.2* | 90 | 3 / 4.94 | 0.75 | 89 |
| MAP | 82 | 4 | | 81 | | 82 | | 83 | 4 | | 82 | | 82 | | 84 | 4 | | 82 |
| S/D | 112/69 | 5 | | 111/68 | | 98/71 | | 100/73 | 5 | | 99/71 | | 97/70 | | 100/72 | 5 | | 97/70 |
| PA Press | 23 | 6 | | 23 | | 23 | | 22 | 6 | | 23 | | 22 | | 23 | 6 | | 23 |
| PA S/D | 29/20 | 7 | | 29/21 | | 28/21 | | 27/20 | 7 | | 29/20 | | 28/19 | | 29/20 | 7 | | 29/19 |
| Halo. I/E | I 1.5 / E 1.3 | 8 | | I 1.5 / E 1.3 | | I 1.5 / E 1.3 | | I 1.5 / E 1.3 | 8 | | I 1.5 / E 1.3 | | I 1.4 / E 1.3 | | I 1.5 / E 1.3 | 8 | | I 1.5 / E 1.3 |
| ET CO2 | 32 | 9 | | 32 | | 32 | | 32 | 9 | | 33 | | 32 | | 32 | 9 | | 32 |
| Hb | 12.9 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 139 | | | | | | | | | | | | | | | | | |
| Time Li [] | 2:28 0.20 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

Not analyzed in chapter 3 (objective 1) – Sensor exclusion
Analyzed in chapter 3 (objective 2)

**Appendix 4.2:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 2**

Date: Sept 29/99     Anesthetic Plane: Start: 2:56  Finish: 3:16     Premed: Butorphanol 0.4 mg/kg IM     LiCla: 0.2mM     LiClb: 0.6mM

Animal # 2     Induction: Thiopental 10 mg/kg IV     Rate of CO: normal

Weight: 45.4 kg     MAP Range: 81 to 83 mmHg     Volume of Iced Dextrose Used: 10 ml     Maintenance: Halothane     Li Sensor Constant: 10.5     Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:56 | 2:57 | | 2:59 | 3:01 | 3:03 | 3:04 | 3:05 | 3:06 | | 3:08 | 3:10 | 3:11 | 3:12 | 3:13 | 3:14 | | 3:16 |
| Temp (C) | 33.6 | 1 | | 33.5 | ½ ml | 33.5 | 1½ml | 33.5 | 1 | | 33.4 | 1½ml | 33.4 | ½ ml | 33.4 | 1 | | 33.3 |
| RR | 11 | 4.86 | 0.75 | 11 | 5.33 | 11 | 5.94 | 11 | 4.96 | 0.7 | 11 | 5.44 | 11 | 5.8 | 11 | 5.25 | 0.8 | 11 |
| HR | 90 | 4.80 | 0.7 | 88 | S/N 0.2* | 88 | S/N 0.55 | 88 | 4.78 | 0.7 | 88 | S/N 0.55 | 87 | S/N 0.2* | 88 | 4.96 | 0.75 | 87 |
| MAP | 83 | 4.83 | 0.75 | 82 | | 82 | | 82 | 4.71 | 0.7 | 81 | | 82 | | 82 | 5.03 | 0.7 | 82 |
| S/D | 99/71 | 4 | | 100/71 | | 97/70 | | 97/70 | 4 | | 98/70 | | 97/70 | | 98/70 | 4 | | 98/70 |
| PA Press | 23 | 5 | | 23 | | 22 | | 23 | 5 | | 23 | | 22 | | 22 | 5 | | 23 |
| PA S/D | 29/20 | 6 | | 28/20 | | 28/20 | | 28/20 | 6 | | 29/21 | | 28/20 | | 30/20 | 6 | | 30/20 |
| Halo. I/E | I 1.5 E 1.3 | 7 | | I 1.5 E 1.3 | | I 1.5 E 1.3 | | I 1.5 E 1.3 | 7 | | I 1.4 E 1.3 | | I 1.5 E 1.3 | | I 1.5 E 1.3 | 7 | | I 1.5 E 1.3 |
| ET CO2 | 31 | 8 | | 32 | | 31 | | 31 | 8 | | 34 | | 32 | | 31 | 8 | | 33 |
| Hb | 12.9 | 9 | | | | | | | 9 | | | | | | | 9 | | |
| Na++ | 139 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Time Li [] | 2:53 0.23 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

Not analyzed in chapter 3 (objective 1) – Sensor exclusion
Analyzed in chapter 3 (objective 2)

Appendix 4.2:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 2

Date: Sept 29/99        Anesthetic Plane: Start: 3:21  Finish: 3:42        Premed: Butorphanol 0.4 mg/kg IM        LiCla: 0.6mM        LiClb: 0.2mM

Animal # 2        MAP Range: 82 to 89 mmHg        Induction: Thiopental 10 mg/kg IV        Rate of CO: normal

Weight: 45.4 kg        Volume of Iced Dextrose Used: 10 ml        Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:21 | 3:22 | | 3:25 | 3:26 | 3:27 | 3:29 | 3:31 | 3:32 | | 3:33 | 3:35 | 3:36 | 3:38 | 3:39 | 3:40 | | 3:42 |
| Temp (C) | 33.3 | 1 / 5.09 | 0.75 | 33.2 | 1½ml | 33.2 | ½ml | 33.2 | 1 / 4.51 | 0.75 | 33.0 | ½ ml | 33.1 | 1½ml | 33.1 | 1 / 4.48 | 0.65 | 33.0 |
| RR | 11 | 2 / 4.85 | 0.8 | 11 | 5.61 | 11 | 5.22 | 11 | 2 / 4.24 | 0.8 | 11 | 5.05 | 11 | 5.38 | 11 | 2 / 4.26 | 0.7 | 11 |
| HR | 87 | 3 / 4.80 | 0.75 | 85 | S/N 0.52 | 84 | S/N 0.18* | 83 | 3 / 4.26 | 0.8 | 82 | S/N 0.2* | 82 | S/N 0.51 | 81 | 3 / 4.26 | 0.75 | 81 |
| MAP | 82 | 4 | | 82 | | 82 | | 85 | 4 | | 85 | | 87 | | 86 | 4 | | 89 |
| S/D | 99/70 | 5 | | 99/71 | | 100/72 | | 99/73 | 5 | | 103/74 | | 102/75 | | 104/75 | 5 | | 104/76 |
| PA Press | 21 | 6 | | 22 | | 22 | | 21 | 6 | | 22 | | 21 | | 21 | 6 | | 22 |
| PA S/D | 30/19 | 7 | | 27/19 | | 28/19 | | 24/18 | 7 | | 27/19 | | 27/19 | | 27/19 | 7 | | 28/20 |
| Halo. I/E | I 1.5 E 1.3 | 8 | | I 1.5 E 1.3 | | I 1.5 E 1.3 | | I 1.4 E 1.3 | 8 | | I 1.5 E 1.3 | | I 1.5 E 1.3 | | I 1.5 E 1.3 | 8 | | I 1.5 E 1.3 |
| ET CO2 | 30 | 9 | | 30 | | 30 | | 29 | 9 | | 30 | | 30 | | 30 | 9 | | 30 |
| Hb | 12.4 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 138 | | | | | | | | | | | | | | | | | |
| Time Li[ ] | 3:17 0.26 | | | | | | | | | | | | | | | | | 3:44 0.28 |

* peak concentration below recommended level for the device

Not analyzed in chapter 3 (objective 1) – Sensor exclusion
Analyzed in chapter 3 (objective 2)

**Appendix 4.3:    Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 3**

Date: Oct 5/99    Anesthetic Plane: Start: 10:24  Finish: 10:52  Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 3    MAP Range: 74 to 85 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 37 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane   Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 10:24 | 10:26 | | 10:29 | 10:30 | 10:33 | 10:35 | 10:36 | 10:37 | | 10:41 | 10:44 | 10:45 | 10:47 | 10:49 | 10:50 | | 10:52 |
| Temp (C) | 38.0 | 1 / 1.97 | | 37.8 | 1 ml | 37.8 | 1/3ml | 37.8 | 1 / 2.11 | | 37.6 | 1/3ml | 37.6 | 1 ml | 37.5 | 1 / 2.17 | | 37.4 |
| RR | 11 | 2 / 1.94 | 1.5 | 11 | 2.02 | 11 | 1.92 | 11 | 2 / 2.24 | 1.5 | 11 | 2.14 | 11 | 2.36 | 11 | 2 / 2.11 | 1.4 | 11 |
| HR | 65 | 3 / 2.1 | 1.5 | 66 | S/N 0.52 | 65 | S/N 0.24* | 65 | 3 / 1.96 | 1.5 | 66 | S/N 0.21* | 65 | S/N 0.51 | 66 | 3 / 2.07 | 1.5 | 65 |
| MAP | 85 | 4 | 1.2 | 82 | | 74 | | 82 | 4 / 1.99 | 1.5 | 80 | | 82 | | 78 | 4 | 1.5 | 78 |
| S/D | 103/77 | 5 | | 115/70 | | 118/72 | | 113/70 | 5 / 2.10 | 1.5 | 113/69 | | 114/71 | | 111/67 | 5 | | 112/67 |
| PA Press | 17 | 6 | | 17 | | 18 | | 18 | 6 | | 17 | | 17 | | 17 | 6 | | 18 |
| PA S/D | 24/13 | 7 | | 24/13 | | 24/14 | | 23/14 | 7 | | 24/14 | | 24/13 | | 24/12 | 7 | | 25/14 |
| Halo. I/E | I 1.5 / E 1.3 | 8 | | I 1.6 / E 1.3 | | I 1.5 / E 1.3 | | I 1.6 / E 1.3 | 8 | | I 1.6 / E 1.3 | | I 1.6 / E 1.3 | | I 1.6 / E 1.3 | 8 | | I 1.6 / E 1.3 |
| ET CO2 | 26 | 9 | | 30 | | 30 | | 28 | 9 | | 30 | | 28 | | 28 | 9 | | 29 |
| Hb | 14.3 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 146 | | | | | | | | | | | | | | | | | |
| Time Li[] | 10:15 / 0.01 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device                    Analyzed in chapters 2 and 3.

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**Appendix 4.3:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 3**

Date: Oct 5/99          Anesthetic Plane: Start: 11:36  Finish: 12:03  Premed: Butorphanol 0.4 mg/kg IM          LiCla: 0.6mM     LiClb: 0.2mM

Animal # 3          MAP Range: 42 to 47 mmHg          Induction: Thiopental 10 mg/kg IV          Rate of CO: mildly low - deep anesthesia

Weight: 37 kg          Volume of Iced Dextrose Used: 5 ml          Maintenance: Halothane    Li Sensor Constant: 10.5     Cardiac Output Constant: 0.247

| sensor | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 11:36 | 11:37 | | 11:40 | 11:43 | 11:45 | 11:47 | 11:48 | 11:49 | | 11:52 | 11:54 | 11:55 | 11:58 | 12:00 | 12:01 | | 12:03 |
| Temp (C) | 36.9 | 1 / 1.12 | 0.6 | 36.9 | 1 ml | 36.8 | ½ ml | 36.8 | 1 / 1.10 | 0.6 | 36.8 | ½ ml | 36.8 | 1 ml | 36.8 | 1 / 1.18 | 0.6 | 36.7 |
| RR | 11 | 2 / 1.05 | 0.5 | 11 | 1.13 | 11 | 1.23 | 11 | 2 / 1.10 | 0.6 | 11 | 1.24 | 11 | 1.35 | 11 | 2 / 1.10 | 0.6 | 11 |
| HR | 78 | 3 / 1.04# | 0.6 | 83 | S/N 0.5 | 88 | S/N 0.25 | 92 | 3 / 1.07 | 0.6 | 93 | S/N 0.25 | 98 | S/N 0.45 | 96 | 3 / 1.08 | 0.7 | 96 |
| MAP | 47 | 4 | | 45 | | 44 | | 44 | 4 | | 44 | | 45 | | 44 | 4 | | 42 |
| S/D | 59/43 | 5 | | 54/40 | | 53/40 | | 51/40 | 5 | | 51/40 | | 52/41 | | 50/41 | 5 | | 48/39 |
| PA Press | 18 | 6 | | 18 | | 18 | | 19 | 6 | | 18 | | 19 | | 18 | 6 | | 19 |
| PA S/D | 22/15 | 7 | | 23/15 | | 23/16 | | 24/16 | 7 | | 24/15 | | 24/16 | | 23/15 | 7 | | 24/15 |
| Halo. I/E | I 3.1 E 2.7 | 8 | | I 3.2 E 2.8 | | I 3.3 E 2.9 | | I 3.4 E 2.9 | 8 | | I 3.4 E 2.9 | | I 3.4 E 2.9 | | I 3.4 E 3.0 | 8 | | I 3.5 E 2.9 |
| ET CO2 | 21 | 9 | | 22 | | 22 | | 26 | 9 | | 25 | | 28 | | 28 | 9 | | 29 |
| Hb | 13.2 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 144 | | | | | | | | | | | | | | | | | |
| Time Li [] | 11:35 0.04 | | | | | | | | | | | | | | | | | |

# unsteady baseline

Analyzed in chapters 2 and 3.

## Appendix 4.3:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 3

Date: Oct 5/99    Anesthetic Plane: Start: 12:37  Finish: 1:06    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 3    MAP Range: 76 to 83 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: high – dobutamine

Weight: 37 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 12:37 | 12:39 | | 12:43 | 12:44 | 12:45 | 12:47 | 12:49 | 12:50 | | 12:53 | 12:57 | 12:59 | 1:01 | 1:03 | 1:04 | | 1:06 |
| Temp (C) | 36.7 | 1 / 4.10 | 0.85 | 36.6 | 1 ml | 36.6 | ½ ml | 36.6 | 1 / 4.35 | 0.9 | 36.4 | ½ ml | 36.4 | 1½ml | 36.4 | 1 / 4.79 | 0.7 | 36.3 |
| RR | 11 | 2 / 3.96 | 0.9 | 10 | | 11 | | 11 | 2 / 4.38 | 0.9 | 11 | | 11 | | 11 | 2 / 4.85 | 0.7 | 11 |
| HR | 70 | 3 / 3.89 | 0.9 | 70 | 5.25 | 79 | 5.86 | 76 | 3 / 4.84 | 0.8 | 76 | 7.42 | 81 | 7.33 | 76 | 3 / 4.73 | 0.8 | 75 |
| MAP | 83 | 4 | | | S/N 0.47 | 83 | S/N 0.21* | 77 | 4 / 4.82 | 0.9 | 78 | S/N 0.21* | 82 | S/N 0.55 | 77 | 4 | | 76 |
| S/D | 120/67 | 5 | | | | 119/67 | | 114/62 | 5 / 4.80 | 0.8 | 115/63 | | 118/66 | | 113/61 | 5 | | 114/61 |
| PA Press | 25 | 6 | | 24 | | 25 | | 24 | 6 | | 25 | | 24 | | 23 | 6 | | 24 |
| PA S/D | 38/19 | 7 | | 39/18 | | 42/19 | | 42/18 | 7 | | 42/19 | | 41/18 | | 41/17 | 7 | | 41/18 |
| Halo. I/E | 1 1.8 / E 1.6 | 8 | | 1 1.8 / E 1.6 | | 1 1.8 / E 1.5 | | 1 1.8 / E 1.5 | 8 | | 1 1.7 / E 1.4 | | 1 1.7 / E 1.4 | | 1 1.7 / E 1.5 | 8 | | 1 1.7 / E 1.4 |
| ET CO2 | 36 | 9 | | | | 38 | | 38 | 9 | | 39 | | 40 | | 39 | 9 | | 39 |
| Hb | 18.9 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 146 | | | | | | | | | | | | | | | | | |
| Time / Li[] | 12:33 / 0.05 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

Not analyzed in chapters 2 and 3 (objective 1) – Sensor exclusion
Analyzed in chapter 3 (objective 2)

**Appendix 4.3:** Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 3

Date: Oct 5/99  Anesthetic Plane: Start: 1:38 Finish: 2:06  Premed: Butorphanol 0.4 mg/kg IM  LiCla: 0.2mM  LiClb: 0.6mM

Animal # 3  MAP Range: 33 to 37 mmHg  Induction: Thiopental 10 mg/kg IV  Rate of CO: markedly low - occlusion

Weight: 37 kg  Volume of Iced Dextrose Used: 5 ml  Maintenance: Halothane  Li Sensor Constant: 10.5  Cardiac Output Constant: 0.247

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1:38 | 1:39 | | 1:42 | 1:44 | 1:49 | 1:50 | 1:52 | 1:53 | | 1:57 | 1:58 | 2:00 | 2:02 | 2:03 | 2:04 | | 2:06 |
| Temp (C) | 36.0 | 1  0.56 | 2.0 | 35.8 | 1/3ml | 36.0 | 1 ml | 36.0 | 1  0.60 | 1.5 | 36.0 | 2/3ml | 36.0 | 1/3ml | 36.0 | 1  0.67 | 1.5 | 35.9 |
| RR | 11 | 2  0.55 | 2.0 | 11 | ** | 11 | *** 0.94 | 11 | 2  0.59 | 1.5 | 11 | *** 0.90 | 11 | 1.02 | 11 | 2  0.66 | 1.5 | 11 |
| HR | 112 | 3  0.57 | 2.0 | 105 | S/N | 106 | S/N >0.6 | 104 | 3  0.59 | 1.5 | 100 | S/N 0.45 | 91 | S/N 0.25 | 99 | 3  0.65 | 1.5 | 96 |
| MAP | 34 | 4 | | 34 | 1:47 | 33 | | 34 | 4 | | | | 35 | | 36 | 4 | | 37 |
| S/D | 35/33 | 5 | | 35/33 | ½ ml | 34/33 | | 35/34 | 5 | | | | 37/35 | | 38/36 | 5 | | 39/36 |
| PA Press | 10 | 6 | | 10 | *** 0.94 | 11 | | 10 | 6 | | 8 | | 11 | | 10 | 6 | | 11 |
| PA S/D | 13/9 | 7 | | 12/8 | S/N 0.25 | 14/10 | | 13/9 | 7 | | 13/7 | | 14/9 | | 12/8 | 7 | | 15/9 |
| Halo. I/E | I 1.9 E 1.7 | 8 | | I 2.0 E 1.8 | | I 2.0 E 1.9 | | I 2.0 E 1.9 | 8 | | I 2.0 E 1.9 | | I 2.0 E 1.9 | | I 1.8 E 1.7 | 8 | | I 1.9 E 1.8 |
| ET CO2 | 13 | 9 | | 17 | | 17 | | 20 | 9 | | 18 | | 20 | | 22 | 9 | | 20 |
| Hb | 14.0 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 144 | | | | | | | | | | | | | | | | | |
| Time Li [] | 1:38  0.09 | | | | | | | | | | | | | | | | | |

** battery ran out during determination but LiCl had already been injected
*** cardiac output outside the range of the device

Not analyzed in chapters 2 and 3 (objective 1) – Sensor exclusion
Analyzed in chapter 3 (objective 2)

**Appendix 4.3:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 3**

Date: Oct 5/99    Anesthetic Plane: Start: 2:39  Finish: 3:04    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 3    MAP Range: 57 to 61 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 37 kg    Volume of Iced Dextrose Used: 5 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.247

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:39 | 2:40 | | 2:44 | 2:46 | 2:47 | 2:50 | 2:51 | 2:52 | | 2:54 | 2:56 | 2:57 | 3:00 | 3:01 | 3:02 | | 3:04 |
| Temp (C) | 35.7 | 1 / 3.73 | 0.6 | 35.6 | 1 ml | 35.6 | 2 ml | 35.6 | 1 / 3.79 | 0.6 | 35.5 | 2 ml | 35.5 | 1 ml | 35.5 | 1 / 3.86 | 0.55 | 35.4 |
| RR | 10 | 2 / 3.56 | 0.6 | 10 | 5.86 | 10 | 6.59 | 10 | 2 / 3.76 | 0.6 | 10 | 6.84 | 10 | 7.17 | 10 | 2 / 3.62 | 0.6 | 10 |
| HR | 84 | 3 / 3.51 | 0.6 | 81 | S/N 0.27 | 81 | S/N 0.51 | 83 | 3 / 3.68 | 0.6 | 85 | S/N 0.5 | 84 | S/N 0.25 | 84 | 3 / 3.51 | 0.6 | 83 |
| MAP | 57 | 4 | | 58 | | 58 | | 61 | 4 | | 58 | | 60 | | 61 | 4 | | 61 |
| S/D | 72/47 | 5 | | 76/49 | | 76/49 | | 79/51 | 5 | | 75/48 | | 78/51 | | 79/51 | 5 | | 79/51 |
| PA Press | 18 | 6 | | 18 | | 18 | | 18 | 6 | | 18 | | 18 | | 18 | 6 | | 18 |
| PA S/D | 25/13 | 7 | | 24/13 | | 24/13 | | 24/14 | 7 | | 24/13 | | 23/14 | | 23/13 | 7 | | 23/13 |
| Halo. I/E | 1 1.5 E 1.4 | 8 | | 1 1.5 E 1.3 | | 1 1.5 E 1.3 | | 1 1.5 E 1.3 | 8 | | 1 1.5 E 1.3 | | 1 1.5 E 1.3 | | 1 1.5 E 1.3 | 8 | | 1 1.5 E 1.3 |
| ET CO2 | 33 | 9 | | 34 | | 34 | | 35 | 9 | | 36 | | 36 | | 35 | 9 | | 35 |
| Hb | 13.8 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 140 | | | | | | | | | | | | | | | | | |
| Time Li[] | 2:28 0.12 | | | | | | | | | | | | | | | | | |

Not analyzed in chapter 3 (objective 1) – sensor exclusion
Analyzed in chapter 3 (objective 2)

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**Appendix 4.3:    Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 3**

Date: Oct 5/99    Anesthetic Plane: Start: 3:12  Finish: 3:41    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 3    MAP Range: 61 to 66 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 37 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:12 | 3:13 |  | 3:15 | 3:17 | 3:19 | 3:21 | 3:23 | 3:24 |  | 3:30 | 3:32 | 3:33 | 3:36 | 3:37 | 3:38 |  | 3:41 |
| Temp (C) | 35.4 | 1  3.72 |  | 35.3 | 1 ml | 35.3 | 1/3ml | 35.3 | 1  3.70 |  | 35.3 | 1/3ml | 35.2 | 1 ml | 35.2 | 1  3.51 | 0.6 | 35.1 |
| RR | 10 | 2  3.27 | 0.6 | 10 | 4.05 | 10 | 4.11 | 10 | 2  3.49 | 0.6 | 10 | 5.41 | 10 | 4.15 | 10 | 2  3.38 | 0.65 | 10 |
| HR | 84 | 3  3.31 | 0.6 | 81 | S/N 0.6 | 81 | S/N 0.2* | 83 | 3  3.59 | 0.6 | 81 | S/N 0.13* | 84 | S/N 0.5 | 81 | 3  3.12 | 0.7 | 82 |
| MAP | 62 | 4  3.44 | 0.6 | 61 |  | 62 |  | 64 | 4 |  | 66 |  | 66 |  | 65 | 4  3.29 | 0.65 | 65 |
| S/D | 80/52 | 5 |  | 80/52 |  | 81/52 |  | 83/54 | 5 |  | 85/57 |  | 86/57 |  | 85/56 | 5 |  | 84/56 |
| PA Press | 17 | 6 |  | 17 |  | 17 |  | 17 | 6 |  | 17 |  | 17 |  | 17 | 6 |  | 17 |
| PA S/D | 23/13 | 7 |  | 23/13 |  | 23/13 |  | 22/13 | 7 |  | 23/13 |  | 23/13 |  | 22/13 | 7 |  | 22/13 |
| Halo. I/E | 11.5 E1.3 | 8 |  | 11.5 E1.3 |  | 11.5 E1.3 |  | 11.5 E1.3 | 8 |  | 11.5 E1.3 |  | 11.5 E1.3 |  | 11.5 E1.3 | 8 |  | 11.4 E1.3 |
| ET CO2 | 33 | 9 |  | 35 |  | 35 |  | 34 | 9 |  | 32 |  | 33 |  | 32 | 9 |  | 34 |
| Hb | 13.2 | 10 |  |  |  |  |  |  | 10 |  |  |  |  |  |  | 10 |  |  |
| Na++ | 142 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Time | 3:06 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 3:45 |
| Li[] | 0.24 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.25 |

* peak concentration below recommended level for the device    Analyzed in chapter 3.

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**Appendix 4.4:**    Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 4

Date: Oct 6/99     Anesthetic Plane: Start: 10:49 Finish: 11:13 Premed: Butorphanol 0.4 mg/kg IM     LiCla: 0.2mM    LiClb: 0.6mM

Animal # 4     MAP Range: 78 to 87 mmHg     Induction: Thiopental 10 mg/kg IV     Rate of CO: high – dobutamine

Weight: 37 kg     Volume of Iced Dextrose Used: 10 ml     Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 10:49 | 10:50 | | 10:52 | 10:57 | 10:59 | 11:00 | 11:02 | 11:03 | | 11:04 | 11:05 | 11:07 | 11:09 | 11:10 | 11:11 | | 11:13 |
| Temp (C) | 37.7 | 1 8.62 | | 37.6 | ½ ml | 37.7 | 1½ml | 37.8 | 1 9.16 | | 37.7 | 1½ml | 37.7 | ½ ml | 37.8 | 1 9.48 | | 37.7 |
| RR | 10 | 2 8.14 | 0.6 | 10 | ** 9.52 | 10 | ** 9.69 | 11 | 2 8.85 | 0.5 | 11 | 9.46 | 11 | ** 10.05 | 11 | 2 9.07 | 0.4 | 11 |
| HR | 87 | 3 8.2 | 0.6 | 113 | S/N 0.25 | 108 | S/N >0.6 | 122 | 3 9.19 | 0.5 | 108 | S/N >0.6 | 89 | S/N 0.21* | 111 | 3 9.57 | 0.5 | 100 |
| MAP | 83 | 4 | | 80 | | 84 | | 83 | 4 | | 87 | | 78 | | 82 | 4 | | 85 |
| S/D | 150/58 | 5 | | 137/58 | | 148/58 | | 147/60 | 5 | | 142/60 | | 136/53 | | 136/58 | 5 | | 150/61 |
| PA Press | 26 | 6 | | 24 | | 24 | | 25 | 6 | | 25 | | 24 | | 24 | 6 | | 26 |
| PA S/D | 45/18 | 7 | | 37/18 | | 45/21 | | 45/20 | 7 | | 43/21 | | 46/20 | | 45/19 | 7 | | 45/21 |
| Halo. I/E | 1 1.2 E 0.8 | 8 | | 1 1.3 E 0.8 | | 1 1.1 E 0.7 | | 1 1.1 E 0.7 | 8 | | 1 1.1 E 0.7 | | 1 1.1 E 0.7 | | 1 1.1 E 0.7 | 8 | | 1 1.1 E 0.7 |
| ET CO2 | 47 | 9 | | 48 | | 49 | | 49 | 9 | | 44 | | 48 | | 43 | 9 | | 47 |
| Hb | 19.0 | 10 | | | | | | | | | | | | | | 10 | | |
| Na++ | 148 | | | | | | | | | | | | | | | | | |
| Time | 10:25 | | | | | | | | | | | | | | | | | |
| Li [ ] | 0.00 | | | | | | | | | | | | | | | | | |

\* peak concentration below recommended level for the device

\*\* unusual fitted curve

Not analyzed in chapter 3 (objective 1) – cardiac output > 5 L/min

Analyzed in chapters 2 and 3 (objective 2).

**Appendix 4.4:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 4**

Date: Oct 6/99        Anesthetic Plane: Start: 12:04  Finish: 12:38  Premed: Butorphanol 0.4 mg/kg IM        LiCla: 0.6mM    LiClb: 0.2mM

Animal # 4        MAP Range: 29 to 42 mmHg        Induction: Thiopental 10 mg/kg IV        Rate of CO: markedly low - occlusion

Weight: 37 kg        Volume of Iced Dextrose Used: 5 ml        Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.247

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 12:04 | 12:05 |  | 12:07 | 12:19 | 12:21 | 12:23 | 12:26 | 12:27 |  | 12:28 | 12:30 | 12:32 | 12:34 | 12:36 | 12:37 |  | 12:38 |
| Temp (C) | 37.6 | 1 / 1.11 | 0.85 | 37.5 | 1 ml | 37.6 | 1/3ml | 37.7 | 1 / 0.81 | 0.9 | 37.6 | 1/3ml | 37.5 | 2/3ml | 37.5 | 1 / 0.83 | 1.2 | 37.4 |
| RR | 13 | 2 / 1.04 | 0.85 | 13 | ** 0.62 | 13 | ** 0.56 | 13 | 2 / 0.77 | 1.0 | 13 | ** 0.8 | 13 | ** 0.78 | 13 | 2 / 0.79 | 1.2 | 13 |
| HR | 96 | 3 / 0.98 | 0.9 | 88 | S/N >0.6 | 92 | S/N 0.32 | 96 | 3 / 0.73 | 1.0 | 92 | S/N 0.28 | 99 | S/N 0.6 | 105 | 3 / 0.75 | 1.2 | 111 |
| MAP | 35 | 4 / 0.97 | 0.9 | 33 |  | 29 |  | 32 | 4 |  | 33 |  | 37 |  | 39 | 4 |  | 42 |
| S/D | 44/32 | 5 |  | 39/30 |  | 34/27 |  | 37/30 | 5 |  | 39/32 |  | 43/34 |  | 48/36 | 5 |  | 50/38 |
| PA Press | 9 | 6 |  | 9 |  | 9 |  | 10 | 6 |  | 9 |  | 11 |  | 10 | 6 |  | 9 |
| PA S/D | 12/6 | 7 |  | 13/7 |  | 12/7 |  | 12/6 | 7 |  | 13/7 |  | 12/7 |  | 13/8 | 7 |  | 11/6 |
| Halo. I/E | I 2.0 / E 1.8 | 8 |  | I 2.1 / E 1.8 |  | I 2.3 / E 2.1 |  | I 2.3 / E 2.1 | 8 |  | I 2.7 / E 2.0 |  | I 2.3 / E 2.1 |  | I 2.3 / E 2.1 | 8 |  | I 2.3 / E 2.1 |
| ET CO2 | 24 | 9 |  | 24 |  | 23 |  | 24 | 9 |  | 22 |  | 23 |  | 21 | 9 |  | 24 |
| Hb | 15.1 | 10 |  |  |  |  |  |  | 10 |  |  |  |  |  |  | 10 |  |  |
| Na++ | 146 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Time | 12:03 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Li [ ] | 0.04 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

** cardiac output outside range of device, unusual shape of curve, curve too long

Not analyzed in chapter 2 and 3 (objective 1) – hemodynamic stability

Analyzed in chapter 3 (objective 2)

**Appendix 4.4:**   **Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 4**

Date: Oct 6/99    Anesthetic Plane: Start: 1:44  Finish: 2:08    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 4    MAP Range: 50 to 53 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: mildly low - deep anesthesia

Weight: 37 kg    Volume of Iced Dextrose Used: 5 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.247

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1:44 | 1:45 | | N/D | 1:49 | 1:51 | 1:52 | 1:54 | 1:55 | | 1:57 | 1:59 | 2:01 | 2:02 | 2:05 | 2:06 | | 2:08 |
| Temp (C) | 37.5 | 1  1.45 | 0.6 | | 1 ml | 37.5 | ½ ml | 37.6 | 1  1.66 | 0.6 | 37.5 | ½ ml | 37.6 | 1 ml | 37.6 | 1  1.69 | 0.6 | 37.6 |
| RR | 11 | 2  1.42 | 0.6 | | | 11 | | 11 | 2  1.58 | 0.6 | 11 | | 11 | | 11 | 2  1.65 | 0.6 | 11 |
| HR | 100 | 3  1.42 | 0.6 | | 1.68  S/N 0.5 | 102 | 1.77  S/N 0.25 | 102 | 3  1.54 | 0.6 | 102 | 1.82  S/N 0.25 | 102 | 1.94  S/N 0.45 | 102 | 3  1.59 | 0.6 | 103 |
| MAP | 50 | 4 | | | | 53 | | 53 | 4 | | 51 | | 53 | | 53 | 4 | | 50 |
| S/D | 65/44 | 5 | | | | 69/46 | | 69/46 | 5 | | 65/44 | | 68/46 | | 68/46 | 5 | | 65/44 |
| PA Press | 21 | 6 | | | | 22 | | 22 | 6 | | 22 | | 22 | | 21 | 6 | | 22 |
| PA S/D | 27/18 | 7 | | | | 29/20 | | 28/20 | 7 | | 28/20 | | 28/20 | | 28/20 | 7 | | 27/20 |
| Halo. I/E | I 2.4  E 2.1 | 8 | | I  E | | I 2.4  E 2.1 | | I 2.4  E 2.1 | 8 | | I 2.6  E 2.1 | | I 2.4  E 2.2 | | I 2.4  E 2.1 | 8 | | I 2.5  E 2.1 |
| ET CO2 | 38 | 9 | | | | 40 | | 42 | 9 | | 45 | | 43 | | 43 | 9 | | 46 |
| Hb | 16.6 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 140 | | | | | | | | | | | | | | | | | |
| Time Li[ ] | 1:42  0.04 | | | | | | | | | | | | | | | | | |

Not analyzed in chapter 2 and 3 (objective 1) – Sensor exclusion
Analyzed in chapter 3 (objective 2)

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**Appendix 4.4:** Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 4

Date: Oct 6/99    Anesthetic Plane: Start: 2:30 Finish: 3:02    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 4    MAP Range: 60 to 65 mmHg    Induction: Thiopental 10 Mg/kg IV    Rate of CO: normal

Weight: 37 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:30 | 2:31 | | 2:34 | 2:38 | 2:41 | 2:42 | 2:44 | 2:45 | | 2:50 | 2:53 | 2:55 | 2:57 | 2:59 | 3:00 | | 3:02 |
| Temp (C) | 37.5 | 1 2.48 | 1.2 | 37.4 | 2/3ml | 37.5 | 1½ml | 37.5 | 1 2.88 | 1.2 | 37.4 | 1½ml | 37.4 | 2/3ml | 37.4 | 1 3.00 | 1.1 | 37.3 |
| RR | 11 | 2 2.48 | 1.2 | 11 | 3.14 | 11 | 3.29 | 11 | 2 2.74 | 1.2 | 11 | 4.32 | 11 | 4.02 | 11 | 2 2.99 | 1.1 | 11 |
| HR | 102 | 3 2.50 | 1.1 | 104 | S/N 0.25* | 107 | S/N 0.6 | 103 | 3 3.26 | 1.1 | 108 | S/N 0.6 | 101 | S/N 0.25* | 101 | 3 2.93 | 1.1 | 101 |
| MAP | 63 | 4 | | 60 | | 61 | | 63 | 4 3.06 | 1.0 | 61 | | 65 | | 65 | 4 | | 63 |
| S/D | 88/53 | 5 | | 83/50 | | 85/51 | | 86/52 | 5 3.37 | 1.1 | 84/50 | | 92/53 | | 95/54 | 5 | | 94/51 |
| PA Press | 20 | 6 | | 22 | | 23 | | 21 | 6 | | 23 | | 22 | | 22 | 6 | | 23 |
| PA S/D | 26/19 | 7 | | 28/21 | | 28/20 | | 27/19 | 7 | | 28/21 | | 28/20 | | 25/18 | 7 | | 28/21 |
| Halo. I/E | 1 1.6 E 1.5 | 8 | | 1 1.6 E 1.5 | | 1 1.5 E 1.5 | | 1 1.5 E 1.5 | 8 | | 1 1.5 E 1.4 | | 1 1.5 E 1.4 | | 1 1.5 E 1.4 | 8 | | 1 1.5 E 1.4 |
| ET CO2 | 38 | 9 | | 47 | | 46 | | 47 | 9 | | 51 | | 48 | | 47 | 9 | | 48 |
| Hb | 17.0 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 142 | | | | | | | | | | | | | | | | | |
| Time Li[] | 2:29 0.06 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

Not analyzed in chapter 2 and 3 (objective 1) – Sensor exclusion

Analyzed in chapter 3 (objective 2)

**Appendix 4.4:**  **Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 4**

Date: Oct 6/99            Anesthetic Plane: Start: 3:11  Finish: 3:35            Premed: Butorphanol 0.4 mg/kg IM            LiCla: 0.2mM      LiClb: 0.6mM

Animal # 4            MAP Range: 64 to 69 mmHg            Induction: Thiopental 10 mg/kg IV            Rate of CO: normal

Weight: 37 kg            Volume of Iced Dextrose Used: 10 ml            Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:11 | 3:12 | | 3:15 | 3:16 | 3:19 | 3:20 | 3:22 | 3:23 | | 3:25 | 3:26 | 3:28 | 3:31 | 3:32 | 3:33 | | 3:35 |
| Temp (C) | 37.3 | 1  2.67 | 1.2 | 37.3 | 2/3ml | 37.3 | 1½ml | 37.3 | 1  3.01 | 1.2 | 37.2 | 1½ml | 37.2 | 2/3ml | 37.2 | 1  3.30 | 1.2 | 37.1 |
| RR | 11 | 2  2.61 | 1.2 | 11 | 3.19 | 11 | 3.34 | 11 | 2  2.96 | 1.2 | 11 | 3.97 | 11 | 3.46 | 11 | 2  2.87 | 1.2 | 11 |
| HR | 95 | 3  2.63 | 1.2 | 98 | S/N 0.3 | 100 | S/N 0.6 | 102 | 3  2.98 | 1.2 | 103 | S/N 0.6 | 99 | S/N 0.26 | 98 | 3  2.89 | 1.2 | 99 |
| MAP | 66 | 4 | | | | 67 | | 67 | 4 | | 64 | | 69 | | 68 | 4  3.05 | 1.2 | 67 |
| S/D | 97/54 | 5 | | | | 96/55 | | 97/55 | 5 | | 92/52 | | 99/56 | | 101/56 | 5 | | 99/54 |
| PA Press | 21 | 6 | | 22 | | 22 | | 22 | 6 | | 23 | | 21 | | 21 | 6 | | 23 |
| PA S/D | 25/18 | 7 | | 25/19 | | 27/20 | | 27/20 | 7 | | 28/20 | | 25/18 | | 25/18 | 7 | | 28/20 |
| Halo. I/E | 1 1.5 E 1.4 | 8 | | 1 1.5 E 1.4 | | 1 1.5 E 1.4 | | 1 1.5 E 1.4 | 8 | | 1 1.5 E 1.4 | | 1 1.5 E 1.4 | | 1 1.5 E 1.4 | 8 | | 1 1.5 E 1.4 |
| ET CO2 | 43 | 9 | | 45 | | 45 | | 47 | 9 | | 49 | | 47 | | 46 | 9 | | 48 |
| Hb | 15.9 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 140 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 3:04  0.12 | | | | | | | | | | | | | | | | | |

Analyzed in chapter 3

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**Appendix 4.4:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 4**

Date: Oct 6/99    Anesthetic Plane: Start: 3:42  Finish: 4:06    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 4    MAP Range: 66 to 69 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 37 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:42 | 3:44 | | 3:46 | 3:48 | 3:50 | 3:51 | 3:53 | 3:54 | | 3:55 | 3:57 | 3:59 | 4:01 | 4:02 | 4:03 | | 4:06 |
| Temp (C) | 37.1 | 1  2.83 | 1.3 | 37.1 | 2/3ml | 37.1 | 1½ml | 37.1 | 1  3.00 | 1.2 | 37.0 | 1½ml | 37.1 | 2/3ml | 37.1 | 1  2.93 | 1.2 | 37.0 |
| RR | 11 | 2  2.68 | 1.3 | 11 | 3.41 | 11 | 3.48 | 11 | 2  3.06 | 1.2 | 11 | 3.96 | 11 | 4.05 | 11 | 2  2.95 | 1.2 | 11 |
| HR | 90 | 3  2.77 | 1.2 | 96 | S/N 0.27 | 96 | S/N 0.65 | 98 | 3  3.07 | 1.2 | 95 | S/N 0.51 | 95 | S/N 0.25 | 95 | 3  2.99 | 1.2 | 92 |
| MAP | 66 | 4 | | 67 | | 69 | | 69 | 4 | | 67 | | 68 | | 67 | 4 | | 66 |
| S/D | 97/55 | 5 | | 101/55 | | 103/57 | | 101/56 | 5 | | 100/54 | | 102/56 | | 100/55 | 5 | | 100/54 |
| PA Press | 21 | 6 | | 22 | | 22 | | 22 | 6 | | 22 | | 21 | | 23 | 6 | | 21 |
| PA S/D | 25/18 | 7 | | 27/20 | | 25/18 | | 25/18 | 7 | | 27/20 | | 25/19 | | 27/19 | 7 | | 25/18 |
| Halo. I/E | 1 1.4 E 1.3 | 8 | | 1 1.5 E 1.4 | | 1 1.5 E 1.4 | | 1 1.5 E 1.4 | 8 | | 1 1.5 E 1.3 | | 1 1.5 E 1.3 | | 1 1.5 E 1.3 | 8 | | 1 1.5 E 1.3 |
| ET CO2 | 43 | 9 | | 46 | | 45 | | 46 | 9 | | 48 | | 46 | | 45 | 9 | | 47 |
| Hb | 15.0 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 139 | | | | | | | | | | | | | | | | | |
| Time Li [] | 3:38  0.16 | | | | | | | | | | | | | | | | | |

Analyzed in chapter 3

**Appendix 4.4:**   **Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 4**

Date: Oct 6/99       Anesthetic Plane: Start: 4:18  Finish: 4:39       Premed: Butorphanol 0.4 mg/kg IM       LiCla: 0.2mM    LiClb: 0.6mM

Animal # 4       MAP Range: 67 to 70 mmHg       Induction: Thiopental 10 ng/kg IV       Rate of CO: normal

Weight: 37 kg       Volume of Iced Dextrose Used: 10 ml       Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 4:18 | 4:20 | | 4:22 | 4:23 | 4:25 | 4:27 | 4:28 | 4:29 | | 4:30 | 4:32 | 4:33 | 4:35 | 4:37 | 4:38 | | 4:39 |
| Temp (C) | 37.0 | 1  2.72 | 1.5 | 36.9 | 2/3ml | 37.0 | 1½ml | 37.0 | 1  3.01 | 1.2 | 36.9 | 1½ml | 36.9 | 2/3ml | 36.9 | 1  3.02 | 1.2 | 36.8 |
| RR | 11 | 2  2.65 | 1.5 | 11 | 3.42 | 11 | 3.67 | 11 | 2  2.86 | 1.2 | 11 | 3.98 | 11 | 4.11 | 11 | 2  2.96 | 1.2 | 11 |
| HR | 97 | 3  2.58 | 1.2 | 93 | S/N 0.25 | 96 | S/N 0.51 | 93 | 3  2.86 | 1.2 | 93 | S/N 0.51 | 92 | S/N 0.23* | 87 | 3  2.98 | 1.1 | 86 |
| MAP | 69 | 4 | | 67 | | 69 | | 69 | 4 | | 68 | | 69 | | 70 | 4 | | 67 |
| S/D | 105/57 | 5 | | 103/55 | | 103/57 | | 103/57 | 5 | | 102/55 | | 103/56 | | 107/57 | 5 | | 104/54 |
| PA Press | 21 | 6 | | 22 | | 22 | | 21 | 6 | | 22 | | 21 | | 20 | 6 | | 21 |
| PA S/D | 26/18 | 7 | | 27/20 | | 28/20 | | 25/18 | 7 | | 27/20 | | 27/17 | | 26/17 | 7 | | 25/18 |
| Halo. I/E | 11.4 E 1.3 | 8 | | 11.4 E 1.3 | | 11.4 E 1.3 | | 11.4 E 1.3 | 8 | | 11.4 E 1.3 | | 11.4 E 1.3 | | 11.4 E 1.3 | 8 | | 11.4 E 1.3 |
| ET CO2 | 43 | 9 | | 44 | | 44 | | 44 | 9 | | 46 | | 45 | | 45 | 9 | | 45 |
| Hb | 14.1 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 140 | | | | | | | | | | | | | | | | | |
| Time | 4:09 | | | | | | | | | | | | | | | | | 4:41 |
| Li [ ] | 0.18 | | | | | | | | | | | | | | | | | 0.22 |

* peak concentration below recommended level for the device

Not analyzed in chapter 3 (objective 1) – Sensor exclusion

Analyzed in chapter 3 (objective 2)

**Appendix 4.5:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 5**

Date: Oct 12/99    Anesthetic Plane: Start: 10:03  Finish: 10:32 Premed: Butorphanol 0.4 mg/kg IM        LiCla: 0.2mM    LiClb: 0.6mM

Animal # 5    MAP Range: 62 to 64 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 35 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 10:03 | 10:05 | | 10:09 | 10:11 | 10:14 | 10:16 | 10:18 | 10:19 | | 10:22 | 10:23 | 10:25 | 10:27 | 10:29 | 10:30 | | 10:32 |
| Temp (C) | 35.8 | 1 1.87 | 1.2 | 35.7 | 1/3ml | 35.7 | 1 ml | 35.6 | 1 2.06 | 0.9 | 35.5 | 1 ml | 35.5 | 1/3ml | 35.5 | 1 2.22 | 0.8 | 35.4 |
| RR | 9 | 2 2.01 | 0.8 | 9 | 1.85 | 9 | 1.95 | 9 | 2 2.10 | 0.9 | 9 | 2.19 | 9 | 2.24 | 9 | 2 2.34 | 0.8 | 9 |
| HR | 60 | 3 2.01 | 0.9 | 61 | S/N 0.18* | 63 | S/N 0.45 | 64 | 3 2.17 | 0.8 | 64 | S/N 0.45 | 64 | S/N 0.17* | 64 | 3 2.23 | 0.8 | 66 |
| MAP | 63 | 4 | | 63 | | 63 | | 62 | 4 | | 64 | | 63 | | 63 | 4 | | 64 |
| S/D | 82/57 | 5 | | 81/56 | | 81/55 | | 81/55 | 5 | | 84/57 | | 82/56 | | 82/56 | 5 | | 85/57 |
| PA Press | 11 | 6 | | 11 | | 10 | | 11 | 6 | | 11 | | 11 | | 11 | 6 | | 12 |
| PA S/D | 13/7 | 7 | | 15/8 | | 15/9 | | 18/9 | 7 | | 14/7 | | 12/6 | | 14/7 | 7 | | 13/7 |
| Halo. I/E | I 1.4 E 1.2 | 8 | | I 1.4 E 1.2 | | I 1.4 E 1.2 | | I 1.4 E 1.2 | 8 | | I 1.5 E 1.2 | | I 1.4 E 1.2 | | I 1.4 E 1.2 | 8 | | I 1.5 E 1.2 |
| ET CO2 | 40 | 9 | | 41 | | 45 | | 42 | 9 | | 42 | | 43 | | 46 | 9 | | 47 |
| Hb | 15.0 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 147 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 10:02 0.01 | | | | | | | | | | | | | | | | | |

\* peak concentration below recommended level for the device        Analyzed in chapters 2 and 3.

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**Appendix 4.5:    Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 5**

Date: Oct 12/99    Anesthetic Plane: Start: 11:16 Finish: 11:42 Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 5    MAP Range: 85 to 89 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: high – dobutamine

Weight: 35 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor l | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 11:16 | 11:17 | | 11:22 | 11:2 | 11:27 | 11:29 | 11:30 | 11:31 | | 11:33 | 11:35 | 11:36 | 11:38 | 11:39 | 11:40 | | 11:42 |
| Temp (C) | 35.7 | 1 9.42 | 0.45 | 35.6 | 1 ml | 35.7 | 2 ml | 35.7 | 1 9.4 | 0.4 | 35.6 | 1½ml | 35.7 | 2/3ml | 35.7 | 1 9.30 | 0.3 | 35.7 |
| RR | 10 | 2 9.28 | 0.45 | 10 | 9.54 | 10 | 8.95 | 10 | 2 9.26 | 0.3 | 11 | 8.79 | 10 | 8.68 | 10 | 2 9.29 | 0.4 | 11 |
| HR | 125 | 3 9.63 | 0.4 | 135 | S/N 0.37 | 130 | S/N >0.6 | 133 | 3 8.84 | 0.4 | 132 | S/N 0.52 | 129 | S/N 0.25 | 135 | 3 9.64 | 0.3 | 149 |
| MAP | 89 | 4 | | 88 | | 87 | | 88 | 4 | | 86 | | 85 | | 85 | 4 | | 86 |
| S/D | 121/ 69 | 5 | | 118/ 69 | | 116/ 68 | | 118/ 69 | 5 | | 118/ 67 | | 115/ 66 | | 114/ 66 | 5 | | 114/ 68 |
| PA Press | 18 | 6 | | 20 | | 20 | | 20 | 6 | | 20 | | 19 | | 20 | 6 | | 19 |
| PA S/D | 26/10 | 7 | | 25/15 | | 31/16 | | 27/15 | 7 | | 27/16 | | 27/16 | | 28/18 | 7 | | 26/12 |
| Halo. I/E | I 1.8 E 1.0 | 8 | | I 1.8 E 1.1 | | I 1.9 E 1.1 | | I 1.9 E 1.1 | 8 | | I 1.9 E 1.1 | | I 2.0 E 1.1 | | I 1.9 E 1.2 | 8 | | I 2.1 E 1.2 |
| ET CO2 | 46 | 9 | | 47 | | 47 | | 47 | 9 | | 47 | | 47 | | 48 | 9 | | 48 |
| Hb | 19.5 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 151 | | | | | | | | | | | | | | | | | |
| Time Li[ ] | 11:15 0.03 | | | | | | | | | | | | | | | | | |

Not analyzed in chapter 3 (objective 1) – cardiac output > 5 L/min
Analyzed in chapters 2 and 3 (objective 2).

**Appendix 4.5:**   **Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 5**

Date: Oct 12/99     Anesthetic Plane: Start: 12:18  Finish: 12:48  Premed: Butorphanol 0.4 mg/kg IM     LiCla: 0.2mM     LiClb: 0.6mM

Animal # 5     MAP Range: 32 to 36 mmHg     Induction: Thiopental 10 mg/kg IV     Rate of CO: markedly low - occlusion

Weight: 35 kg     Volume of Iced Dextrose Used: 5 ml     Maintenance: Halothane     Li Sensor Constant: 10.5     Cardiac Output Constant: 0.247

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 12:18 | 12:19 | | 12:23 | 12:25 | 12:27 | 12:29 | 12:31 | 12:32 | | 12:36 | 12:38 | 12:40 | 12:41 | 12:44 | 12:45 | | 12:48 |
| Temp (C) | 35.6 | 1  1.26 | 0.65 | 35.5 | 1/3ml | 35.6 | 1 ml | 35.6 | 1  1.43 | 0.5 | 35.5 | 1 ml | 35.5 | 1/3ml | 35.5 | 1  1.42 | 0.6 | 35.4 |
| RR | 10 | 2  1.34 | 0.6 | 10 | ** | 10 | ** | 10 | 2  1.44 | 0.6 | 10 | ** | 10 | ** | 10 | 2  1.39 | 0.6 | 10 |
| HR | 88 | 3  1.40 | 0.6 | 90 | S/N 0.89  0.19* | 92 | 1.17  S/N 0.42 | 94 | 3  1.46 | 0.5 | 95 | 1.25  S/N 0.42 | 96 | 1.30  S/N 0.15* | 96 | 3  1.41 | 0.6 | 96 |
| MAP | 33 | 4 | | 32 | | 33 | | 33 | 4 | | 34 | | 35 | | 34 | 4 | | 36 |
| S/D | 36/31 | 5 | | 35/30 | | 36/31 | | 36/31 | 5 | | 38/32 | | 37/32 | | 37/31 | 5 | | 40/34 |
| PA Press | 8 | 6 | | 10 | | 10 | | 11 | 6 | | 12 | | 13 | | 13 | 6 | | 14 |
| PA S/D | 10/7 | 7 | | 13/8 | | 14/7 | | 16/10 | 7 | | 16/11 | | 17/12 | | 17/12 | 7 | | 15/12 |
| Halo. I/E | I 2.7 E 2.3 | 8 | | I 2.7 E 2.3 | | I 2.7 E 2.3 | | I 2.7 E 2.3 | 8 | | I 2.7 E 2.2 | | I 2.7 E 2.3 | | I 2.8 E 2.2 | 8 | | I 2.8 E 2.2 |
| ET CO2 | 27 | 9 | | 37 | | 36 | | 41 | 9 | | 41 | | 41 | | 42 | 9 | | 44 |
| Hb | 17.2 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 146 | | | | | | | | | | | | | | | | | |
| Time | 12:15 | | | | | | | | | | | | | | | | | 1:15 |
| Li[] | 0.07 | | | | | | | | | | | | | | | | | 0.09 |

* peak concentration below recommended level for the device
** cardiac output below analyzer range, unusual shape of curve, curve too long

Analyzed in chapters 2 and 3.

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**Appendix 4.6:** Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 6

Date: Oct 13/99    Anesthetic Plane: Start: 10:54  Finish: 11:14  Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 6    Induction: Thiopental 10 mg/kg IV    Rate of CO: markedly low - occlusion

Weight: 34.4 kg    MAP Range: 39 to 43 mmHg    Volume of Iced Dextrose Used: 5 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.247

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 10:54 | 10:55 | | 10:57 | 10:58 | 11:00 | 11:02 | 11:04 | 11:05 | | 11:06 | 11:07 | 11:09 | 11:11 | 11:12 | 11:13 | | 11:14 |
| Temp (C) | 36.2 | 1 / 1.39 | 0.8 | 36.1 | 1 ml | 36.1 | 1/3ml | 36.1 | 1 / 1.6 | 0.8 | 36.0 | 1/3ml | 36.0 | 1 ml | 36.0 | 1 / 1.53 | 1.0 | 35.9 |
| RR | 11 | 2 / 1.36 | 1.0 | 11 | 1.35 | 11 | 0.95 | 11 | 2 / 1.55 | 0.8 | 11 | 1.37 | 11 | 1.39 | 11 | 2 / 1.50 | 0.9 | 11 |
| HR | 90 | 3 / 1.36 | 1.0 | 91 | S/N 0.6 | 92 | S/N 0.25 | 88 | 3 / 1.59 | 1.0 | 86 | S/N 0.22* | 88 | S/N 0.6 | 86 | 3 / 1.53 | 0.9 | 83 |
| MAP | 39 | 4 | | 42 | | 43 | | 43 | 4 | | 43 | | 42 | | 41 | 4 | | 42 |
| S/D | 51/34 | 5 | | 57/37 | | 57/38 | | 58/38 | 5 | | 59/38 | | 57/37 | | 56/36 | 5 | | 58/37 |
| PA Press | 8 | 6 | | 8 | | 8 | | 8 | 6 | | 8 | | 8 | | 8 | 6 | | 8 |
| PA S/D | 11/6 | 7 | | 11/6 | | 11/6 | | 11/6 | 7 | | 12/6 | | 12/6 | | 11/6 | 7 | | 12/6 |
| Halo. I/E | I 1.8 E 1.6 | 8 | | I 1.9 E 1.6 | | I 1.9 E 1.6 | | I 1.9 E 1.6 | 8 | | I 1.9 E 1.6 | | I 1.9 E 1.6 | | I 1.9 E 1.6 | 8 | | I 1.9 E 1.6 |
| ET CO2 | 27 | 9 | | 31 | | 32 | | 32 | 9 | | 34 | | 32 | | 34 | 9 | | 33 |
| Hb | 14.0 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 145 | | | | | | | | | | | | | | | | | |
| Time Li [] | 10:45 0.00 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device    Analyzed in chapter 2 and 3.

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**Appendix 4.6:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 6**

Date: Oct 13/99    Anesthetic Plane: Start: 11:41  Finish: 12:10  Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 6    MAP Range: 34 to 37 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: mildly low

Weight: 34.4 kg    Volume of Iced Dextrose Used: 5 ml    Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.247

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 11:41 | 11:42 | | 11:44 | 11:47 | 11:49 | 11:51 | 11:53 | 11:54 | | 11:59 | 12:01 | 12:03 | 12:05 | 12:06 | 12:07 | | 12:10 |
| Temp (C) | 35.8 | 1 / 1.38 | 0.7 | 35.7 | 1 ml | 35.6 | ½ ml | 35.6 | 1 / 1.21 | 0.5 | 35.5 | ½ ml | 35.5 | 1 ml | 35.5 | 1 / 1.11 | 0.5 | 35.5 |
| RR | 11 | 2 / 1.29 | 0.7 | 11 | ** / 1.30 | 11 | ** / 1.18 | 11 | 2 / 1.14 | 0.5 | 11 | ** / 1.33 | 11 | ** / 1.19 | 11 | 2 / 1.11 | 0.5 | 11 |
| HR | 70 | 3 / 1.27 | 0.7 | 72 | S/N 0.4 | 75 | S/N 0.22* | 77 | 3 / 1.03 | 0.6 | 79 | S/N 0.22* | 79 | S/N 0.4 | 79 | 3 / 1.12 | 0.5 | 80 |
| MAP | 37 | 4 | | 35 | | 35 | | 34 | 4 / 1.16 | 0.5 | 33 | | 34 | | 34 | 4 | | 33 |
| S/D | 54/32 | 5 | | 49/31 | | 48/30 | | 45/30 | 5 / 1.14 | 0.5 | 45/30 | | 45/30 | | 45/30 | 5 | | 45/29 |
| PA Press | 12 | 6 | | 12 | | 12 | | 12 | 6 / 1.15 | 0.5 | 12 | | 12 | | 13 | 6 | | 12 |
| PA S/D | 15/9 | 7 | | 15/10 | | 15/10 | | 15/10 | 7 | | 16/10 | | 16/10 | | 16/10 | 7 | | 16/10 |
| Halo. I/E | I 2.7 E 2.3 | 8 | | I 2.8 E 2.3 | | I 2.8 E 2.3 | | I 2.8 E 2.3 | 8 | | I 2.9 E 2.3 | | I 2.8 E 2.3 | | I 2.9 E 2.3 | 8 | | I 2.9 E 2.4 |
| ET CO2 | 32 | 9 | | 35 | | 35 | | 34 | 9 | | 37 | | 37 | | 37 | 9 | | 35 |
| Hb | 13.4 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 143 | | | | | | | | | | | | | | | | | |
| Time | 11:40 | | | | | | | | | | | | | | | | | |
| Li[] | 0.04 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

** curve too long and unusually shape curve

Analyzed in chapter 2 and 3.

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**Appendix 4.6:** **Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 6**

Date: Oct 13/99  Anesthetic Plane: Start: 12:31  Finish: 12:56  Premed: Butorphanol 0.4 mg/kg IM  LiCla: 0.6mM  LiClb: 0.2mM

Animal # 6  MAP Range: 59 to 76 mmHg  Induction: Thiopental 10 mg/kg IV  Rate of CO: high – dobutamine

Weight: 34.4 kg  Volume of Iced Dextrose Used: 10 ml  Maintenance: Halothane  Li Sensor Constant: 10.5  Cardiac Output Constant: 0.542

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 12:31 | 12:32 | | 12:34 | 12:42 | 12:44 | 12:45 | 12:46 | 12:47 | | 12:48 | 12:50 | 12:51 | 12:52 | 12:54 | 12:55 | | 12:56 |
| Temp (C) | 35.5 | 1 / 4.57 | 0.8 | 35.5 | 2 ml | 35.5 | ½ ml | 35.5 | 1 / 4.70 | 0.9 | 35.4 | ½ ml | 35.4 | 1½ ml | 35.4 | 1 / 4.79 | 0.8 | 35.3 |
| RR | 11 | 2 / 4.47 | 0.8 | 11 | 4.91 | 11 | 4.58 | 11 | 2 / 4.47 | 0.9 | 11 | 5.20 | 11 | 5.62 | 11 | 2 / 4.85 | 0.7 | 11 |
| HR | 74 | 3 / 4.46 | 0.8 | 72 | S/N >0.6# | 74 | S/N 0.25 | 75 | 3 / 4.66 | 0.8 | 74 | S/N 0.22* | 74 | S/N 0.7 | 75 | 3 / 4.70 | 0.7 | 75 |
| MAP | 76 | 4 | | 67 | | 64 | | 63 | 4 | | 60 | | 59 | | 62 | 4 | | 60 |
| S/D | 102/63 | 5 | | 112/51 | | 109/48 | | 109/47 | 5 | | 106/45 | | 103/45 | | 107/47 | 5 | | 104/46 |
| PA Press | 16 | 6 | | 16 | | 15 | | 15 | 6 | | 16 | | 16 | | 16 | 6 | | 16 |
| PA S/D | 26/11 | 7 | | 26/11 | | 24/11 | | 24/11 | 7 | | 24/11 | | 24/11 | | 24/11 | 7 | | 24/11 |
| Halo. I/E | I 1.9 E 1.6 | 8 | | I 1.9 E 1.6 | | I 1.9 E 1.5 | | I 1.8 E 1.6 | 8 | | I 1.8 E 1.7 | | I 1.9 E 1.5 | | I 1.9 E 1.5 | 8 | | I 1.9 E 1.6 |
| ET CO2 | 41 | 9 | | 44 | | 42 | | 44 | 9 | | 45 | | 44 | | 44 | 9 | | 44 |
| Hb | 17.4 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 144 | | | | | | | | | | | | | | | | | |
| Time Li [] | 12:30 / 0.06 | | | | | | | | | | | | | | | | | |

\* peak concentration below recommended level for the device
# peak concentration above recommended level for the device

Not analyzed in chapter 3 (objective 1) – cardiac output > 5 L/min
Analyzed in chapter 2 and 3 (objective 2).

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**Appendix 4.6: Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 6**

Date: Oct 13/99   Anesthetic Plane: Start: 1:15  Finish: 1:37   Premed: Butorphanol 0.4 mg/kg IM   LiCla: 0.6mM   LiClb: 0.2mM

Animal # 6   MAP Range: 48 to 55 mmHg   Induction: Thiopental 10 mg/kg IV   Rate of CO: normal

Weight: 34.4 kg   Volume of Iced Dextrose Used: 10 ml   Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1:15 | 1:16 | | 1:18 | 1:21 | 1:23 | 1:25 | 1:26 | 1:27 | | 1:29 | 1:30 | 1:31 | 1:33 | 1:34 | 1:35 | | 1:37 |
| Temp (C) | 35.2 | 1 / 3.01 | 1.0 | 35.0 | 1 ml | 35.0 | ½ ml | 35.0 | 1 / 3.06 | 1.0 | 35.0 | ½ ml | 35.0 | 1½ml | 35.0 | 1 / 3.11 | 1.2 | 34.8 |
| RR | 11 | 2 / 2.81 | 1.0 | 11 | 2.94 | 11 | 2.92 | 11 | 2 / 2.81 | 1.0 | 11 | 3.40 | 11 | 3.46 | 11 | 2 / 2.88 | 1.2 | 11 |
| HR | 65 | 3 / 2.93 | 1.0 | 64 | S/N 0.4 | 67 | S/N 0.23* | 68 | 3 / 2.76 | 1.2 | 68 | S/N 0.21* | 70 | S/N 0.6 | 69 | 3 / 2.90 | 1.2 | 69 |
| MAP | 55 | 4 | | 50 | | 50 | | 50 | 4 | | 49 | | 49 | | 50 | 4 | | 48 |
| S/D | 84/45 | 5 | | 77/40 | | 76/41 | | 77/42 | 5 | | 75/40 | | 76/40 | | 77/42 | 5 | | 74/40 |
| PA Press | 12 | 6 | | 13 | | 12 | | 12 | 6 | | 12 | | 12 | | 12 | 6 | | 12 |
| PA S/D | 18/10 | 7 | | 18/10 | | 18/10 | | 17/10 | 7 | | 18/10 | | 17/10 | | 17/10 | 7 | | 17/10 |
| Halo. I/E | I 1.7 E 1.5 | 8 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | 8 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | 8 | | I 1.7 E 1.5 |
| ET CO2 | 36 | 9 | | 40 | | 39 | | 38 | 9 | | 40 | | 40 | | 39 | 9 | | 41 |
| Hb | 14.9 | 10 | | | | | | | | | | | | | | 10 | | |
| Na++ | 144 | | | | | | | | | | | | | | | | | |
| Time Li[ ] | 1:14 / 0.10 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device        Analyzed in chapters 2 and 3.

**Appendix 4.6:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 6**

Date: Oct 13/99      Anesthetic Plane: Start: 1:47  Finish: 2:15      Premed: Butorphanol 0.4 mg/kg IM      LiCla: 0.2mM    LiClb: 0.6mM

Animal # 6      MAP Range: 47 to 50 mmHg      Induction: Thiopental 10 mg/kg IV      Rate of CO: normal

Weight: 34.4 kg      Volume of Iced Dextrose Used: 10 ml      Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 3 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1:47 | 1:48 | | 1:52 | 1:55 | 1:56 | 1:58 | 2:00 | 2:01 | | 2:02 | 2:04 | 2:08 | 2:11 | 2:12 | 2:13 | | 2:15 |
| Temp (C) | 34.9 | 1 / 2.56 | 1.1 | 34.8 | ½ ml | 34.8 | 1½ml | 34.8 | 1 / 2.93 | 1.2 | 34.7 | 1½ml | 34.7 | ½ ml | 34.7 | 1 / 3.03 | 1.0 | 34.6 |
| RR | 11 | 2 / 2.55 | 1.1 | 11 | 2.79 | 11 | 2.86 | 11 | 2 / 2.76 | 1.2 | 11 | NR** | 11 | 2.94 | 11 | 2 / 2.85 | 1.0 | 11 |
| HR | 65 | 3 / 2.49 | 1.1 | 67 | S/N 0.23* | 67 | S/N 0.65 | 69 | 3 / 2.77 | 1.2 | 68 | S/N 0.6 | 69 | S/N 0.2* | 68 | 3 / 2.81 | 1.0 | 68 |
| MAP | 49 | 4 | | 47 | | 49 | | 50 | 4 | | 48 | | 48 | | 49 | 4 | | 48 |
| S/D | 75/41 | 5 | | 72/38 | | 75/41 | | 76/41 | 5 | | 74/39 | 2:07 | 74/39 | | 75/41 | 5 | | 72/39 |
| PA Press | 12 | 6 | | 12 | | 12 | | 12 | 6 | | 12 | | 12 | | 12 | 6 | | 12 |
| PA S/D | 17/9 | 7 | | 17/9 | | 17/9 | | 17/10 | 7 | | 17/10 | 3.15 | 17/10 | | 17/9 | 7 | | 17/10 |
| Halo. I/E | I 1.7 E 1.5 | 8 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | 8 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | 8 | | I 1.7 E 1.5 |
| ET CO2 | 36 | 9 | | 37 | | 37 | | 38 | 9 | | 39 | | 39 | | 39 | 9 | | 39 |
| Hb | 13.7 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 143 | | | | | | | | | | | | | | | | | |
| Time | 1:39 | | | | | | | | | | | | | | | | | |
| Li [ ] | 0.16 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device
** battery ran out and the test was repeated

Analyzed in chapter 3.

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**Appendix 4.6:** **Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 6**

Date: Oct 13/99    Anesthetic Plane: Start: 2:22 Finish: 2:46    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 6    MAP Range: 46 to 49 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 34.4 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 3 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:22 | 2:23 | | 2:25 | 2:27 | 2:29 | 2:31 | 2:32 | 2:33 | | 2:37 | 2:39 | 2:40 | 2:42 | 2:43 | 2:44 | | 2:46 |
| Temp (C) | 34.6 | 1 | | 34.5 | ½ ml | 34.5 | 1½ml | 34.5 | 1 | | 34.3 | 1½ml | 34.4 | ½ ml | 34.4 | 1 | | 34.3 |
| RR | 11 | 2 2.42 | 1.0 | 11 | 2.57 | 11 | 2.83 | 11 | 2 2.85 | 1.0 | 11 | 3.28 | 11 | 3.03 | 11 | 2 2.93 | 1.1 | 11 |
| HR | 63 | 3 2.32 | 1.1 | 64 | S/N 0.2* | 66 | S/N 0.57 | 67 | 3 2.69 | 1.1 | 68 | S/N 0.55 | 69 | S/N 0.2* | 69 | 3 3.01 | 1.0 | 68 |
| MAP | 49 | 4 | | 47 | | 48 | | 48 | 4 3.00 | 1.0 | 46 | | 46 | | 48 | 4 | | 46 |
| S/D | 76/40 | 5 | | 73/39 | | 74/39 | | 73/39 | 5 2.90 | 1.0 | 69/37 | | 72/38 | | 73/39 | 5 | | 70/38 |
| PA Press | 12 | 6 | | 12 | | 12 | | 12 | 6 2.87 | 1.2 | 13 | | 13 | | 12 | 6 | | 13 |
| PA S/D | 17/9 | 7 | | 17/10 | | 17/10 | | 18/10 | 7 | | 17/10 | | 17/10 | | 17/10 | 7 | | 18/10 |
| Halo. I/E | 1 1.7 E 1.5 | 8 | | 1 1.7 E 1.6 | | 1 1.7 E 1.5 | | 1 1.6 E 1.5 | 8 | | 1 1.7 E 1.5 | | 1 1.6 E 1.5 | | 1 1.7 E 1.5 | 8 | | 1 1.7 E 1.5 |
| ET CO2 | 35 | 9 | | 37 | | 37 | | 39 | 9 | | 40 | | 39 | | 37 | 9 | | 40 |
| Hb | 12.6 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 141 | | | | | | | | | | | | | | | | | |
| Time / Li[] | 2:17 0.22 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

Not analyzed in chapter 3 (objective 1) – Hemodynamic stability

Analyzed in chapter 3 (objective 2)

**Appendix 4.6:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 6**

Date: Oct 13/99    Anesthetic Plane: Start: 2:54  Finish: 3:24    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 6    MAP Range: 45 to 49 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 34.4 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 4 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:54 | 2:55 | | 2:57 | 3:00 | 3:03 | 3:04 | 3:05 | 3:06 | | 3:09 | 3:13 | 3:16 | 3:18 | 3:20 | 3:21 | | 3:24 |
| Temp (C) | 34.3 | 1 / 2.72 | 1.0 | 34.2 | 1½ml | 34.2 | ½ml | 34.2 | 1 / 2.93 | 1.0 | 34.1 | ½ml | 34.1 | 1½ml | 34.1 | 1 / 3.12 | 1.0 | 34.0 |
| RR | 11 | 2 / 2.75 | 1.0 | 11 | 2.85 | 11 | 2.67 | 11 | 2 / 2.80 | 1.0 | 11 | 2.56 | 11 | 2.99 | 11 | 2 / 3.02 | 1.0 | 11 |
| HR | 64 | 3 / 2.65 | 1.0 | 63 | S/N 0.5 | 66 | S/N 0.2* | 66 | 3 / 2.93 | 1.0 | 66 | S/N 0.2* | 66 | S/N 0.5 | 65 | 3 / 2.95 | 1.0 | 66 |
| MAP | 49 | 4 | | 45 | | 48 | | 48 | 4 | | 47 | | 49 | | 48 | 4 | | 48 |
| S/D | 76/40 | 5 | | 70/37 | | 80/37 | | 73/40 | 5 | | 71/38 | | 75/41 | | 74/40 | 5 | | 73/39 |
| PA Press | 12 | 6 | | 12 | | 12 | | 13 | 6 | | 13 | | 12 | | 12 | 6 | | 12 |
| PA S/D | 17/10 | 7 | | 17/10 | | 17/10 | | 17/11 | 7 | | 17/11 | | 17/10 | | 17/9 | 7 | | 17/10 |
| Halo. I/E | I 1.7 E 1.5 | 8 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | 8 | | I 1.7 E 1.5 | | I 1.7 E 1.4 | | I 1.6 E 1.4 | 8 | | I 1.6 E 1.4 |
| ET CO2 | 35 | 9 | | 36 | | 37 | | 37 | 9 | | 37 | | 35 | | 36 | 9 | | 34 |
| Hb | 12.1 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 140 | | | | | | | | | | | | | | | | | |
| Time | 2:48 | | | | | | | | | | | | | | | | | |
| Li [ ] | 0.25 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device                    Analyzed in chapter 3.

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**Appendix 4.6:    Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 6**

Date: Oct 13/99    Anesthetic Plane: Start: 3:29 Finish: 3:57    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 6    MAP Range: 46 to 51 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 34.4 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 4 | CV Status | TD | TD S/N | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:29 | 3:31 | | 3:35 | 3:37 | 3:41 | 3:42 | 3:42 | | 3:45 | 3:47 | 3:48 | 3:52 | 3:54 | 3:55 | | 3:57 |
| Temp (C) | 34.0 | 1 / 2.58 | 1.0 | 1½ml | 33.9 | ½ml | 33.9 | 1 / 3.60 | 1.1 | 33.8 | ½ml | 33.9 | 1½ml | 33.9 | 1 / 3.55 | 1.0 | 33.8 |
| RR | 11 | 2 / 2.35 | 1.0 | ** 2.47 | 11 | 3.49 | 11 | 2 / 3.47 | 0.9 | 11 | 3.51 | 11 | *** NR | 11 | 2 / 3.44 | 0.9 | 11 |
| HR | 60 | 3 / 2.47 | 1.0 | S/N 0.5 | 61 | S/N 0.18* | 72 | 3 / 3.57 | 0.9 | 72 | S/N 0.18* | 72 | S/N 0.45 | 71 | 3 / 3.46 | 0.9 | 70 |
| MAP | 51 | 4 | | | 46 | | 46 | 4 | | 47 | | 49 | | 49 | 4 | | 48 |
| S/D | 79/42 | 5 | | 3:38 | 71/38 | | 71/38 | 5 | | 71/38 | | 74/39 | 3:53 | 74/39 | 5 | | 73/38 |
| PA Press | 12 | 6 | | 1½ml | 12 | | 12 | 6 | | 13 | | 13 | 1½ml | 13 | 6 | | 13 |
| PA S/D | 17/9 | 7 | | 3.42 | 17/10 | | 17/9 | 7 | | 18/10 | | 18/10 | 3.71 | 17/10 | 7 | | 17/10 |
| Halo. I/E | I 1.6 E 1.4 | 8 | | S/N 0.5 | I 1.5 E 1.4 | | I 1.5 E 1.4 | 8 | | I 1.6 E 1.4 | | I 1.6 E 1.4 | S/N 0.45 | I 1.6 E 1.4 | 8 | | I 1.6 E 1.4 |
| ET CO2 | 31 | 9 | | | 35 | | 35 | 9 | | 36 | | 36 | | 35 | 9 | | 36 |
| Hb | 12.3 | 10 | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 139 | | | | | | | | | | | | | | | | |
| Time Li [] | 3:26 0.27 | | | | | | | | | | | | | | | | |

\* peak concentration below recommended level for the device

\** sensor voltage fluxed, thus repeated    \*** battery stopped, thus repeated

Not analyzed in chapter 3 (objective 1) – Hemodynamic stability

Analyzed in chapter 3 (objective 2)

**Appendix 4.6:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 6**

Date: Oct 13/99     Anesthetic Plane: Start: 4:06  Finish: 4:32     Premed: Butorphanol 0.4 mg/kg IM

Animal # 6          MAP Range: 48 to 51 mmHg     Induction: Thiopental 10 mg/kg IV

LiCla: 0.2mM     LiClb: 0.6mM     Rate of CO: normal

Weight: 34.4 kg     Volume of Iced Dextrose Used: 10 ml     Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 5 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 4:06 | 4:07 | | 4:08 | 4:15 | 4:18 | 4:20 | 4:22 | 4:23 | | 4:24 | 4:26 | 4:27 | 4:29 | 4:30 | 4:31 | | 4:32 |
| Temp (C) | 33.8 | 1  2.94 | 1.0 | 33.7 | ½ ml | 33.7 | 1½ml | 33.7 | 1  3.15 | 1.1 | 33.6 | 1½ml | 33.7 | ½ ml | 33.7 | 1  3.24 | 1.0 | 33.6 |
| RR | 11 | 2  2.89 | 1.0 | 11 | 3.18 | 11 | 2.95 | 10 | 2  2.91 | 1.1 | 11 | 3.42 | 11 | 3.18 | 11 | 2  2.99 | 1.2 | 11 |
| HR | 62 | 3  2.80 | 1.0 | 62 | S/N 0.2* | 63 | S/N 0.55 | 63 | 3  3.03 | 1.1 | 64 | S/N 0.52 | 66 | S/N 0.2* | 65 | 3  3.15 | 1.2 | 64 |
| MAP | 51 | 4 | | 48 | | 50 | | 48 | 4 | | 48 | | 49 | | 49 | 4 | | 48 |
| S/D | 77/42 | 5 | | 74/39 | | 76/40 | | 73/39 | 5 | | 73/39 | | 74/40 | | 75/40 | 5 | | 73/39 |
| PA Press | 12 | 6 | | 13 | | 12 | | 12 | 6 | | 12 | | 12 | | 12 | 6 | | 13 |
| PA S/D | 17/10 | 7 | | 18/10 | | 17/9 | | 18/9 | 7 | | 17/10 | | 17/9 | | 17/9 | 7 | | 17/10 |
| Halo. I/E | I 1.6 / E 1.4 | 8 | | I 1.6 / E 1.4 | | I 1.6 / E 1.4 | | I 1.6 / E 1.4 | 8 | | I 1.6 / E 1.5 | | I 1.6 / E 1.4 | | I 1.6 / E 1.4 | 8 | | I 1.6 / E 1.4 |
| ET CO2 | 32 | 9 | | 35 | | 36 | | 34 | 9 | | 36 | | 35 | | 34 | 9 | | 36 |
| Hb | 11.9 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 137 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 4:00 NR | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device                    Analyzed in chapter 3

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**Appendix 4.6:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 6**

Date: Oct 13/99        Anesthetic Plane: Start: 4:37  Finish: 5:02    Premed: Butorphanol 0.4 mg/kg IM        LiCla: 0.6mM    LiClb: 0.2mM

Animal # 6             MAP Range: 48 to 51 mmHg        Induction: Thiopental 10 mg/kg IV        Rate of CO: normal

Weight: 34.4 kg        Volume of Iced Dextrose Used: 10 ml        Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 5 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 4:37 | 4:38 | | 4:43 | 4:44 | 4:46 | 4:48 | 4:50 | 4:51 | | 4:52 | 4:53 | 4:56 | 4:57 | 4:58 | 5:00 | | 5:02 |
| Temp (C) | 33.6 | 1 2.87 | 1.1 | 33.5 | 1½ml | 33.6 | ½ ml | 33.5 | 1 3.06 | 1.1 | 33.5 | ½ ml | 33.5 | 1½ml | 33.5 | 1 3.31 | 1.0 | 33.4 |
| RR | 10 | 2 2.71 | 1.1 | 11 | 3.03 | 11 | 2.87 | 11 | 2 2.93 | 1.1 | 11 | ** NR | 11 | 3.27 | 11 | 2 3.00 | 1.0 | 11 |
| HR | 63 | 3 2.87 | 1.0 | 63 | S/N 0.52 | 61 | S/N 0.19* | 61 | 3 2.92 | 1.1 | 61 | S/N | 63 | S/N 0.51 | 63 | 3 3.00 | 1.0 | 62 |
| MAP | 51 | 4 | | 48 | | 49 | | 49 | 4 | | 48 | | 48 | | 49 | 4 3.26 | 1.1 | 48 |
| S/D | 78/42 | 5 | | 74/39 | | 75/40 | | 75/40 | 5 | | 74/40 | | 73/39 | | 75/40 | 5 | | 74/40 |
| PA Press | 12 | 6 | | 13 | | 12 | | 12 | 6 | | 12 | | 12 | | 12 | 6 | | 13 |
| PA S/D | 17/10 | 7 | | 17/11 | | 17/10 | | 18/9 | 7 | | 17/10 | | 17/9 | | 17/9 | 7 | | 18/10 |
| Halo. I/E | 1 1.6 E 1.4 | 8 | | 1 1.6 E 1.4 | | 1 1.6 E 1.4 | | 1 1.6 E 1.4 | 8 | | 1 1.6 E 1.4 | | 1 1.6 E 1.4 | | 1 1.6 E 1.4 | 8 | | 1 1.6 E 1.5 |
| ET CO2 | 32 | 9 | | 34 | | 34 | | 34 | 9 | | 35 | | 34 | | 35 | 9 | | 34 |
| Hb | 11.7 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 137 | | | | | | | | | | | | | | | | | |
| Time | 4:34 | | | | | | | | | | | | | | | | | 5:03 |
| Li [ ] | 0.37 | | | | | | | | | | | | | | | | | 0.40 |

\* peak concentration below recommended level for the device
\*\* battery stopped – no LiCl was given

Analyzed in chapter 3

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## Appendix 4.7: Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 7

Date: Oct 19/99   Anesthetic Plane: Start: 11:02 Finish: 11:27 Premed: Butorphanol 0.4 mg/kg IM   LiCla: 0.6mM   LiClb: 0.2mM

Animal # 7   MAP Range: 64 to 68 mmHg   Induction: Thiopental 10 mg/kg IV   Rate of CO: high - dobutamine

Weight: 36.8 kg   Volume of Iced Dextrose Used: 10 ml   Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 11:02 | 11:03 |  | 11:05 | 11:12 | 11:13 | 11:15 | 11:16 | 11:17 |  | 11:19 | 11:21 | 11:22 | 11:24 | 11:25 | 11:26 |  | 11:27 |
| Temp (C) | 34.4 | 1 / 7.43 | 0.5 | 34.3 | 1½ ml | 34.3 | ½ ml | 34.2 | 1 / 7.94 | 0.45 | 34.1 | ½ ml | 34.1 | 1½ ml | 34.1 | 1 / 7.95 | 0.4 | 34.0 |
| RR | 10 | 2 / 7.09 | 0.51 | 10 | 7.21 | 10 | 6.45 | 10 | 2 / 7.64 | 0.5 | 10 | 7.00 | 10 | 7.41 | 10 | 2 / 7.75 | 0.48 | 10 |
| HR | 82 | 3 / 7.08 | 0.55 | 84 | S/N 0.45 | 85 | S/N 0.15* | 83 | 3 / 7.54 | 0.49 | 84 | S/N 0.15* | 84 | S/N 0.4 | 85 | 3 / 7.89 | 0.45 | 85 |
| MAP | 64 | 4 |  | 65 |  | 64 |  | 67 | 4 |  | 67 |  | 67 |  | 68 | 4 |  | 68 |
| S/D | 112/47 | 5 |  | 114/47 |  | 115/47 |  | 121/49 | 5 |  | 122/49 |  | 122/49 |  | 124/49 | 5 |  | 124/49 |
| PA Press | 21 | 6 |  | 23 |  | 20 |  | 20 | 6 |  | 16 |  | 15 |  | 15 | 6 |  | 16 |
| PA S/D | 24/20 | 7 |  | 26/17 |  | 21/20 |  | 20/19 | 7 |  | 17/14 |  | 16/13 |  | 16/13 | 7 |  | 17/13 |
| Halo. I/E | I 2.2 E 1.7 | 8 |  | I 2.1 E 1.8 |  | I 2.1 E 1.7 |  | I 2.2 E 1.7 | 8 |  | I 2.2 E 1.7 |  | I 2.2 E 1.7 |  | I 2.2 E 1.7 | 8 |  | I 2.2 E 1.6 |
| ET CO2 | 30 | 9 |  | 31 |  | 30 |  | 31 | 9 |  | 32 |  | 32 |  | 32 | 9 |  | 32 |
| Hb | 17.3 | 10 |  |  |  |  |  |  | 10 |  |  |  |  |  |  | 10 |  |  |
| Na++ | 147 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Time Li [ ] | 11:00 0.00 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

* peak concentration below recommended level for the device

Not analyzed in chapter 3 (objective 1) – cardiac output > 5 L/min

Analyzed in chapters 2 and 3 (objective 2)

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**Appendix 4.7:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 7**

Date: Oct 19/99    Anesthetic Plane: Start: 12:00  Finish: 12:30  Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 7    MAP Range: 37 to 42 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: markedly low - occlusion

Weight: 36.8 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 12:00 | 12:02 | | 12:06 | 12:08 | 12:09 | 12:12 | 12:14 | 12:15 | | 12:18 | 12:20 | 12:21 | 12:24 | 12:26 | 12:28 | | 12:30 |
| Temp (C) | 33.8 | 1 1.46 | 0.85 | 33.6 | 1/3ml | 33.7 | 1 ml | 33.7 | 1 1.44 | 0.75 | 33.5 | 1 ml | 33.6 | 1/3ml | 33.6 | 1 1.51 | 0.65 | 33.4 |
| RR | 10 | 2 1.53 | 0.85 | 10 | ** 0.98 | 10 | ** 1.22 | 10 | 2 1.45 | 0.75 | 10 | ** 1.27 | 10 | ** 1.13 | 10 | 2 1.53 | 0.55 | 10 |
| HR | 84 | 3 1.48 | 0.9 | 82 | S/N 0.21* | 83 | S/N 0.5 | 83 | 3 1.51 | 0.7 | 80 | S/N 0.45 | 80 | S/N 0.18* | 80 | 3 1.62 | 0.6 | 78 |
| MAP | 42 | 4 | | 41 | | 39 | | 38 | 4 | | 39 | | 37 | | 38 | 4 | | 41 |
| S/D | 58/38 | 5 | | 57/37 | | 53/35 | | 52/34 | 5 | | 54/35 | | 52/33 | | 53/34 | 5 | | 58/36 |
| PA Press | 7 | 6 | | 9 | | 8 | | 9 | 6 | | 9 | | 8 | | 8 | 6 | | 8 |
| PA S/D | 8/6 | 7 | | 9/7 | | 8/7 | | 10/8 | 7 | | 10/8 | | 9/7 | | 8/6 | 7 | | 9/7 |
| Halo. I/E | I 2.0 E 1.9 | 8 | | I 2.3 E 2.1 | | I 2.3 E 2.1 | | I 2.2 E 2.1 | 8 | | I 2.2 E 2.1 | | I 2.2 E 2.1 | | I 2.3 E 2.1 | 8 | | I 2.3 E 2.1 |
| ET CO2 | 21 | 9 | | 21 | | 21 | | 21 | 9 | | 24 | | 24 | | 24 | 9 | | 24 |
| Hb | 15.5 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 143 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 11:52 0.02 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device
** curve too long

Analyzed in chapters 2 and 3.

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**Appendix 4.7:    Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 7**

Date: Oct 19/99      Anesthetic Plane: Start: 1:25  Finish: 1:50      Premed: Butorphanol 0.4 mg/kg IM      LiCla: 0.6mM    LiClb: 0.2mM

Animal # 7      MAP Range: 69 to 70 mmHg      Induction: Thiopental 10 mg/kg IV      Rate of CO: normal

Weight: 36.8 kg      Volume of Iced Dextrose Used: 10 ml      Maintenance: Halothane   Li Sensor Constant: 10.5      Cardiac Output Constant: 0.542

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1:25 | 1:26 | | 1:31 | 1:33 | 1:35 | 1:37 | 1:38 | 1:39 | | 1:41 | 1:43 | 1:45 | 1:47 | 1:48 | 1:49 | | 1:50 |
| Temp (C) | 32.9 | 1  2.52 | 0.7 | 32.7 | 1½ml | 32.7 | ½ ml | 32.7 | 1  3.10 | 0.6 | 32.6 | ½ ml | 32.6 | 1½ml | 32.6 | 1  3.31 | 0.55 | 32.5 |
| RR | 10 | 2  2.53 | 0.65 | 10 | 2.74 | 10 | 2.92 | 10 | 2  3.05 | 0.6 | 10 | 3.02 | 10 | 3.13 | 10 | 2  3.25 | 0.5 | 10 |
| HR | 75 | 3  2.84 | 0.6 | 71 | S/N >0.6 | 69 | S/N 0.2 * | 69 | 3  3.09 | 0.55 | 68 | S/N 0.2 * | 67 | S/N 0.6 | 66 | 3  3.15 | 0.5 | 65 |
| MAP | 69 | 4  2.66 | 0.7 | 69 | | 69 | | 70 | 4 | | 69 | | 70 | | 70 | 4 | | 70 |
| S/D | 97/58 | 5  2.82 | 0.6 | 99/57 | | 100/56 | | 101/57 | 5 | | 102/56 | | 103/57 | | 104/57 | 5 | | 105/56 |
| PA Press | 15 | 6 | | 16 | | 16 | | 16 | 6 | | 16 | | 16 | | 16 | 6 | | 15 |
| PA S/D | 15/12 | 7 | | 16/14 | | 16/13 | | 17/15 | 7 | | 17/13 | | 16/14 | | 17/15 | 7 | | 16/12 |
| Halo. I/E | I 1.4 E 1.5 | 8 | | I 1.4 E 1.4 | | I 1.4 E 1.4 | | I 1.4 E 1.4 | 8 | | I 1.4 E 1.4 | | I 1.4 E 1.4 | | I 1.4 E 1.4 | 8 | | I 1.3 E 1.3 |
| ET CO2 | 25 | 9 | | 26 | | 26 | | 26 | 9 | | 26 | | 26 | | 26 | 9 | | 28 |
| Hb | 13.7 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 144 | | | | | | | | | | | | | | | | | |
| Time Li[ ] | 1:10  0.06 | | | | | | | | | | | | | | | | | |

\* peak concentration below recommended level for the device                  Analyzed in chapters 2 and 3.

Appendix 4.7:     Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 7

Date: Oct 19/99     Anesthetic Plane: Start: 2:11  Finish: 2:38     Premed: Butorphanol 0.4 mg/kg IM     LiCla: 0.6mM     LiClb: 0.2mM

Animal # 7     MAP Range: 47 to 60 mmHg     Induction: Thiopental 10 mg/kg IV     Rate of CO: mildly low

Weight: 36.8 kg     Volume of Iced Dextrose Used: 10 ml     Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:11 | 2:12 |  | 2:16 | 2:19 | 2:20 | 2:22 | 2:25 | 2:26 |  | 2:28 | 2:30 | 2:31 | 2:33 | 2:34 | 2:36 |  | 2:38 |
| Temp (C) | 32.7 | 1 / 2.10 | 0.65 | 32.6 | 1½ml | 32.6 | ½ml | 32.7 | 1 / 1.91 | 0.6 | 32.6 | ½ ml | 32.6 | 1½ml | 32.6 | 1 / 1.77 | 0.7 | 32.6 |
| RR | 10 | 2 / 2.09 | 0.65 | 10 | ** / 1.85 | 10 | ** / 1.83 | 10 | 2 / 1.83 | 0.6 | 10 | ** / 1.69 | 10 | ** / 1.84 | 10 | 2 / 1.78 | 0.65 | 10 |
| HR | 74 | 3 / 2.09 | 0.65 | 72 | S/N / 0.6 | 72 | S/N / 0.2 * | 72 | 3 / 1.85 | 0.65 | 71 | S/N / 0.2 * | 71 | S/N / 0.6 | 71 | 3 / 1.76 | 0.6 | 71 |
| MAP | 60 | 4 |  | 55 |  | 53 |  | 52 | 4 |  | 49 |  | 50 |  | 47 | 4 |  | 47 |
| S/D | 75/53 | 5 |  | 79/49 |  | 78/45 |  | 77/44 | 5 |  | 74/42 |  | 73/42 |  | 64/41 | 5 |  | 70/40 |
| PA Press | 14 | 6 |  | 13 |  | 13 |  | 13 | 6 |  | 12 |  | 13 |  | 13 | 6 |  | 14 |
| PA S/D | 15/12 | 7 |  | 13/11 |  | 15/11 |  | 15/12 | 7 |  | 13/10 |  | 15/11 |  | 15/11 | 7 |  | 15/13 |
| Halo. I/E | I 2.2 / E 2.0 | 8 |  | I 2.3 / E 2.0 |  | I 2.3 / E 2.1 |  | I 2.3 / E 2.1 | 8 |  | I 2.3 / E 2.1 |  | I 2.3 / E 2.1 |  | I 2.3 / E 2.1 | 8 |  | I 2.2 / E 2.1 |
| ET CO2 | 21 | 9 |  | 23 |  | 22 |  | 22 | 9 |  | 23 |  | 24 |  | 25 | 9 |  | 25 |
| Hb | 13.3 | 10 |  |  |  |  |  |  | 10 |  |  |  |  |  |  | 10 |  |  |
| Na++ | 141 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Time | 2:10 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Li [ ] | 0.10 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

* peak concentration below recommended level for the device
** curve too long

Analyzed in chapters 2 and 3.

**Appendix 4.7:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 7**

Date: Oct 19/99    Anesthetic Plane: Start: 3:01  Finish: 3:25    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 7    MAP Range: 61 to 70 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 36.8 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 3 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:01 | 3:02 | | 3:04 | 3:06 | 3:07 | 3:09 | 3:10 | 3:11 | | 3:14 | 3:15 | 3:16 | 3:18 | 3:22 | 3:23 | | 3:25 |
| Temp (C) | 32.7 | 1 2.40 | 0.6 | 32.6 | 1½ml | 32.6 | ½ ml | 32.6 | 1 2.63 | 0.65 | 32.6 | ½ ml | 32.6 | 1½ml | 32.6 | 1 2.78 | 0.65 | 32.5 |
| RR | 10 | 2 2.37 | 0.65 | 10 | 2.52 | 10 | 2.59 | 10 | 2 2.65 | 0.6 | 10 | 2.89 | 10 | 3.15 | 10 | 2 2.65 | 0.65 | 10 |
| HR | 63 | 3 2.42 | 0.65 | 62 | S/N 0.6 | 63 | S/N 0.21* | 63 | 3 2.63 | 0.63 | 63 | S/N 0.21* | 64 | S/N 0.5 | 64 | 3 2.59 | 0.6 | 62 |
| MAP | 67 | 4 | | 61 | | 64 | | 63 | 4 | | 62 | | 65 | | 70 | 4 | | 68 |
| S/D | 100/55 | 5 | | 94/50 | | 95/52 | | 95/52 | 5 | | 94/50 | | 97/56 | | 90/60 | 5 | | 105/54 |
| PA Press | 14 | 6 | | 14 | | 14 | | 15 | 6 | | 14 | | 14 | | 13 | 6 | | 13 |
| PA S/D | 16/12 | 7 | | 17/12 | | 17/12 | | 17/15 | 7 | | 17/12 | | 16/11 | | 18/13 | 7 | | 16/12 |
| Halo. I/E | I 1.6 E 1.6 | 8 | | I 1.6 E 1.6 | | I 1.6 E 1.6 | | I 1.7 E 1.6 | 8 | | I 1.6 E 1.6 | | I 1.6 E 1.5 | | I 1.6 E 1.6 | 8 | | I 1.6 E 1.5 |
| ET CO2 | 22 | 9 | | 25 | | 25 | | 25 | 9 | | 26 | | 26 | | 24 | 9 | | 25 |
| Hb | 12.8 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 141 | | | | | | | | | | | | | | | | | |
| Time Li[] | 2:54 0.14 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device        Analyzed in chapter 3.

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## Appendix 4.7: Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 7

Date: Oct 19/99  Anesthetic Plane: Start: 3:30 Finish: 3:49  Premed: Butorphanol 0.4 mg/kg IM  LiCla: 0.2mM  LiClb: 0.6mM

Animal # 7  MAP Range: 67 to 78 mmHg  Induction: Thiopental 10 mg/kg IV  Rate of CO: normal

Weight: 36.8 kg  Volume of Iced Dextrose Used: 10 ml  Maintenance: Halothane  Li Sensor Constant: 10.5  Cardiac Output Constant: 0.542

| sensor 3 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:30 | 3:31 |  | 3:33 | 3:35 | 3:36 | 3:37 | 3:38 | 3:39 |  | 3:41 | 3:43 | 3:44 | 3:45 | 3:47 | 3:48 |  | 3:49 |
| Temp (C) | 32.6 | 1  3.00 | 0.65 | 32.5 | ½ ml | 32.5 | 1½ml | 32.6 | 1  3.00 | 0.65 | 32.5 | 1½ml | 32.5 | ½ ml | 32.5 | 1  2.99 | 0.6 | 32.5 |
| RR | 10 | 2  2.87 | 0.65 | 10 | 3.06 | 10 | 3.58 | 10 | 2  2.99 | 0.6 | 10 | 3.79 | 10 | 4.11 | 10 | 2  2.89 | 0.6 | 10 |
| HR | 72 | 3  2.86 | 0.6 | 69 | S/N 0.2 * | 68 | S/N 0.5 | 66 | 3  2.92 | 0.65 | 66 | S/N 0.45 | 66 | S/N 0.18* | 64 | 3  2.91 | 0.65 | 63 |
| MAP | 78 | 4 |  | 72 |  | 72 |  | 70 | 4 |  | 68 |  | 68 |  | 68 | 4 |  | 67 |
| S/D | 96/67 | 5 |  | 92/63 |  | 89/63 |  | 87/60 | 5 |  | 87/58 |  | 103/55 |  | 103/55 | 5 |  | 103/54 |
| PA Press | 13 | 6 |  | 13 |  | 13 |  | 15 | 6 |  | 14 |  | 15 |  | 15 | 6 |  | 16 |
| PA S/D | 14/11 | 7 |  | 14/11 |  | 14/10 |  | 17/12 | 7 |  | 17/10 |  | 17/12 |  | 16/12 | 7 |  | 17/12 |
| Halo. I/E | I 1.6 E 1.5 | 8 |  | I 1.6 E 1.5 |  | I 1.5 E 1.4 |  | I 1.5 E 1.4 | 8 |  | I 1.5 E 1.4 |  | I 1.5 E 1.4 |  | I 1.5 E 1.4 | 8 |  | I 1.5 E 1.4 |
| ET CO2 | 24 | 9 |  | 24 |  | 25 |  | 26 | 9 |  | 26 |  | 26 |  | 26 | 9 |  | 26 |
| Hb | 12.4 | 10 |  |  |  |  |  |  | 10 |  |  |  |  |  |  | 10 |  |  |
| Na++ | 141 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Time Li[] | 3:27  0.18 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

* peak concentration below recommended level for the device          Analyzed in chapter 3.

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**Appendix 4.7:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 7**

Date: Oct 19/99    Anesthetic Plane: Start: 4:00 Finish: 4:21    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 7    MAP Range: 64 to 71 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 36.8 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane   Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 4 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 4:00 | 4:01 | | 4:03 | 4:05 | 4:06 | 4:08 | 4:09 | 4:11 | | 4:13 | 4:14 | 4:16 | 4:17 | 4:18 | 4:19 | | 4:21 |
| Temp (C) | 32.6 | 1 / 2.76 | 0.6 | 32.5 | 1½ml | 32.5 | ½ ml | 32.5 | 1 / 2.84 | 0.6 | 32.5 | ½ ml | 32.5 | 1½ml | 32.5 | 1 / 2.84 | 0.65 | 32.5 |
| RR | 10 | 2 / 2.70 | 0.6 | 10 | 2.80 | 10 | 3.04 | 10 | 2 / 2.82 | 0.6 | 10 | 3.07 | 10 | 3.11 | 10 | 2 / 2.81 | 0.65 | 10 |
| HR | 61 | 3 / 2.72 | 0.65 | 60 | S/N 0.6 | 60 | S/N 0.23* | 60 | 3 / 2.79 | 0.6 | 59 | S/N 0.2* | 60 | S/N 0.51 | 60 | 3 / 2.86 | 0.6 | 60 |
| MAP | 71 | 4 | | 69 | | 67 | | 67 | 4 | | 64 | | 64 | | 65 | 4 | | 64 |
| S/D | 110/57 | 5 | | 108/55 | | 105/54 | | 105/53 | 5 | | 102/50 | | 102/51 | | 102/52 | 5 | | 103/50 |
| PA Press | 14 | 6 | | 12 | | 14 | | 13 | 6 | | 15 | | 14 | | 14 | 6 | | 13 |
| PA S/D | 16/12 | 7 | | 14/11 | | 16/13 | | 15/12 | 7 | | 18/12 | | 17/12 | | 18/10 | 7 | | 17/10 |
| Halo. I/E | I 1.5 E 1.4 | 8 | | I 1.5 E 1.4 | | I 1.5 E 1.4 | | I 1.5 E 1.4 | 8 | | I 1.5 E 1.4 | | I 1.5 E 1.4 | | I 1.5 E 1.4 | 8 | | I 1.5 E 1.4 |
| ET CO2 | 24 | 9 | | 25 | | 25 | | 25 | 9 | | 26 | | 26 | | 27 | 9 | | 27 |
| Hb | 12.3 | 10 | | | | | | | | | | | | | | 10 | | |
| Na++ | 139 | | | | | | | | | | | | | | | | | |
| Time Li[] | 3:51 / 0.22 | | | | | | | | | | | | | | | | | |

\* peak concentration below recommended level for the device                                                   Analyzed in chapter 3.

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**Appendix 4.7: Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 7**

Date: Oct 19/99   Anesthetic Plane: Start: 4:33  Finish: 4:55   Premed: Butorphanol 0.4 mg/kg IM        LiCla: 0.6mM    LiClb: 0.2mM

Animal # 7    MAP Range: 63 to 71 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 36.8 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane   Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 4 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 4:33 | 4:34 | | 4:37 | 4:38 | 4:39 | 4:41 | 4:43 | 4:44 | | 4:46 | 4:47 | 4:48 | 4:51 | 4:52 | 4:53 | | 4:55 |
| Temp (C) | 32.5 | 1 2.73 | 0.6 | 32.4 | 1½ml | 32.5 | ½ ml | 32.5 | 1 2.90 | 0.6 | 32.4 | ½ ml | 32.5 | 1½ml | 32.5 | 1 2.89 | 0.6 | 32.4 |
| RR | 10 | 2 2.73 | 0.6 | 10 | 2.97 | 10 | 3.06 | 10 | 2 2.77 | 0.65 | 10 | 3.27 | 10 | 3.42 | 10 | 2 2.91 | 0.55 | 10 |
| HR | 58 | 3 2.59 | 0.65 | 58 | S/N 0.5 | 59 | S/N 0.18* | 59 | 3 2.78 | 0.6 | 58 | S/N 0.16* | 60 | S/N 0.45 | 58 | 3 2.87 | 0.55 | 60 |
| MAP | 71 | 4 | | 67 | | 66 | | 67 | 4 | | 63 | | 65 | | 66 | 4 | | 65 |
| S/D | 111/ 57 | 5 | | 107/ 54 | | 107/ 53 | | 107/ 53 | 5 | | 104/ 50 | | 104/ 52 | | 105/ 53 | 5 | | 104/ 51 |
| PA Press | 14 | 6 | | 15 | | 14 | | 13 | 6 | | 14 | | 14 | | 14 | 6 | | 14 |
| PA S/D | 16/12 | 7 | | 16/13 | | 16/12 | | 17/9 | 7 | | 16/10 | | 15/12 | | 17/11 | 7 | | 17/12 |
| Halo. I/E | I 1.5 E 1.4 | 8 | | I 1.5 E 1.4 | | I 1.5 E 1.4 | | I 1.5 E1.4 | 8 | | I 1.5 E 1.4 | | I 1.5 E 1.4 | | I 1.5 E 1.4 | 8 | | I 1.5 E 1.4 |
| ET CO2 | 23 | 9 | | 25 | | 26 | | 25 | 9 | | 26 | | 27 | | 26 | 9 | | 27 |
| Hb | 11.9 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 139 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 4:23 0.26 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device                         Analyzed in chapter 3.

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**Appendix 4.7:    Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 7**

Date: Oct 19/99        Anesthetic Plane: Start: 5:04  Finish: 5:28        Premed: Butorphanol 0.4 mg/kg IM        LiCla: 0.2mM        LiClb: 0.6mM

Animal # 7        MAP Range: 63 to 70 mmHg        Induction: Thiopental 10 mg/kg IV        Rate of CO: normal

Weight: 36.8 kg        Volume of Iced Dextrose Used: 10 ml        Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 5 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 5:04 | 5:05 | | 5:07 | 5:08 | 5:09 | 5:11 | 5:12 | 5:13 | | 5:15 | 5:17 | 5:21 | 5:23 | 5:25 | 5:26 | | 5:28 |
| Temp (C) | 32.5 | 1 / 2.73 | 0.6 | 32.4 | ½ ml | 32.4 | 1½ml | 32.5 | 1 / 2.72 | 0.55 | 32.4 | 1½ml | 32.4 | ½ ml | 32.5 | 1 / 2.84 | 0.6 | 32.4 |
| RR | 10 | 2 / 2.66 | 0.6 | 10 | 2.48 | 10 | 2.86 | 10 | 2 / 2.73 | 0.65 | 10 | ** NR | 10 | 2.94 | 10 | 2 / 2.73 | 0.6 | 10 |
| HR | 57 | 3 / 2.69 | 0.6 | 57 | S/N 0.24* | 57 | S/N 0.55 | 57 | 3 / 2.73 | 0.6 | 57 | S/N | 57 | S/N 0.21* | 56 | 3 / 3.01 | 0.5 | 59 |
| MAP | 70 | 4 | | 68 | | 66 | | 67 | 4 | | 63 | | 67 | | 67 | 4 | | 63 |
| S/D | 111/57 | 5 | | 109/54 | | 110/53 | | 108/53 | 5 | | 104/50 | 5:20 | 109/55 | | 110/52 | 5 | | 103/50 |
| PA Press | 14 | 6 | | 13 | | 14 | | 13 | 6 | | 15 | 1½ml | 15 | | 15 | 6 | | 15 |
| PA S/D | 16/11 | 7 | | 16/10 | | 17/12 | | 17/10 | 7 | | 16/12 | 3.04 | 16/12 | | 18/11 | 7 | | 18/12 |
| Halo. I/E | I 1.5 E 1.4 | 8 | | I 1.5 E 1.4 | | I 1.5 E 1.4 | | I 1.5 E 1.4 | 8 | | I 1.5 E 1.4 | S/N 0.52 | I 1.5 E 1.4 | | I 1.5 E 1.4 | 8 | | I 1.5 E 1.4 |
| ET CO2 | 25 | 9 | | 25 | | 26 | | 27 | 9 | | 28 | | 26 | | 27 | 9 | | 27 |
| Hb | 12.2 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 139 | | | | | | | | | | | | | | | | | |
| Time | 4:57 | | | | | | | | | | | | | | | | | 5:29 |
| Li[ ] | 0.28 | | | | | | | | | | | | | | | | | 0.34 |

* peak concentration below recommended level for the device
** battery ran out – no result and repeated test

Analyzed in chapter 3.

**Appendix 4.8:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 8**

LiCla: 0.6mM    LiClb: 0.2mM

Date: Oct 20/99    Anesthetic Plane: Start: 10:00  Finish: 10:38 Premed: Butorphanol 0.4 mg/kg IM    Rate of CO: mildly low

Animal # 8    MAP Range: 61 to 67 mmHg    Induction: Thiopental 10 mg/kg IV

Weight: 35.7 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 10:00 | 10:01 |  | 10:03 | 10:08 | 10:10 | 10:13 | 10:14 | 10:19 |  | 10:21 | 10:23 | 10:25 | 10:28 | 10:35 | 10:36 |  | 10:38 |
| Temp (C) | 35.7 | 1 / 2.28 | 1.2 | 35.5 | 1 ml | 35.6 | ½ ml | 35.5 | 1 / 2.38 | 1.2 | 35.4 | ½ ml | 35.5 | 1½ml | 35.5 | 1 / 2.64 | 1.2 | 35.3 |
| RR | 10 | 2 / 2.21 | 1.2 | 10 | *** 3.13 | 10 | 1.89 | 10 | 2 / 2.55 | 1.2 | 10 | 2.48 | 10 | ** NR | 10 | 2 / 2.47 | 1.2 | 10 |
| HR | 62 | 3 / 2.19 | 1.2 | 65 | S/N 0.37 | 70 | S/N 0.26 | 70 | 3 / 2.36 | 1.2 | 71 | S/N 0.25 | 69 | S/N | 73 | 3 / 2.44 | 1.2 | 71 |
| MAP | 64 | 4 |  | 66 |  | 67 |  | 65 | 4 |  | 64 |  |  |  | 62 | 4 |  | 61 |
| S/D | 106/51 | 5 |  | 105/54 |  | 104/55 |  | 87/57 | 5 |  | 85/55 |  | 83/54 |  | 96/51 | 5 |  | 94/50 |
| PA Press> | 11 | 6 |  | 17 |  | 12 | 1½ml | 14 | 6 |  | 14 | 1½ml | 14 |  | 12 | 6 |  | 12 |
| PA S/D | 12/11 | 7 |  | 19/15 |  | 13/11 | 2.69 | 14/11 | 7 |  | 14/12 |  | 15/11 | 2.20 | 13/10 | 7 |  | 13/10 |
| Halo. I/E | I 1.9 E 1.4 | 8 |  | I 2.0 E 1.4 |  | I 2.0 E 1.5 | S/N >0.6 | I 2.1 E 1.5 | 8 |  | I 2.1 E 1.5 |  | I 2.0 E 1.5 | S/N 0.6 | I 2.0 E 1.6 | 8 |  | I 2.1 E 1.6 |
| ET CO2 | 30 | 9 |  | 34 |  | 31 |  | 33 | 9 |  | 35 |  | 35 |  | 34 | 9 |  | 35 |
| Hb | 14.0 | 10 |  |  |  |  |  |  | 10 |  |  |  |  |  |  | 10 |  |  |
| Na++ | 148 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Time Li[] | 9:57 / 0.00 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

** arterial catheter obstructed – repeat test

*** baseline irregular – computer calculated it in the cardiac output

Not analyzed in chapter 2 and 3 (objective 1) – Arterial catheter obstru.

Analyzed in chapter 3 (objective 2)

**Appendix 4.8:**   **Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 8**

Date: Oct 20/99     Anesthetic Plane: Start: 10:48  Finish: 10:57  Premed: Butorphanol 0.4 mg/kg IM     LiCla: 0.2mM    LiClb: 0.6mM

Animal # 8     MAP Range: 83 to 84 mmHg     Induction: Thiopental 10 mg/kg IV     Rate of CO: markedly low - occlusion

Weight: 35.7 kg     Volume of Iced Dextrose Used: 5 ml     Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.247

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 10:48 | 10:49 | | 10:50 | 10:53 | 10:54 | 10:57 | | 1 | | | | | | | 1 | | |
| Temp (C) | 35.3 | 1  1.31 | 1.0 | 35.2 | 1/3  ml | 35.3 | 1 ml | | 1 | | | | | | | 1 | | |
| RR | 10 | 2  1.31 | 1.0 | 10 | 0.96 | 10 | ** 0.23 | | 2 | | | | | | | 2 | | |
| HR | 83 | 3  1.24 | 1.0 | 84 | S/N 0.24* | 84 | S/N >0.6 | | 3 | | | S/N | | S/N | | 3 | | |
| MAP | 42 | 4 | | 42 | | 38 | | | 4 | | | | | | | 4 | | |
| S/D | 52/37 | 5 | | 53/38 | | 45/34 | | | 5 | | | | | | | 5 | | |
| PA Press | 9 | 6 | | 9 | | 9 | | | 6 | | | | | | | 6 | | |
| PA S/D | 10/8 | 7 | | 10/8 | | 10/8 | | | 7 | | | | | | | 7 | | |
| Halo. I/E | I 2.2  E 1.9 | 8 | | I 2.4  E 1.9 | | I 2.4  E 1.9 | | I  E | 8 | | I  E | | I  E | | I  E | 8 | | I  E |
| ET CO2 | 24 | 9 | | 27 | | 27 | | | 9 | | | | | | | 9 | | |
| Hb | 13.4 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 143 | | | | | | | | | | | | | | | | | |
| Time Li[] | 10:46  0.06 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device
** arterial catheter obstructed again – resulting curve way too long

Not analyzed in chapter 2 and 3 (objective 1) – Arterial catheter obstru.
Analyzed in chapter 3 (objective 2)

**Appendix 4.8: Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 8**

Date: Oct 20/99    Anesthetic Plane: Start: 11:04  Finish: 11:22 Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 8    MAP Range: 30 to 32 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: markedly low – occlusion

Weight: 35.7 kg    Volume of Iced Dextrose Used: 5 ml    Maintenance: Halothane  Li Sensor Constant: 10.5   Cardiac Output Constant: 0.247

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 11:04 | 11:05 | | 11:08 | 11:09 | 11:10 | 11:12 | 11:13 | 11:14 | | 11:15 | 11:17 | 1120 | 11:22 | | | | |
| Temp (C) | 35.4 | 1 0.84 | 1.1 | 35.3 | 1/3ml | 35.4 | 1 ml | 35.4 | 1 0.82 | 1.0 | 35.3 | 1 ml | 35.4 | 1/3ml | | 1 | | |
| RR | 10 | 2 0.79 | 1.1 | 10 | ** 0.71 | 10 | ** 0.77 | 10 | 2 0.78 | 1.0 | 10 | ** 0.77# | 10 | ** 0.48# | | 2 | | |
| HR | 85 | 3 0.78 | 1.1 | 85 | S/N 0.26 | 86 | S/N >0.6 | 87 | 3 0.77 | 1.1 | 86 | S/N >0.6 | 88 | S/N 0.25 | | 3 | | |
| MAP | 31 | 4 | | 30 | | 30 | | 30 | 4 | | 31 | | 32 | | | 4 | | |
| S/D | 35/29 | 5 | | 34/28 | | 33/28 | | 33/28 | 5 | | 34/29 | | 36/30 | | | 5 | | |
| PA Press | 8 | 6 | | 8 | | 8 | | 7 | 6 | | 8 | | 8 | | | 6 | | |
| PA S/D | 8/6 | 7 | | 9/7 | | 9/7 | | 8/7 | 7 | | 9/7 | | 9/8 | | | 7 | | |
| Halo. I/E | I 2.3 E 2.1 | 8 | | I 2.5 E 2.0 | | I 2.3 E 2.0 | | I 2.4 E 2.1 | 8 | | I 2.3 E 2.1 | | I 2.4 E 2.1 | | I E | 8 | | I E |
| ET CO2 | 20 | 9 | | 22 | | 26 | | 26 | 9 | | 31 | | 26 | | | 9 | | |
| Hb | 13.4 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 143 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 11:05 0.09 | | | | | | | | | | | | | | | | | |

** cardiac output outside range for the device and curve too long    Not analyzed in chapter 2 and 3 (objective 1) – Arterial catheter obstru.
# unusual shape curve and are being included in the cardiac output calculation    Analyzed in chapter 3 (objective 2)

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**Appendix 4.8:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 8**

Date: Oct 20/99     Anesthetic Plane: Start: 12.01  Finish: 12:21  Premed: Butorphanol 0.4 mg/kg IM     LiCla: 0.6mM     LiClb: 0.2mM

Animal # 8     MAP Range: 91 to 95 mmHg     Induction: Thiopental 10 mg/kg IV     Rate of CO: normal

Weight: 35.7 kg     Volume of Iced Dextrose Used: 10 ml     Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 12:01 | 12:02 | | 12:04 | 12:06 | 12:08 | 12:09 | 12:10 | 12:11 | | 12:12 | 12:14 | 12:15 | 12:17 | 12:18 | 12:19 | | 12:21 |
| Temp (C) | 35.1 | 1 / 4.48 | 1.0 | 35.0 | 1½ml | 35.0 | ½ml | 35.0 | 1 / 4.33 | 0.9 | 34.9 | ½ ml | 34.9 | 1½ml | 34.9 | 1 / 4.72 | 1.0 | 34.9 |
| RR | 10 | 2 / 4.20 | 1.1 | 11 | 4.31 | 10 | 4.25 | 10 | 2 / 4.26 | 1.0 | 10 | 4.28 | 10 | 4.55 | 10 | 2 / 4.37 | 1.1 | 10 |
| HR | 103 | 3 / 4.28 | 1.1 | 103 | S/N 0.55 | 103 | S/N 0.22* | 104 | 3 / 4.23 | 0.9 | 103 | S/N 0.2* | 104 | S/N 0.5 | 104 | 3 / 4.34 | 1.1 | 102 |
| MAP | 92 | 4 | | 95 | | 93 | | 91 | 4 | | 92 | | 93 | | 93 | 4 | | 95 |
| S/D | 125/78 | 5 | | 129/80 | | 126/79 | | 91/78 | 5 | | 98/78 | | 107/79 | | 127/78 | 5 | | 129/80 |
| PA Press | 8 | 6 | | 9 | | 9 | | 9 | 6 | | 9 | | 9 | | 10 | 6 | | 8 |
| PA S/D | 10/6 | 7 | | 14/2 | | 13/4 | | 13/3 | 7 | | 12/4 | | 11/7 | | 11/8 | 7 | | 10/7 |
| Halo. I/E | I 1.4 E 1.1 | 8 | | I 1.4 E 1.2 | | I 1.4 E 1.1 | | I 1.4 E 1.1 | 8 | | I 1.4 E 1.1 | | I 1.4 E 1.1 | | I 1.4 E 1.1 | 8 | | I 1.4 E 1.1 |
| ET CO2 | 37 | 9 | | 37 | | 37 | | 37 | 9 | | 36 | | 36 | | 36 | 9 | | 34 |
| Hb | 13.6 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 147 | | | | | | | | | | | | | | | | | |
| Time | 12:00 | | | | | | | | | | | | | | | | | |
| Li [ ] | 0.09 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

Analyzed in chapters 2 and 3.

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## Appendix 4.8:    Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 8

Date: Oct 20/99          Anesthetic Plane: Start: 1:42  Finish: 2:03    Premed: Butorphanol 0.4 mg/kg IM          LiCla: 0.6mM     LiClb: 0.2mM

Animal # 8               MAP Range: 66 to 88 mmHg                 Induction: Thiopental 10 mg/kg IV           Rate of CO: high – dobutamine

Weight: 35.7 kg          Volume of Iced Dextrose Used: 10 ml        Maintenance: Halothane   Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1:42 | 1:43 | | 1:45 | 1:47 | 1:50 | 1:51 | 1:52 | 1:53 | | 1:55 | 1:56 | 1:57 | 1:59 | 2:00 | 2:01 | | 2:03 |
| Temp (C) | 35.2 | 1 5.48 | 1.0 | 35.2 | 1½ml | 35.2 | ½ ml | 35.3 | 1 5.45 | 1.0 | 35.2 | ½ ml | 35.2 | 1½ml | 35.3 | 1 5.70 | 1.0 | 35.2 |
| RR | 10 | 2 5.32 | 1.0 | 11 | 6.68 | 10 | 6.60 | 10 | 2 5.17 | 1.0 | 10 | 8.02 | 10 | 7.49 | 10 | 2 5.75 | 0.95 | 10 |
| HR | 175 | 3 5.40 | 1.0 | 203 | S/N 0.6 | 188 | S/N 0.2* | 179 | 3 5.13 | 1.0 | 172 | S/N 0.18* | 166 | S/N 0.51 | 155 | 3 6.14 | 0.85 | 142 |
| MAP | 74 | 4 | | 67 | | 68 | | 66 | 4 | | 68 | | 77 | | 82 | 4 | | 88 |
| S/D | 77/64 | 5 | | 70/59 | | 71/59 | | 77/60 | 5 | | 80/60 | | 94/67 | | 101/ 68 | 5 | | 114/ 71 |
| PA Press | 21 | 6 | | | | | | | 6 | | | | | | 7 | 6 | | 6 |
| PA S/D | 24/3 | 7 | | | | | | | 7 | | | | | | 10/3 | 7 | | 10/4 |
| Halo. I/E | I 1.5 E 1.1 | 8 | | I 1.4 E 1.1 | | I 1.3 E 1.0 | | I 1.3 E 1.0 | 8 | | I 1.3 E 1.0 | | I 1.4 E 1.0 | | I 1.4 E 1.0 | 8 | | I 1.3 E 1.0 |
| ET CO2 | 35 | 9 | | 34 | | 32 | | 32 | 9 | | 32 | | 35 | | 35 | 9 | | 36 |
| Hb | 17.9 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 146 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 1:40 0.12 | | | | | | | | | | | | | | | | | |

\* peak concentration below recommended level for the device
the dog was fighting the ventilator throughout the sheet

Not analyzed in chapter 2 and 3 (objective 1) – Incorrect Na and Hb
Analyzed in chapter 3 (objective 2)

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**Appendix 4.8:** Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 8

Date: Oct 20/99  Anesthetic Plane: Start: 2:33 Finish: 2:54  Premed: Butorphanol 0.4 mg/kg IM  LiCla: 0.2mM  LiClb: 0.6mM

Animal # 8  MAP Range: 80 to 89 mmHg  Induction: Thiopental 10 mg/kg IV  Rate of CO: normal

Weight: 35.7 kg  Volume of Iced Dextrose Used: 10 ml  Maintenance: Halothane  Li Sensor Constant: 10.5  Cardiac Output Constant: 0.542

| sensor 3 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:33 | 2:34 | | 2:35 | 2:39 | 2:40 | 2:42 | 2:43 | 2:44 | | 2:46 | 2:47 | 2:48 | 2:50 | 2:51 | 2:52 | | 2:54 |
| Temp (C) | 35.2 | 1 / 3.33 | 1.3 | 35.0 | ½ ml | 35.1 | 1½ml | 35.1 | 1 / 3.20 | 1.1 | 35.0 | 1½ml | 35.0 | ½ ml | 35.0 | 1 / 3.01 | 1.2 | 34.9 |
| RR | 10 | 2 / 3.18 | 1.2 | 10 | 3.20 | 10 | 3.50 | 10 | 2 / 3.25 | 1.1 | 10 | 3.62 | 10 | 3.44 | 10 | 2 / 3.25 | 1.2 | 10 |
| HR | 96 | 3 / 3.31 | 1.2 | 95 | S/N 0.26 | 95 | S/N >0.6 | 96 | 3 / 3.31 | 1.1 | 94 | S/N >0.6 | 95 | S/N 0.24* | 95 | 3 / 3.10 | 1.0 | 93 |
| MAP | 89 | 4 | | 86 | | 84 | | 85 | 4 | | 84 | | 80 | | 82 | 4 | | 81 |
| S/D | 102/79 | 5 | | 101/78 | | 109/74 | | 110/74 | 5 | | 109/73 | | 106/70 | | 95/73 | 5 | | 91/69 |
| PA Press | 11 | 6 | | 10 | | 10 | | | 6 | | 11 | | 11 | | 11 | 6 | | 10 |
| PA S/D | 13/7 | 7 | | 14/7 | | 14/7 | | | 7 | | 14/8 | | 14/8 | | 14/8 | 7 | | 14/8 |
| Halo. I/E | I 1.5 E 1.2 | 8 | | I 1.5 E 1.3 | | I 1.5 E 1.3 | | I 1.6 E 1.3 | 8 | | I 1.6 E 1.3 | | I 1.6 E 1.3 | | I 1.6 E 1.3 | 8 | | I 1.6 E 1.3 |
| ET CO2 | 31 | 9 | | 32 | | 34 | | 33 | 9 | | 32 | | 34 | | 34 | 9 | | 34 |
| Hb | 16.9 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 143 | | | | | | | | | | | | | | | | | |
| Time Li[] | 2:32 0.19 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device    Analyzed in chapter 3.

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**Appendix 4.8:**   **Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 8**

Date: Oct 20/99    Anesthetic Plane: Start: 3:01 Finish: 3:19    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 8    MAP Range: 68 to 77 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 35.7 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 3 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:01 | 3:02 | | 3:05 | 3:06 | 3:07 | 3:08 | 3:09 | 3:10 | | 3:12 | 3:13 | 3:14 | 3:16 | 3:17 | 3:18 | | 3:19 |
| Temp (C) | 35.0 | 1 / 2.79 | 1.1 | 34.8 | 1½ml | 34.9 | ½ ml | 34.9 | 1 / 3.20 | 1.1 | 34.7 | ½ ml | 34.8 | 1½ml | 34.8 | 1 / 2.90 | 1.1 | 34.7 |
| RR | 10 | 2 / 2.67 | 1.2 | 10 | 3.06 | 10 | 3.23 | 10 | 2 / 2.96 | 1.1 | 10 | 3.28 | 10 | 3.37 | 10 | 2 / 2.76 | 1.2 | 10 |
| HR | 90 | 3 / 2.64 | 1.2 | 90 | S/N >0.6 | 90 | S/N 0.23* | 90 | 3 / 2.72 | 1.1 | 90 | S/N 0.24* | 89 | S/N >0.6 | 90 | 3 / 2.66 | 1.2 | 88 |
| MAP | 77 | 4 | | 76 | | 74 | | 74 | 4 / 2.99 | 1.1 | 72 | | 72 | | 70 | 4 | | 68 |
| S/D | 101/67 | 5 | | 100/66 | | 98/64 | | 85/65 | 5 | | 84/64 | | 82/63 | | 92/61 | 5 | | 90/59 |
| PA Press | 11 | 6 | | 11 | | 11 | | 11 | 6 | | 12 | | 13 | | 12 | 6 | | 12 |
| PA S/D | 15/9 | 7 | | 14/9 | | 15/10 | | 15/9 | 7 | | 16/9 | | 16/10 | | 16/9 | 7 | | 16/11 |
| Halo. I/E | 11.6 E1.3 | 8 | | 11.6 E1.3 | | 11.6 E1.3 | | 11.6 E1.3 | 8 | | 11.6 E1.3 | | 11.6 E1.3 | | 11.6 E1.3 | 8 | | 11.6 E1.4 |
| ET CO2 | 32 | 9 | | 35 | | 34 | | 34 | 9 | | 35 | | 35 | | 35 | 9 | | 35 |
| Hb | 15.9 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 142 | | | | | | | | | | | | | | | | | |
| Time Li[ ] | 2:55 / 0.24 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device                Analyzed in chapter 3.

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| sensor 4 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:26 | 3:27 | | 3:32 | 3:34 | 3:36 | 3:39 | 3:40 | 3:41 | | 3:44 | 3:45 | 3:46 | 3:49 | 3:50 | 3:51 | | 3:52 |
| Temp (C) | 34.7 | 1 / 2.69 | 1.2 | 34.7 | 1½ml | 34.8 | ½ ml | 34.7 | 1 / 2.67 | 1.1 | 34.6 | ½ ml | 34.6 | 1½ml | 34.7 | 1 / 2.65 | 1.2 | 34.5 |
| RR | 10 | 2 / 2.54 | 1.2 | 10 | 2.71 | 10 | ** / 3.04 | 10 | 2 / 2.58 | 1.2 | 10 | 3.16 | 10 | 3.20 | 10 | 2 / 2.53 | 1.2 | 10 |
| HR | 87 | 3 / 2.63 | 1.2 | 87 | S/N >0.6 | 91 | S/N 0.25 | 90 | 3 / 2.66 | 1.2 | 90 | S/N 0.24* | 89 | S/N >0.6 | 90 | 3 / 2.52 | 1.1 | 88 |
| MAP | 68 | 4 | | 64 | | 67 | | 64 | 4 | | 63 | | 62 | | 62 | 4 | | 60 |
| S/D | 90/59 | 5 | | 83/56 | | 82/59 | | 77/57 | 5 | | 84/54 | | 82/53 | | 83/53 | 5 | | 81/52 |
| PA Press | 12 | 6 | | 12 | | 14 | | 12 | 6 | | 14 | | 12 | | 12 | 6 | | 12 |
| PA S/D | 14/10 | 7 | | 15/7 | | 16/10 | | 15/7 | 7 | | 15/9 | | 15/7 | | 15/8 | 7 | | 15/7 |
| Halo. I/E | I 1.6 E 1.4 | 8 | | I 1.6 E 1.4 | | I 1.7 E 1.4 | | I 1.7 E 1.4 | 8 | | I 1.7 E 1.4 | | I 1.7 E 1.4 | | I 1.7 E 1.4 | 8 | | I 1.7 E 1.4 |
| ET CO2 | 32 | 9 | | 33 | | 34 | | 36 | 9 | | 36 | | 37 | | 36 | 9 | | 38 |
| Hb | 15.1 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 140 | | | | | | | | | | | | | | | | | |
| Time Li[] | 3:21 / 0.27 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

** battery stopped during test – was repeated but there were two injections of ½ ml of LiCl

Analyzed in chapter 3.

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**Appendix 4.8:** Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 8

Date: Oct 20/99   Anesthetic Plane: Start: 4:00 Finish: 4:25   Premed: Butorphanol 0.4 mg/kg IM   LiCla: 0.6mM   LiClb: 0.2mM

Animal # 8   MAP Range: 57 to 62 mmHg   Induction: Thiopental 10 mg/kg IV   Rate of CO: normal

Weight: 35.7 kg   Volume of Iced Dextrose Used: 10 ml   Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 4 | CV Status | TD | TD S/N | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 4:00 | 4:01 | | 4:04 | 4:05 | 4:06 | 4:08 | 4:09 | | 4:10 | 4:15 | 4:18 | 4:20 | 4:22 | 4:23 | | 4:25 |
| Temp (C) | 34.6 | 1 / 2.56 | 1.2 | 1½ml | 34.5 | ½ml | 34.5 | 1 / 2.66 | 1.1 | 34.4 | ½ ml | 34.5 | 1½ml | 34.5 | 1 / 2.68 | 1.2 | 34.4 |
| RR | 10 | 2 / 2.44 | 1.1 | 3.02 | 10 | 3.06 | 10 | 2 / 2.56 | 1.1 | 10 | # 3.16 | 10 | 3.41 | 10 | 2 / 2.56 | 1.2 | 10 |
| HR | 88 | 3 / 2.42 | 1.1 | S/N >0.6 | 88 | S/N 0.24* | 89 | 3 / 2.51 | 1.1 | 88 | S/N 0.23* | 90 | S/N 0.55 | 91 | 3 / 2.67 | 1.2 | 89 |
| MAP | 62 | 4 | | | 59 | | 59 | 4 | | 58 | | 58 | | 58 | 4 | | 57 |
| S/D | 83/54 | 5 | | | 80/50 | | 80/51 | 5 | | 78/50 | | 78/50 | | 79/50 | 5 | | 77/48 |
| PA Press | 12 | 6 | | | 12 | | 12 | 6 | | 12 | | 11 | | 12 | 6 | | 12 |
| PA S/D | 14/7 | 7 | | | 15/7 | | 15/7 | 7 | | 15/8 | | 15/7 | | 15/8 | 7 | | 14/8 |
| Halo. I/E | 1 1.6 E1.4 | 8 | | | 1 1.6 E1.4 | | 1 1.7 E1.4 | 8 | | 1 1.8 E1.4 | | 1 1.7 E1.4 | | 1 1.7 E1.4 | 8 | | 1 1.7 E1.4 |
| ET CO2 | 34 | 9 | | | 37 | | 37 | 9 | | 39 | | 37 | | 37 | 9 | | 38 |
| Hb | 14.7 | 10 | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 144 | | | | | | | | | | | | | | | | |
| Time | 3:55 | | | | | | | | | | | | | | | | |
| Li [] | 0.29 | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device
# 3 injections of ½ ml of LiCl were done due to sensor voltage shifts

Analyzed in chapter 3.

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**Appendix 4.8:** Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 8

Date: Oct 20/99  Anesthetic Plane: Start: 4:32 Finish: 4:52  Premed: Butorphanol 0.4 mg/kg IM  LiCla: 0.2mM  LiClb: 0.6mM

Animal # 8  MAP Range: 57 to 61 mmHg  Induction: Thiopental 10 mg/kg IV  Rate of CO: normal

Weight: 35.7 kg  Volume of Iced Dextrose Used: 10 ml  Maintenance: Halothane  Li Sensor Constant: 10.5  Cardiac Output Constant: 0.542

| sensor 5 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 4:32 | 4:33 | | 4:35 | 4:37 | 4:38 | 4:40 | 4:41 | 4:42 | | 4:44 | 4:45 | 4:47 | 4:48 | 4:50 | 4:51 | | 4:52 |
| Temp (C) | 34.4 | 1 / 2.50 | 1.1 | 34.3 | ½ ml | 34.3 | 1½ml | 34.4 | 1 / 2.99 | 1.0 | 34.3 | 1½ml | 34.4 | ½ ml | 34.3 | 1 / 3.12 | 1.1 | 34.2 |
| RR | 10 | 2 / 2.35 | 1.2 | 10 | 2.73 | 10 | 2.94 | 10 | 2 / 3.00 | 1.0 | 10 | 3.56 | 10 | 3.11 | 10 | 2 / 3.00 | 1.1 | 10 |
| HR | 88 | 3 / 2.54 | 1.1 | 88 | S/N 0.24* | 90 | S/N >0.6 | 89 | 3 / 2.92 | 1.0 | 90 | S/N 0.55 | 92 | S/N 0.21* | 92 | 3 / 2.87 | 1.1 | 91 |
| MAP | 61 | 4 | | 59 | | 61 | | 57 | 4 | | 60 | | 61 | | 60 | 4 | | 59 |
| S/D | 83/52 | 5 | | 81/50 | | 84/52 | | 79/48 | 5 | | 83/50 | | 85/52 | | 81/50 | 5 | | 82/49 |
| PA Press | 12 | 6 | | 13 | | 12 | | 12 | 6 | | 13 | | 13 | | 13 | 6 | | |
| PA S/D | 15/9 | 7 | | 15/10 | | 15/8 | | 14/8 | 7 | | 16/11 | | 15/9 | | 16/10 | 7 | | |
| Halo. I/E | I 1.7 E 1.5 | 8 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | | I 1.7 E 1.4 | 8 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | | I 1.7 E 1.5 | 8 | | I 1.7 E 1.4 |
| ET CO2 | 36 | 9 | | 37 | | 36 | | 37 | 9 | | 38 | | 39 | | 39 | 9 | | 38 |
| Hb | 14.1 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 141 | | | | | | | | | | | | | | | | | |
| Time Li[] | 4:27 / 0.32 | | | | | | | | | | | | | | | | | 4:54 / 0.38 |

* peak concentration below recommended level for the device

Analyzed in chapter 3.

Appendix 4.9:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 9

Date: Oct 26/99   Anesthetic Plane: Start: 10:20  Finish: 10:40  Premed: Butorphanol 0.4 mg/kg IM   LiCla: 0.2mM   LiClb: 0.6mM

Animal # 9   MAP Range: 70 to 84 mmHg   Induction: Thiopental 10 mg/kg IV   Rate of CO: normal

Weight: 30.5 kg   Volume of Iced Dextrose Used: 10 ml   Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 10:20 | 10:21 | | 10:24 | 10:25 | 10:27 | 10:29 | 10:30 | 10:31 | | 10:32 | 10:34 | 10:35 | 10:36 | 10:37 | 10:38 | | 10:40 |
| Temp (C) | 35.3 | 1 / 2.61 | 1.5 | 35.1 | 1/3ml | 35.1 | 1 ml | 35.1 | 1 / 3.53 | 1.1 | 35.0 | 1 ml | 35.1 | 1/3ml | 35.1 | 1 / 3.11 | 1.1 | 35.0 |
| RR | 10 | 2 / 3.30 | 1.2 | 10 | 3.05 | 10 | 3.21 | 10 | 2 / 3.23 | 1.1 | 10 | 3.44 | 10 | 2.79 | 10 | 2 / 3.11 | 1.1 | 10 |
| HR | 92 | 3 / 3.36 | 1.2 | 85 | S/N 0.18* | 83 | S/N 0.5 | 77 | 3 / 3.38 | 1.2 | 80 | S/N 0.49 | 79 | S/N 0.2* | 74 | 3 / 3.14 | 1.1 | 74 |
| MAP | 84 | 4 / 3.46 | 1.2 | 81 | | 79 | | 76 | 4 | | 77 | | 73 | | 70 | 4 | | 70 |
| S/D | 111/73 | 5 | | 108/69 | | 106/67 | | 105/64 | 5 | | 102/67 | | 99/62 | | 97/59 | 5 | | 98/59 |
| PA Press | 13 | 6 | | 13 | | 13 | | 13 | 6 | | 13 | | 8 | | 11 | 6 | | 12 |
| PA S/D | 14/13 | 7 | | 20/8 | | 16/9 | | 16/11 | 7 | | 14/11 | | 9/8 | | 11/10 | 7 | | 13/11 |
| Halo. I/E | I 1.3 E 1.0 | 8 | | I 1.3 E 1.0 | | I 1.3 E 1.0 | | I 1.3 E 1.0 | 8 | | I 1.3 E 1.0 | | I 1.3 E 1.1 | | I 1.3 E 1.1 | 8 | | I 1.3 E 1.0 |
| ET CO2 | 41 | 9 | | 42 | | 42 | | 41 | 9 | | 40 | | 39 | | 41 | 9 | | 40 |
| Hb | 12.8 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 145 | | | | | | | | | | | | | | | | | |
| Time Li[] | 10:04 0.01 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device      Analyzed in chapters 2 and 3.

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**Appendix 4.9:**    Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 9

Date: Oct 26/99    Anesthetic Plane: Start: 11:13   Finish: 11:33   Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 9    Induction: Thiopental 10 mg/kg IV    Rate of CO: high – dobutamine

MAP Range: 68 to 76 mmHg    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

Weight: 30.5 kg    Volume of Iced Dextrose Used: 10 ml

| sensor | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 11:13 | 11:14 | | 11:15 | 11:19 | 11:20 | 11:22 | 11:23 | 11:24 | | 11:25 | 11:27 | 11:29 | 11:30 | 11:31 | 11:32 | | 11:33 |
| Temp (C) | 35.3 | 1 / 7.44 | 0.7 | 35.3 | 1½ml | 35.4 | ½ ml | 35.4 | 1 / 7.25 | 0.7 | 35.3 | ½ ml | 35.4 | 1½ml | 35.4 | 1 / 7.13 | 0.7 | 35.3 |
| RR | 10 | 2 / 6.94 | 0.7 | 10 | 8.55 | 10 | 7.33 | 10 | 2 / 6.87 | 0.7 | 10 | 8.05 | 10 | 8.33 | 10 | 2 / 7.03 | 0.7 | 10 |
| HR | 133 | 3 / 7.01 | 0.7 | 131 | S/N >0.6 | 130 | S/N 0.24* | 128 | 3 / 7.25 | 0.7 | 127 | S/N 0.2* | 130 | S/N 0.5 | 126 | 3 / 7.03 | 0.7 | 123 |
| MAP | 73 | 4 | | 76 | | 73 | | 73 | 4 | | 69 | | 71 | | 68 | 4 | | 69 |
| S/D | 105/57 | 5 | | 105/58 | | 107/57 | | 104/55 | 5 | | 101/52 | | 102/53 | | 102/51 | 5 | | 100/50 |
| PA Press | 15 | 6 | | 17 | | 21 | | 16 | 6 | | 17 | | 15 | | 16 | 6 | | 16 |
| PA S/D | 20/10 | 7 | | 25/13 | | 24/16 | | 29/13 | 7 | | 29/15 | | 32/14 | | 32/14 | 7 | | 32/15 |
| Halo. I/E | I 1.4 E 0.9 | 8 | | I 1.5 E 0.9 | | I 1.4 E 0.9 | | I 1.4 E 1.0 | 8 | | I 1.5 E 0.9 | | I 1.4 E 0.9 | | I 1.4 E 1.0 | 8 | | I 1.5 E 1.0 |
| ET CO2 | 44 | 9 | | 46 | | 46 | | 46 | 9 | | 47 | | 47 | | 48 | 9 | | 48 |
| Hb | 17.0 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 148 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 11:12 0.03 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

Not analyzed in chapter 3 (objective 1) – cardiac output > 5 L/min

Analyzed in chapters 2 and 3 (objective 2).

**Appendix 4.9:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 9**

Date: Oct 26/99   Anesthetic Plane: Start: 11:59  Finish: 12:18  Premed: Butorphanol 0.4 mg/kg IM   LiCla: 0.2mM   LiClb: 0.6mM

Animal # 9   MAP Range: 57 to 63 mmHg   Induction: Thiopental 10 mg/kg IV   Rate of CO: mildly low

Weight: 30.5 kg   Volume of Iced Dextrose Used: 10 ml   Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 11:59 | 12:00 | | 12:02 | 12:04 | 12:05 | 12:06 | 12:08 | 12:09 | | 12:10 | 12:12 | 12:13 | 12:14 | 12:15 | 12:16 | | 12:18 |
| Temp (C) | 35.2 | 1  2.30 | 1.2 | 35.1 | 1/3ml | 35.1 | 1 ml | 35.1 | 1  2.22 | 1.1 | 35.0 | 1 ml | 35.0 | 1/3ml | 35.0 | 1  2.22 | 1.1 | 34.9 |
| RR | 10 | 2  2.35 | 1.1 | 10 | 2.42 | 10 | 2.73 | 10 | 2  2.16 | 1.1 | 10 | 2.75 | 10 | 2.66 | 10 | 2  2.33 | 1.1 | 10 |
| HR | 71 | 3  2.20 | 1.2 | 70 | S/N 0.21* | 76 | S/N 0.51 | 64 | 3  2.18 | 1.2 | 72 | S/N 0.51 | 72 | S/N 0.2* | 73 | 3  2.17 | 1.1 | 71 |
| MAP | 63 | 4 | | 62 | | 60 | | 60 | 4 | | 59 | | 60 | | 58 | 4 | | 57 |
| S/D | 93/52 | 5 | | 90/51 | | 87/49 | | 87/50 | 5 | | 85/48 | | 90/50 | | 84/48 | 5 | | 83/48 |
| PA Press | 14 | 6 | | 16 | | 15 | | 17 | 6 | | 17 | | 14 | | 12 | 6 | | 16 |
| PA S/D | 21/11 | 7 | | 20/13 | | 19/11 | | 19/14 | 7 | | 20/14 | | 19/9 | | 20/10 | 7 | | 19/11 |
| Halo. I/E | 1 1.8 E 1.4 | 8 | | 1 1.9 E 1.4 | | 1 2.0 E 1.5 | | 1 2.0 E 1.5 | 8 | | 1 1.9 E 1.5 | | 1 2.1 E 1.5 | | 1 2.0 E 1.5 | 8 | | 1 2.0 E 1.5 |
| ET CO2 | 37 | 9 | | 39 | | 39 | | 40 | 9 | | 39 | | 41 | | 40 | 9 | | 42 |
| Hb | 14.1 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 146 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 11:43 0.08 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device          Analyzed in chapters 2 and 3.

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Date: Oct 26/99       Anesthetic Plane: Start: 12:46  Finish: 1:10   Premed: Butorphanol 0.4 mg/kg IM       LiCla: 0.2mM     LiClb: 0.6mM

Animal # 9         MAP Range: 37 to 44 mmHg        Induction: Thiopental 10 mg/kg IV        Rate of CO: markedly low - deep anesthesia

Weight: 30.5 kg        Volume of Iced Dextrose Used: 5 ml       Maintenance: Halothane   Li Sensor Constant: 10.5    Cardiac Output Constant: 0.247

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 12:46 | 12:47 |  | 12:49 | 12:52 | 12:53 | 12:54 | 12:56 | 12:57 |  | 12:59 | 1:01 | 1:03 | 1:04 | 1:06 | 1:07 |  | 1:10 |
| Temp (C) | 34.9 | 1 1.59 | 0.5 | 34.9 | 1/3ml | 34.9 | 1 ml | 34.9 | 1 1.44 | 0.5 | 34.9 | 1 ml | 34.9 | 1/3ml | 34.9 | 1 1.43 | 0.4 | 34.8 |
| RR | 10 | 2 1.48 | 0.5 | 10 | 1.36 | 10 | 1.53 | 10 | 2 1.38 | 0.5 | 10 | 1.53 | 10 | 1.46 | 10 | 2 1.33 | 0.45 | 10 |
| HR | 82 | 3 1.52 | 0.5 | 83 | S/N 0.2* | 85 | S/N 0.5 | 85 | 3 1.35 | 0.5 | 86 | S/N 0.48 | 87 | S/N 0.2* | 86 | 3 1.27 | 0.5 | 88 |
| MAP | 44 | 4 |  | 42 |  | 39 |  | 39 | 4 |  | 39 |  | 37 |  | 37 | 4 1.24 | 0.5 | 38 |
| S/D | 60/38 | 5 |  | 56/36 |  | 51/34 |  | 52/34 | 5 |  | 52/34 |  | 47/33 |  | 48/33 | 5 |  | 48/33 |
| PA Press | 12 | 6 |  | 15 |  | 12 |  | 13 | 6 |  | 14 |  | 12 |  | 14 | 6 |  | 13 |
| PA S/D | 17/8 | 7 |  | 17/11 |  | 16/8 |  | 16/10 | 7 |  | 16/11 |  | 17/8 |  | 16/11 | 7 |  | 16/9 |
| Halo. I/E | I 2.6 E 2.2 | 8 |  | I 2.8 E 2.2 |  | I 3.0 E 2.2 |  | I 2.7 E 2.3 | 8 |  | I 2.9 E 2.2 |  | I 2.9 E 2.3 |  | I 3.0 E 2.3 | 8 |  | I 2.9 E 2.4 |
| ET CO2 | 33 | 9 |  | 35 |  | 38 |  | 37 | 9 |  | 38 |  | 38 |  | 39 | 9 |  | 36 |
| Hb | 12.8 | 10 |  |  |  |  |  |  | 10 |  |  |  |  |  |  | 10 |  |  |
| Na++ | 142 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Time Li[] | 12:45 0.10 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

* peak concentration below recommended level for the device                    Analyzed in chapters 2 and 3.

**Appendix 4.9:**  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 9

Date: Oct 26/99    Anesthetic Plane: Start: 2:00  Finish: 2:24    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 9    MAP Range: 60 to 63 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 30.5 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 3 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | LiCla | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:00 | 2:01 | | 2:02 | 2:05 | 2:06 | 2:08 | 2:10 | 2:11 | | 2:12 | 2:14 | 2:15 | 2:17 | 2:19 | 2:20 | 2:22 | | 2:24 |
| Temp (C) | 34.6 | 1 / 2.21 | | 34.5 | ½ ml | 34.5 | 1½ml | 34.6 | 1 / 2.33 | | 34.5 | 1½ml | 34.5 | ½ ml | 34.6 | ½ ml | 1 / 2.20 | | 34.5 |
| RR | 10 | 2 / 2.28 | 1.0 | 10 | 2.21 | 10 | 2.44 | 10 | 2 / 2.31 | 1.0 | 10 | 2.51 | 10 | ** 6.88 | 10 | 2.38 | 2 / 2.13 | 1.0 | 10 |
| HR | 65 | 3 / 2.12 | 1.0 | 68 | S/N 0.25 | 68 | S/N >0.6 | 69 | 3 / 2.22 | 1.0 | 68 | S/N >0.6 | 70 | S/N 0.25 | 69 | | 3 / 2.28 | 1.1 | 68 |
| MAP | 63 | 4 | 1.0 | 60 | | 63 | | 61 | 4 | 1.0 | 60 | | 61 | | 61 | | 4 | 1.0 | 61 |
| S/D | 92/52 | 5 | | 87/50 | | 90/52 | | 89/51 | 5 | | 87/50 | | 87/51 | | 98/51 | | 5 | | 87/50 |
| PA Press | 13 | 6 | | 16 | | 14 | | 15 | 6 | | 16 | | 15 | | 14 | | 6 | | 16 |
| PA S/D | 19/9 | 7 | | 18/11 | | 20/9 | | 19/10 | 7 | | 20/12 | | 19/10 | | 19/11 | | 7 | | 18/12 |
| Halo. I/E | I 1.4 E 1.3 | 8 | | I 1.4 E 1.3 | | I 1.4 E 1.3 | | I 1.4 E 1.3 | 8 | | I 1.5 E 1.3 | | I 1.4 E 1.3 | | I 1.4 E 1.3 | | 8 | | I 1.5 E 1.3 |
| ET CO2 | 34 | 9 | | 38 | | 37 | | 38 | 9 | | 39 | | 38 | | 39 | | 9 | | 39 |
| Hb | 12.6 | 10 | | | | | | | 10 | | | | | | | | 10 | | |
| Na++ | 143 | | | | | | | | | | | | | | | | | | |
| Time | 1:55 | | | | | | | | | | | | | | | | | | |
| Li [ ] | 0.11 | | | | | | | | | | | | | | | | | | |

** ½ ml of LiCl injected but computer was expecting 1½ ml – therefore repeated

Analyzed in chapter 3.

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**Appendix 4.9:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 9**

Date: Oct 26/99      Anesthetic Plane: Start: 2:31  Finish: 2:54      Premed: Butorphanol 0.4 mg/kg IM      LiCla: 0.2mM      LiClb: 0.6mM

Animal # 9      MAP Range: 59 to 64 mmHg      Induction: Thiopental 10 mg/kg IV      Rate of CO: normal

Weight: 30.5 kg      Volume of Iced Dextrose Used: 10 ml      Maintenance: Halothane      Li Sensor Constant: 10.5      Cardiac Output Constant: 0.542

| sensor 3 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:31 | 2:32 |  | 2:34 | 2:37 | 2:38 | 2:40 | 2:41 | 2:42 |  | 2:47 | 2:48 | 2:49 | 2:51 | 2:52 | 2:53 |  | 2:54 |
| Temp (C) | 34.6 | 1 / 2.36 | 1.0 | 34.5 | ½ ml | 34.6 | 1½ml | 34.6 | 1 / 2.18 | 1.1 | 34.5 | 1½ml | 34.5 | ½ ml | 34.6 | 1 / 2.25 | 1.1 | 34.5 |
| RR | 10 | 2 / 2.14 | 1.0 | 10 | 2.22 | 10 | 2.55 | 10 | 2 / 2.17 | 1.1 | 10 | 2.64 | 10 | 2.49 | 10 | 2 / 2.26 | 1.0 | 10 |
| HR | 65 | 3 / 2.04 | 1.0 | 70 | S/N 0.25 | 65 | S/N >0.6 | 69 | 3 / 2.41 | 1.0 | 68 | S/N >0.6 | 68 | S/N 0.24* | 67 | 3 / 2.45 | 1.0 | 68 |
| MAP | 64 | 4 / 2.08 | 1.0 | 61 |  | 61 |  | 61 | 4 / 2.27 | 1.0 | 60 |  | 60 |  | 61 | 4 |  | 59 |
| S/D | 94/53 | 5 |  | 88/51 |  | 87/51 |  | 87/51 | 5 / 2.19 | 1.1 | 87/49 |  | 87/50 |  | 88/50 | 5 |  | 86/49 |
| PA Press | 14 | 6 |  | 14 |  | 14 |  | 15 | 6 / 2.37 | 1.1 | 15 |  | 14 |  | 15 | 6 |  | 15 |
| PA S/D | 20/10 | 7 |  | 16/10 |  | 20/10 |  | 18/10 | 7 |  | 18/11 |  | 20/10 |  | 20/11 | 7 |  | 19/11 |
| Halo. I/E | I 1.4 E 1.3 | 8 |  | I 1.5 E 1.3 |  | I 1.4 E 1.3 |  | I 1.4 E 1.3 | 8 |  | I 1.4 E 1.3 |  | I 1.4 E 1.3 |  | I 1.4 E 1.3 | 8 |  | I 1.5 E 1.3 |
| ET CO2 | 35 | 9 |  | 39 |  | 39 |  | 39 | 9 |  | 41 |  | 42 |  | 41 | 9 |  | 42 |
| Hb | 12.1 | 10 |  |  |  |  |  |  | 10 |  |  |  |  |  |  | 10 |  |  |
| Na++ | 141 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Time Li[] | 2:25 / 0.18 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

* peak concentration below recommended level for the device

Analyzed in chapter 3.

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**Appendix 4.9:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 9**

Date: Oct 26/99    Anesthetic Plane: Start: 3:00  Finish: 3:20    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 9    MAP Range: 57 to 64 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 30.5 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 4 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | CV Status | TD | TD S/N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:00 | 3:01 | | 3:04 | 3:05 | 3:06 | 3:07 | 3:09 | 3:10 | | 3:12 | 3:13 | 3:15 | 3:16 | 3:18 | 3:20 | 3:20 | |
| Temp (C) | 34.6 | 1  2.36 | 1.0 | 34.5 | 1½ml | 34.6 | ½ml | 34.6 | 1  2.30 | 1.0 | 34.6 | ½ml | 34.6 | 1½ml | 34.6 | | | 1  2.31 | 1.0 |
| RR | 10 | 2  2.31 | 1.0 | 10 | 2.72 | 10 | 2.62 | 10 | 2  2.26 | 1.0 | 10 | 2.61 | 10 | 2.94 | 10 | | | 2  2.27 | 1.0 |
| HR | 65 | 3  2.28 | 1.0 | 64 | S/N >0.6 | 67 | S/N 0.25 | 66 | 3  2.42 | 1.0 | 67 | S/N 0.25 | 63 | S/N >0.6 | 67 | | | 3  2.34 | 1.0 |
| MAP | 64 | 4 | | 60 | | 60 | | 57 | 4 | | 59 | | 59 | | 59 | | | 4 | |
| S/D | 92/53 | 5 | | 88/48 | | 86/49 | | 82/47 | 5 | | 86/48 | | 92/46 | | 93/48 | 87/48 | | 5 | |
| PA Press | 16 | 6 | | 14 | | 14 | | 15 | 6 | | 15 | | 15 | | 17 | | | 6 | |
| PA S/D | 19/10 | 7 | | 20/10 | | 19/10 | | 20/10 | 7 | | 21/11 | | 20/12 | | 20/13 | | | 7 | |
| Halo. I/E | I 1.4 E 1.3 | 8 | | I 1.5 E 1.3 | | I 1.4 E 1.3 | | I 1.4 E 1.3 | 8 | | I 1.4 E 1.3 | | I 1.4 E 1.3 | | I 1.4 E 1.3 | | | 8 | |
| ET CO2 | 37 | 9 | | 40 | | 39 | | 40 | 9 | | 43 | | 43 | | 43 | | | 9 | |
| Hb | 11.8 | 10 | | | | | | | 10 | | | | | | | | | 10 | |
| Na++ | 139 | | | | | | | | | | | | | | | | | | |
| Time Li[ ] | 2:55  0.22 | | | | | | | | | | | | | | | | | | |

Analyzed in chapter 3.

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**Appendix 4.9:**    Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 9

Date: Oct 26/99    Anesthetic Plane: Start: 3:24 Finish: 3:42    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6mM

Animal # 9    MAP Range: 58 to 66 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 30.5 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 4 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:24 | 3:25 | | 3:26 | 3:28 | 3:29 | 3:30 | 3:31 | 3:32 | | 3:34 | 3:36 | 3:37 | 3:38 | 3:39 | 3:40 | | 3:42 |
| Temp (C) | 34.6 | 1 / 2.20 | 1.0 | 34.6 | ½ ml | 34.7 | 1½ml | 34.7 | 1 / 2.35 | 1.0 | 34.6 | 1½ml | 34.7 | ½ ml | 34.7 | 1 / 2.32 | 1.0 | 34.6 |
| RR | 10 | 2 / 2.31 | 1.0 | 10 | 2.65 | 10 | 3.02 | 10 | 2 / 2.26 | 1.0 | 10 | 3.00 | 10 | 3.14 | 10 | 2 / 2.42 | 1.0 | 10 |
| HR | 65 | 3 / 2.32 | 1.0 | 66 | S/N 0.24* | 66 | S/N >0.6 | 66 | 3 / 2.42 | 1.0 | 68 | S/N >0.6 | 65 | S/N 0.22* | 65 | 3 / 2.47 | 1.0 | 67 |
| MAP | 66 | 4 | | 60 | | 60 | | 61 | 4 | | 60 | | 59 | | 58 | 4 | | 58 |
| S/D | 95/54 | 5 | | 88/49 | | 92/47 | | 89/50 | 5 | | 87/49 | | 88/48 | | 85/47 | 5 | | 84/47 |
| PA Press | 15 | 6 | | 15 | | 14 | | 16 | 6 | | 15 | | 14 | | 14 | 6 | | 17 |
| PA S/D | 21/10 | 7 | | 19/11 | | 20/10 | | 21/12 | 7 | | 19/12 | | 20/10 | | 20/10 | 7 | | 19/12 |
| Halo. I/E | I 1.4 E 1.3 | 8 | | I 1.5 E 1.3 | | I 1.4 E 1.2 | | I 1.4 E 1.3 | 8 | | I 1.4 E 1.3 | | I 1.4 E 1.3 | | I 1.4 E 1.3 | 8 | | I 1.4 E 1.2 |
| ET CO2 | 40 | 9 | | 41 | | 43 | | 42 | 9 | | 42 | | 43 | | 43 | 9 | | 44 |
| Hb | 11.7 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 140 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 3:21 / 0.26 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device          Analyzed in chapter 3.

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**Appendix 4.9:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 9**

LiCla: 0.6mM    LiClb: 0.2mM

Date: Oct 26/99

Anesthetic Plane: Start: 3:47  Finish: 4:14    Premed: Butorphanol 0.4 mg/kg IM

Induction: Thiopental 10 mg/kg IV

Animal # 9

MAP Range: 58 to 65 mmHg

Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

Rate of CO: normal

Weight: 30.5 kg

Volume of Iced Dextrose Used: 10 ml

| sensors | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:47 | 3:48 | | 3:54 | 3:56 | 3:58 | 3:59 | 4:00 | 4:01 | | 4:06 | 4:07 | 4:08 | 4:09 | 4:10 | 4:11 | | 4:14 |
| Temp (C) | 34.7 | 1  2.37 | | 34.6 | 1½ml | 34.7 | ½ml | 34.7 | 1  2.67 | 1.0 | 34.6 | ½ ml | 34.6 | 1½ml | 34.7 | 1  2.39 | 1.0 | 34.6 |
| RR | 10 | 2  2.25 | 1.0 | 10 | | 10 | | 10 | 2  2.45 | 1.0 | 10 | | 10 | | 10 | 2  2.85 | 1.0 | 10 |
| HR | 63 | 3  2.68 | 1.0 | 66 | 3.12  S/N >0.6 | 61 | 2.71  S/N 0.26 | 67 | 3  2.35 | 1.0 | 68 | 3.12  S/N 0.25 | 66 | 3.34  S/N >0.6 | 65 | 3  2.55 | 1.0 | 68 |
| MAP | 65 | 4  2.28 | 1.0 | 58 | | 60 | | 61 | 4  2.84 | 0.9 | 60 | | 60 | | 63 | 4  2.38 | 1.0 | 59 |
| S/D | 96/53 | 5  2.19 | 1.0 | 84/46 | | 89/48 | | 90/50 | 5  2.49 | 1.0 | 89/48 | | 89/49 | | 97/47 | 5  2.44 | 1.0 | 85/47 |
| PA Press | 15 | 6  2.52 | 1.0 | 16 | | 15 | | 14 | 6  2.53 | 1.0 | 16 | | 17 | | 15 | 6 | | 15 |
| PA S/D | 20/11 | 7  2.29 | 1.0 | 19/12 | | 19/10 | | 21/10 | 7  2.44 | 1.0 | 19/11 | | 19/13 | | 17/11 | 7 | | 20/12 |
| Halo. I/E | I 1.4 E 1.3 | 8  2.39 | 1.0 | I 1.4 E 1.3 | | I 1.4 E 1.3 | | I 1.4 E 1.3 | 8 | | I 1.4 E 1.2 | | I 1.4 E 1.3 | | I 1.4 E 1.3 | 8 | | I 1.4 E 1.3 |
| ET CO2 | 39 | 9  2.53 | 1.0 | 43 | | 43 | | 42 | 9 | | 44 | | 43 | | 44 | 9 | | 44 |
| Hb | 11.3 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 138 | | | | | | | | | | | | | | | | | |
| Time Li[ ] | 3:43  0.29 | | | | | | | | | | | | | | | | | 4:32  0.47 |

Note: Injected 7 ½ ml of LiCl at the end of this sheet prior to serum lithium concentration (preliminary study of peripheral vs. central LiDCO)

Analyzed in chapter 3.

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**Appendix 4.10: Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 10**

Date: Nov 3/99    Anesthetic Plane: Start: 9:35  Finish: 10:05    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.2mM    LiClb: 0.6 mM

Animal # 10    MAP Range: 51 to 56 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: mildly low

Weight: 36.4 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane    Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor | CV Status | TD | TD S/ | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 9:35 | 9:37 | | 9:39 | 9:48 | 9:50 | 9:51 | 9:53 | 9:54 | | 9:56 | 9:57 | 9:59 | 10:00 | 10:02 | 10:02 | | 10:05 |
| Temp (C) | 37.6 | 1  1.35 | | 37.4 | 1/3ml | 37.4 | 1 ml | 37.3 | 1  1.57 | | 37.1 | 1 ml | 37.2 | 1/3ml | 37.1 | 1  1.65 | | 37.0 |
| RR | 10 | 2  1.38 | 1.4 | 10 | 1.28 | 10 | 1.48 | 10 | 2  1.51 | 1.3 | 10 | 1.67 | 10 | 1.46 | 10 | 2  1.74 | 1.2 | 10 |
| HR | 60 | 3  1.28 | 1.4 | 63 | S/N 0.2 * | 66 | S/N 0.5 | 67 | 3  1.55 | 1.2 | 69 | S/N 0.5 | 68 | S/N 0.2 * | 70 | 3  1.61 | 1.2 | 71 |
| MAP | 56 | 4 | | 54 | | 53 | | 53 | 4 | | 53 | | 51 | | 51 | 4 | | 51 |
| S/D | 83/48 | 5 | | 79/47 | | 77/46 | | 77/47 | 5 | | 77/47 | | 69/46 | | 75/45 | 5 | | 75/45 |
| PA Press | 14 | 6 | | 14 | | 12 | | 12 | 6 | | 17 | | | | 16 | 6 | | |
| PA S/D | 16/11 | 7 | | 16/12 | | 14/10 | | 13/10 | 7 | | 18/15 | | | | 17/14 | 7 | | |
| Halo. I/E | I 1.9 E 1.5 | 8 | | I 2.0 E 1.5 | | I 2.1 E 1.6 | | I 2.0 E 1.6 | 8 | | I 2.0 E 1.6 | | I 2.1 E 1.5 | | I 2.0 E 1.6 | 8 | | I 2.1 E 1.5 |
| ET CO2 | 32 | 9 | | 36 | | 35 | | 38 | 9 | | 39 | | 40 | | 39 | 9 | | 40 |
| Hb | 11.6 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 149 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 9:33 0.01 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

Analyzed in chapters 2 and 3.

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**Appendix 4.10:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 10**

Date: Nov 3/99          Anesthetic Plane: Start: 10:27  Finish: 11:00  Premed: Butorphanol 0.4 mg/kg IM          LiCla: 0.2mM     LiClb: 0.6mM

Animal # 10          MAP Range: 54 to 59 mmHg          Induction: Thiopental 10 mg/kg IV          Rate of CO: normal

Weight: 36.4 kg          Volume of Iced Dextrose Used: 10 ml          Maintenance: Halothane     Li Sensor Constant: 10.5     Cardiac Output Constant: 0.542

| sensor 1 | CV Status | TD | TD S/ | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 10:27 | 10:28 | | 10:31 | 10:36 | 10:37 | 10:39 | 10:41 | 10:42 | | 10:44 | 10:45 | 10:47 | 10:52 | 10:56 | 10:57 | | 11:00 |
| Temp (C) | 36.8 | 1 / 1.74 | 1.2 | 36.6 | 1/3ml | 36.6 | 1 ml | 36.6 | 1 / 1.98 | 1.2 | 36.4 | 1 ml | 36.4 | 1/3ml | 36.4 | 1 / 1.90 | 1.2 | 36.2 |
| RR | 10 | 2 / 1.80 | 1.2 | 10 | 1.77 | 10 | 2.28 | 10 | 2 / 1.80 | 1.1 | 10 | 2.12 | 10 | ** 1.38 | 10 | 2 / 1.79 | 1.1 | 10 |
| HR | 61 | 3 / 1.84 | 1.2 | 62 | S/N 0.18 * | 62 | S/N 0.38 | 62 | 3 / 1.92 | 1.1 | 61 | S/N 0.4 | 60 | S/N 0.13 * | 61 | 3 / 1.90 | 1.1 | 60 |
| MAP | 59 | 4 | | 57 | | 58 | | 54 | 4 | | 55 | | 57 | 10:55 | 55 | 4 | | 55 |
| S/D | 76/51 | | | 88/48 | | 91/49 | | 83/45 | | | 86/46 | | 89/47 | 1.87 | 78/48 | | | 92/46 |
| PA Press | 14 | | | 15 | | 14 | | 14 | | | 14 | | 14 | 1/3ml | 15 | | | 14 |
| PA S/D | 16/14 | | | 16/12 | | 21/9 | | 20/10 | | | 15/11 | | 14/12 | | 15/11 | | | 21/10 |
| Halo. I/E | I 1.4 E 1.2 | | | I 1.4 E 1.2 | | I 1.4 E 1.2 | | I 1.3 E 1.2 | | | I 1.4 E 1.2 | | I 1.4 E 1.1 | | I 1.3 E 1.1 | | | I 1.4 E 1.2 |
| ET CO2 | 36 | | | 40 | | 38 | | 39 | | | 40 | | 38 | | 39 | | | 38 |
| Hb | 11.7 | | | | | | | | | | | | | | | | | |
| Na++ | 146 | | | | | | | | | | | | | | | | | |
| Time | 10:37 | | | | | | | | | | | | | | | | | |
| Li [ ] | 0.04 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device
** arterial catheter obstructed – repeat test

Analyzed in chapters 2 and 3.

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**Appendix 4.10:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 10**

Date: Nov 3/99    Anesthetic Plane: Start: 11:37 Finish: 12:02  Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 10    MAP Range: 71 to 77 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: high – dobutamine

Weight: 36.4 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.542

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 11:37 | 11:38 | | 11:39 | 11:41 | 11:42 | 11:45 | 11:45 | 11:47 | | 11:48 | 11:49 | 11:50 | 11:52 | 12:00 | 12:01 | | 12:02 |
| Temp (C) | 36.1 | 1  4.90 | 0.9 | 35.9 | 1½ ml | 35.9 | ½ ml | 35.9 | 1  6.13 | 0.7 | 35.8 | ½ ml | 35.8 | 1½ ml | 35.8 | 1  7.79 | 0.7 | 35.7 |
| RR | 10 | 2  4.90 | 0.9 | 10 | 5.56 | 10 | 5.74 | 10 | 2  6.65 | 0.7 | 10 | 6.56 | 10 | **  2.30 | 10 | 2  7.30 | 0.7 | 10 |
| HR | 66 | 3  4.87 | 0.85 | 69 | S/N >0.6 | 73 | S/N 0.23* | 73 | 3  6.05 | 0.7 | 80 | S/N 0.22* | 83 | S/N 0.55 | 95 | 3  7.73 | 0.7 | 92 |
| MAP | 71 | 4 | | 72 | | 70 | | 73 | 4 | | 75 | | 75 | | 72 | 4 | | 77 |
| S/D | 135/51 | 5 | | 140/51 | | 138/50 | | 142/52 | 5 | | 142/55 | | 144/55 | | 137/53 | 5 | | 143/57 |
| PA Press | 21 | 6 | | 21 | | 22 | | 21 | 6 | | 23 | | 23 | | 23 | 6 | | 23 |
| PA S/D | 35/16 | 7 | | 36/18 | | 37/17 | | 38/18 | 7 | | 37/17 | | 37/17 | | 39/16 | 7 | | 38/17 |
| Halo. I/E | 11.6 E1.2 | 8 | | 11.6 E1.3 | | 11.6 E1.2 | | 11.5 E1.2 | 8 | | 11.6 E1.2 | | 11.5 E1.2 | | 11.6 E1.2 | 8 | | 11.7 E1.2 |
| ET CO2 | 40 | 9 | | 42 | | 42 | | 42 | 9 | | 44 | | 44 | | 45 | 9 | | 45 |
| Hb | 16.1 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 147 | | | | | | | | | | | | | | | | | |
| Time Li[ ] | 11:31 0.06 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device
** did not change dosage of LiCl in the computer – repeat test

Not analyzed in chapter 2 and 3 (objective 1) – Method error
Analyzed in chapter 3 (objective 2)

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**Appendix 4.10: Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 10**

Date: Nov 3/99  Anesthetic Plane: Start: 12:42  Finish: 1:00  Premed: Butorphanol 0.4 mg/kg IM  LiCla: 0.6mM  LiClb: 0.2mM

Animal # 10  MAP Range: 22 to 34 mmHg  Induction: Thiopental 10 mg/kg IV  Rate of CO: markedly low - deep anesthesia

Weight: 36.4 kg  Volume of Iced Dextrose Used: 5 ml  Maintenance: Halothane  Li Sensor Constant: 10.5  Cardiac Output Constant: 0.247

| sensor 2 | CV/Status | TD | TD S/N | CV/Status | LiCla | CV/Status | LiClb | CV/Status | TD | TD S/N | CV/Status | LiClb | CV/Status | LiCla | CV/Status | TD | TD S/N | CV/Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 12:42 | 12:44 | | 12:48 | 12:49 | 12:53 | 12:55 | 12:58 | 1:00 | | | | | | | | | |
| Temp (C) | 35.4 | 1  0.80 | 0.5 | 35.3 | 1 ml | 35.3 | 1/3ml | 35.3 | 1  0.33 | | | | | | | 1 | | |
| RR | 10 | 2  0.78 | 0.5 | 10 | 0.69 | 10 | 0.57 | 10 | 2 | | | | | | | 2 | | |
| HR | 77 | 3  0.69 | 0.5 | 78 | S/N 0.48 | 91 | S/N 0.17* | 79 | 3 | | | S/N | | S/N | | 3 | | |
| MAP | 34 | 4  0.68 | 0.5 | 27 | | 24 | | 22 | 4 | | | | | | | 4 | | |
| S/D | 45/31 | 5  0.73 | 0.5 | 32/24 | | 28/23 | | 24/21 | 5 | | | | | | | 5 | | |
| PA Press | 15 | 6 | | 15 | | 14 | | 14 | 6 | | | | | | | 6 | | |
| PA S/D | 20/12 | 7 | | 17/12 | | 19/13 | | 17/12 | 7 | | | | | | | 7 | | |
| Halo. I/E | I 3.2  E 2.8 | 8 | | I 3.3  E 2.9 | | I 3.3  E 2.9 | | I 3.4  E 3.1 | 8 | | I  E | | I  E | | I  E | 8 | | I  E |
| ET CO2 | 24 | 9 | | 24 | | 23 | | 17 | 9 | | | | | | | 9 | | |
| Hb | 13.1 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 143 | | | | | | | | | | | | | | | | | |
| Time Li[] | 12:41  0.14 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device

1:00 pm – dog had very low pressures and ST segment depression aborted sheet to wake dog up

Not analyzed in chapters 2 and 3 (objective 1) – Method error

Analyzed in chapter 3 (objective 2)

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**Appendix 4.10: Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 10**

Date: Nov 3/99          Anesthetic Plane: Start: 1:17  Finish: 1:45    Premed: Butorphanol 0.4 mg/kg IM          LiCla: 0.6mM      LiClb: 0.2mM

Animal # 10             MAP Range: 27 to 38 mmHg                       Induction: Thiopental 10 mg/kg IV          Rate of CO: markedly low - deep anesthesia

Weight: 36.4 kg         Volume of Iced Dextrose Used: 5 ml             Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant: 0.247

| sensor 2 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1:17 | 1:18 | | 1:22 | 1:25 | 1:27 | 1:28 | 1:29 | 1:30 | | 1:34 | 1:36 | 1:37 | 1:39 | 1:40 | 1:41 | | 1:45 |
| Temp (C) | 35.3 | 1 / 1.24 | 0.5 | 35.2 | 1 ml | 35.2 | 1/3 ml | 35.2 | 1 / 0.73 | 0.4 | 35.1 | 1/3 ml | 35.1 | 1 ml | 35.1 | 1 / 0.76 | 0.45 | 35.1 |
| RR | 10 | 2 / 1.09 | 0.5 | 10 | ** 1.20 | 10 | ** 0.97 | 10 | 2 / 0.73 | 0.45 | 10 | ** 0.87 | 10 | ** 0.97 | 10 | 2 / 0.81 | 0.45 | 10 |
| HR | 73 | 3 / 1.05 | 0.5 | 75 | S/N 0.48 | 75 | S/N 0.17* | 78 | 3 / 0.72 | 0.45 | 78 | S/N 0.18* | 79 | S/N 0.47 | 79 | 3 / 0.81 | 0.45 | 80 |
| MAP | 38 | 4 / 0.99 | 0.5 | 31 | | 28 | | 27 | 4 | | 28 | | 27 | | 28 | 4 | | 31 |
| S/D | 51/34 | 5 | | 39/28 | | 34/26 | | 32/25 | 5 | | 33/26 | | 32/25 | | 33/26 | 5 | | 36/28 |
| PA Press | 18 | 6 | | 17 | | 15 | | 16 | 6 | | 16 | | 15 | | 16 | 6 | | 16 |
| PA S/D | 21/14 | 7 | | 17/14 | | 18/13 | | 19/14 | 7 | | 19/14 | | 19/13 | | 20/13 | 7 | | 19/13 |
| Halo. I/E | I 2.7 E 2.3 | 8 | | I 3.0 E 2.4 | | I 3.1 E 2.4 | | I 2.7 E 2.3 | 8 | | I 2.7 E 2.3 | | I 2.7 E 2.2 | | I 2.6 E 2.2 | 8 | | I 2.7 E 2.2 |
| ET CO2 | 36 | 9 | | 33 | | 34 | | 35 | 9 | | 31 | | 33 | | 37 | 9 | | 44 |
| Hb | 13.1 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 142 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 1:15 / 0.16 | | | | | | | | | | | | | | | | | |

\* peak concentration below recommended level for the device        Not analyzed in chapters 2 and 3 (objective 1) – Method error
\*\* curve too long, unusual shape curve                            Analyzed in chapter 3 (objective 2)

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**Appendix 4.10: Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 10**

Date: Nov 3/99  Anesthetic Plane: Start: 2:46 Finish: 2:53  Premed: Butorphanol 0.4 mg/kg IM  LiCla: 0.2mM  LiClb: 0.6mM

Animal # 10  MAP Range: 63 to 65 mmHg  Induction: Thiopental 10 mg/kg IV  Rate of CO: normal

Weight: 36.4 kg  Volume of Iced Dextrose Used: 10 ml  Maintenance: Halothane  Li Sensor Constant: 10.5  Cardiac Output Constant: 0.542

| sensor 2 | CV / Status | TD | TD / S/N | CV / Status | LiCla | CV / Status | LiClb | CV / Status | TD | TD / S/N | CV / Status | LiClb | CV / Status | LiCla | CV / Status | TD | TD / S/N | CV / Status | LiClb | CV / Status | LiCla | CV / Status | TD | TD / S/N | CV / Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:46 | 2:47 | | 2:51 | 2:52 | 2:53 | | | | | | | | | | | | | | | | | | | |
| Temp (C) | 34.4 | 1 / 2.40 | 1.3 | 34.3 | ½ ml | 34.4 | | | 1 | | | | | | | 1 | | | | | | | 1 | | |
| RR | 10 | 2 / 2.31 | 1.3 | 10 | 3.26 | 10 | | | 2 | | | | | | | 2 | | | | | | | 2 | | |
| HR | 77 | 3 / 2.24 | 1.3 | 77 | S/N 0.23* | 78 | S/N | | 3 | | | S/N | | S/N | | 3 | | | S/N | | S/N | | 3 | | |
| MAP | 65 | 4 | | 64 | | 63 | | | 4 | | | | | | | 4 | | | | | | | 4 | | |
| S/D | 90/54 | 5 | | 89/53 | | 88/53 | | | 5 | | | | | | | 5 | | | | | | | 5 | | |
| PA Press | 16 | 6 | | 17 | | 17 | | | 6 | | | | | | | 6 | | | | | | | 6 | | |
| PA S/D | 20/14 | 7 | | 21/15 | | 22/15 | | | 7 | | | | | | | 7 | | | | | | | 7 | | |
| Halo. I/E | I 1.2 / E 1.2 | 8 | | I 1.3 / E 1.2 | | I 1.3 / E 1.2 | | I / E | 8 | | I / E | | I / E | | I / E | 8 | | I / E | | I / E | | I / E | 8 | | I / E |
| ET CO2 | 37 | 9 | | 39 | | 43 | | | 9 | | | | | | | 9 | | | | | | | 9 | | |
| Hb | 12.2 | 10 | | | | | | | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 143 | | | | | | | | | | | | | | | | | | | | | | | | |
| Time / Li [ ] | 2:45 / 0.23 | | | | | | | | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device
Note; forgot to change to new sensor at the beginning of this sheet -- start over

Not analyzed in chapters 2 and 3 (objective 1) – Method error
Analyzed in chapter 3 (objective 2)

**Appendix 4.10:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 10**

Date: Nov 3/99    Anesthetic Plane: Start: 2:57  Finish: 3:15    Premed: Butorphanol 0.4 mg/kg IM    LiCla: 0.6mM    LiClb: 0.2mM

Animal # 10    MAP Range: 63 to 67 mmHg    Induction: Thiopental 10 mg/kg IV    Rate of CO: normal

Weight: 36.4 kg    Volume of Iced Dextrose Used: 10 ml    Maintenance: Halothane   Li Sensor Constant: 10.5    Cardiac Output Constant: 0.542

| sensor 3 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 2:57 | 2:58 | | 3:01 | 3:02 | 3:03 | 3:05 | 3:06 | 3:07 | | 3:08 | 3:09 | 3:10 | 3:12 | 3:13 | 3:14 | | 3:15 |
| Temp (C) | 34.3 | 1 / 2.56 | 1.1 | 34.2 | 1½ ml | 34.2 | ½ ml | 34.2 | 1 / 2.68 | 1.1 | 34.1 | ½ ml | 34.1 | 1½ ml | 34.1 | 1 / 2.71 | 1.0 | 34.0 |
| RR | 10 | 2 / 2.39 | 1.1 | 10 | 2.82 | 10 | 2.76 | 10 | 2 / 2.58 | 1.1 | 10 | 2.83 | 10 | 3.09 | 10 | 2 / 2.76 | 1.0 | 10 |
| HR | 77 | 3 / 2.44 | 1.2 | 76 | S/N >0.6 | 76 | S/N 0.25 | 77 | 3 / 2.65 | 1.1 | 77 | S/N 0.25 | 75 | S/N >0.6 | 74 | 3 / 2.88 | 1.0 | 75 |
| MAP | 67 | 4 | | 64 | | 67 | | 67 | 4 | | 66 | | 67 | | 66 | 4 | | 63 |
| S/D | 94/56 | 5 | | 90/54 | | 94/56 | | 94/56 | 5 | | 92/55 | | 80/57 | | 93/55 | 5 | | 90/53 |
| PA Press | 18 | 6 | | 19 | | 17 | | 18 | 6 | | 19 | | 17 | | 17 | 6 | | 18 |
| PA S/D | 22/16 | 7 | | 20/14 | | 22/14 | | 22/14 | 7 | | 23/16 | | 21/15 | | 18/13 | 7 | | 20/14 |
| Halo. I/E | I 1.2 E 1.2 | 8 | | I 1.2 E 1.2 | | I 1.2 E 1.2 | | I 1.2 E 1.1 | 8 | | I 1.2 E 1.1 | | I 1.2 E 1.1 | | I 1.2 E 1.2 | 8 | | I 1.2 E 1.1 |
| ET CO2 | 39 | 9 | | 40 | | 39 | | 39 | 9 | | 40 | | 40 | | 40 | 9 | | 39 |
| Hb | 12.2 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 143 | | | | | | | | | | | | | | | | | |
| Time Li[ ] | | | | | | | | | | | | | | | | | | |

Analyzed in chapter 3.

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**Appendix 4.10:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 10**

Date: Nov 3/99     Anesthetic Plane: Start: 3:20 Finish: 3:38     Premed: Butorphanol 0.4 mg/kg IM     LiCla: 0.2mM     LiClb: 0.6mM

Animal # 10     MAP Range: 62 to 65 mmHg     Induction: Thiopental 10 mg/kg IV     Rate of CO: normal

Weight: 36.4 kg     Volume of Iced Dextrose Used: 10 ml     Maintenance: Halothane     Li Sensor Constant: 10.5     Cardiac Output Constant: 0.542

| sensor 3 | CV Status | TD | TD S/N | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:20 | 3:21 |  | 3:25 | 3:26 | 3:27 | 3:28 | 3:29 |  | 3:31 | 3:32 | 3:33 | 3:35 | 3:36 | 3:37 |  | 3:38 |
| Temp (C) | 34.1 | 1 2.48 | 1.1 | ½ ml | 34.0 | 1½ ml | 34.0 | 1 2.62 | 1.1 | 33.9 | 1½ ml | 33.9 | ½ ml | 33.9 | 1 2.73 | 1.0 | 33.8 |
| RR | 10 | 2 2.35 | 1.1 | 2.58 | 10 | 3.07 | 10 | 2 2.68 | 1.0 | 10 | 3.18 | 10 | 3.16 | 10 | 2 2.61 | 1.1 | 10 |
| HR | 68 | 3 2.43 | 1.1 | S/N 0.25 | 69 | S/N >0.6 | 72 | 3 2.64 | 1.1 | 70 | S/N >0.6 | 71 | S/N 0.23* | 71 | 3 2.64 | 1.0 | 68 |
| MAP | 65 | 4 |  |  | 62 |  | 63 | 4 |  | 63 |  | 64 |  | 64 | 4 |  | 63 |
| S/D | 94/54 | 5 |  |  | 78/54 |  | 82/52 | 5 |  | 77/52 |  | 79/55 |  | 93/52 | 5 |  | 92/51 |
| PA Press | 17 | 6 |  |  | 17 |  | 17 | 6 |  | 17 |  | 18 |  | 17 | 6 |  | 17 |
| PA S/D | 19/13 | 7 |  |  | 17/13 |  | 18/13 | 7 |  | 19/14 |  | 21/15 |  | 19/13 | 7 |  | 20/13 |
| Halo. I/E | I 1.2 E 1.1 | 8 |  |  | I 1.2 E 1.1 |  | I 1.2 E 1.1 | 8 |  | I 1.2 E 1.1 |  | I 1.2 E 1.1 |  | I 1.1 E 1.0 | 8 |  | I 1.1 E 1.0 |
| ET CO2 | 36 | 9 |  |  | 39 |  | 39 | 9 |  | 38 |  | 39 |  | 38 | 9 |  | 37 |
| Hb | 11.9 | 10 |  |  |  |  |  |  |  |  |  |  |  |  | 10 |  |  |
| Na++ | 140 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Time Li[] | 3:16 0.26 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

* peak concentration below recommended level for the device                    Analyzed in chapter 3.

Appendix 4.10:   Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 10

Date: Nov 3/99     Anesthetic Plane: Start: 3:45  Finish: 4:03     Premed: Butorphanol 0.4 mg/kg IM     LiCla: 0.2mM     LiClb: 0.6mM

Animal # 10     MAP Range: 62 to 64 mmHg     Induction: Thiopental 10 mg/kg IV     Rate of CO: normal

Weight: 36.4 kg     Volume of Iced Dextrose Used: 10 ml     Maintenance: Halothane     Li Sensor Constant: 10.5     Cardiac Output Constant: 0.542

| sensor 4 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3:45 | 3:46 | | 3:48 | 3:50 | 3:51 | 3:52 | 3:53 | 3:54 | | 3:56 | 3:57 | 3:58 | 4:00 | 4:01 | 4:02 | | 4:03 |
| Temp (C) | 33.8 | 1 / 2.22 | 1.1 | 33.7 | ½ ml | 33.7 | 1½ ml | 33.7 | 1 / 2.41 | 1.1 | 33.6 | 1½ ml | 33.7 | ½ ml | 33.7 | 1 / 2.56 | 1.1 | 33.5 |
| RR | 10 | 2 / 2.24 | 1.1 | 10 | 2.56 | 10 | 2.87 | 10 | 2 / 2.54 | 1.0 | 10 | 2.99 | 9 | 2.87 | 10 | 2 / 2.50 | 1.0 | 10 |
| HR | 61 | 3 / 2.26 | 1.1 | 63 | S/N 0.24* | 64 | S/N 0.6 | 64 | 3 / 2.49 | 1.1 | 65 | S/N 0.6 | 64 | S/N 0.22* | 64 | 3 / 2.63 | 1.0 | 64 |
| MAP | 63 | 4 | | 63 | | 63 | | 64 | 4 | | 63 | | 63 | | 63 | 4 | | 62 |
| S/D | 95/52 | 5 | | 93/51 | | 93/51 | | 93/52 | 5 | | 92/51 | | 94/52 | | 92/51 | 5 | | 92/50 |
| PA Press | 18 | 6 | | 17 | | 17 | | 17 | 6 | | 17 | | 18 | | 19 | 6 | | 17 |
| PA S/D | 21/15 | 7 | | 21/15 | | 19/14 | | 22/14 | 7 | | 21/14 | | 21/15 | | 21/16 | 7 | | 22/14 |
| Halo. I/E | 1 1.1 / E 1.0 | 8 | | 1 1.1 / E 1.0 | | 1 1.0 / E 0.9 | | 1 1.1 / E 1.0 | 8 | | 1 1.1 / E 0.9 | | 1 1.1 / E 0.9 | | 1 1.1 / E 1.0 | 8 | | 1 1.0 / E 0.9 |
| ET CO2 | 34 | 9 | | 37 | | 38 | | 39 | 9 | | 37 | | 38 | | 36 | 9 | | 36 |
| Hb | 11.5 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 140 | | | | | | | | | | | | | | | | | |
| Time | 3:40 | | | | | | | | | | | | | | | | | |
| Li [ ] | 0.30 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device                    Analyzed in chapter 3.

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**Appendix 4.10: Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 10**

Date: Nov 3/99  Anesthetic Plane: Start: 4:06  Finish: 4:26  Premed: Butorphanol 0.4 mg/kg IM  LiCla: 0.6nM  LiClb: 0.2nM

Animal # 10  MAP Range: 60 to 63 mmHg  Induction: Thiopental 10 mg/kg IV  Rate of CO: normal

Weight: 36.4 kg  Volume of Iced Dextrose Used: 10 ml  Maintenance: Halothane  Li Sensor Constant: 10.5  Cardiac Output Constant: 0.542

| sensor 4 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 4:06 | 4:07 | | 4:08 | 4:13 | 4:15 | 4:16 | 4:17 | 4:18 | | 4:19 | 4:20 | 4:21 | 4:23 | 4:24 | 4:25 | | 4:26 |
| Temp (C) | 33.6 | 1 2.26 | 1.0 | 33.5 | 1½ ml | 33.5 | ½ ml | 33.5 | 1 2.43 | 1.1 | 33.4 | ½ ml | 33.4 | 1½ ml | 33.4 | 1 2.44 | 1.0 | 33.3 |
| RR | 10 | 2 2.31 | 1.1 | 10 | 2.49 | 10 | 2.39 | 10 | 2 2.32 | 1.1 | 10 | 2.85 | 10 | 2.90 | 10 | 2 2.40 | 1.1 | 11 |
| HR | 60 | 3 2.51 | 1.0 | 59 | S/N 0.6 | 58 | S/N 0.22* | 60 | 3 2.43 | 1.0 | 61 | S/N 0.22* | 61 | S/N 0.55 | 62 | 3 2.51 | 1.0 | 59 |
| MAP | 63 | 4 | | 61 | | 60 | | 60 | 4 | | 60 | | 62 | | 60 | 4 | | 61 |
| S/D | 93/51 | 5 | | 90/50 | | 91/50 | | 92/49 | 5 | | 92/49 | | 92/50 | | 91/49 | 5 | | 91/49 |
| PA Press | 17 | 6 | | 18 | | 17 | | 18 | 6 | | 16 | | 17 | | 18 | 6 | | 17 |
| PA S/D | 19/14 | 7 | | 21/15 | | 20/14 | | 21/15 | 7 | | 20/14 | | 20/14 | | 20/15 | 7 | | 20/14 |
| Halo. I/E | 1 1.0 E 0.9 | 8 | | 1 1.1 E 0.9 | | 1 1.0 E 0.9 | | 1 1.0 E 0.9 | 8 | | 1 1.0 E 0.9 | | 1 1.1 E 0.9 | | 1 1.1 E 0.9 | 8 | | 1 1.0 E 0.9 |
| ET CO2 | 34 | 9 | | 36 | | 37 | | 36 | 9 | | 36 | | 36 | | 36 | 9 | | 37 |
| Hb | 10.9 | 10 | | | | | | | 10 | | | | | | | 10 | | |
| Na++ | 139 | | | | | | | | | | | | | | | | | |
| Time Li [ ] | 4:04 0.34 | | | | | | | | | | | | | | | | | |

* peak concentration below recommended level for the device  Analyzed in chapter 3.

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**Appendix 4.10:  Lithium Dilution Cardiac Output vs. Thermodilution Cardiac Output Data Sheet for Dog 10**

Date: Nov 3/99   Anesthetic Plane: Start: 4:30  Finish: 4:48   Premed: Butorphanol 0.4 mg/kg IM   LiCla: 0.2mM   LiClb :0.6mM

Animal #10   MAP Range: 58 to 62 mmHg   Induction: Thiopental 10 mg/kg IV   Rate of CO: normal

Weight: 36.4  kg   Volume of Iced Dextrose Used: 10 ml   Maintenance: Halothane   Li Sensor Constant: 10.5   Cardiac Output Constant:  0.542

| sensor 5 | CV Status | TD | TD S/N | CV Status | LiCla | CV Status | LiClb | CV Status | TD | TD S/N | CV Status | LiClb | CV Status | LiCla | CV Status | TD | TD S/N | CV Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 4:30 | 4:31 |  | 4:34 | 4:35 | 4:36 | 4:37 | 4:38 | 4:39 |  | 4:41 | 4:42 | 4:43 | 4:44 | 4:45 | 4:46 |  | 4:48 |
| Temp (C) | 33.4 | 1 / 2.26 | 1.0 | 33.3 | ½ ml | 33.3 | 1½ ml | 33.3 | 1 / 2.63 | 1.0 | 33.2 | 1½ ml | 33.2 | ½ ml | 33.2 | 1 / 2.62 | 0.9 | 33.1 |
| RR | 10 | 2 / 2.26 | 1.1 | 10 | 2.82 | 10 | 3.00 | 10 | 2 / 2.44 | 1.1 | 10 | 3.21 | 10 | 3.03 | 10 | 2 / 2.51 | 1.0 | 10 |
| HR | 57 | 3 / 2.33 | 1.0 | 60 | S/N 0.25 | 60 | S/N 0.6 | 60 | 3 / 2.48 | 1.0 | 60 | S/N 0.55 | 59 | S/N 0.22* | 59 | 3 / 2.58 | 1.0 | 59 |
| MAP | 61 | 4 |  | 61 |  | 62 |  | 62 | 4 |  | 60 |  | 62 |  | 60 | 4 |  | 58 |
| S/D | 92/49 | 5 |  | 92/47 |  | 93/51 |  | 92/50 | 5 |  | 91/48 |  | 92/48 |  | 92/49 | 5 |  | 89/47 |
| PA Press | 17 | 6 |  | 18 |  | 18 |  | 17 | 6 |  | 17 |  | 18 |  | 18 | 6 |  | 17 |
| PA S/D | 19/14 | 7 |  | 22/16 |  | 21/15 |  | 20/13 | 7 |  | 20/14 |  | 21/15 |  | 21/15 | 7 |  | 20/13 |
| Halo. I/E | I 1.0 E 0.9 | 8 |  | I 1.0 E 0.9 |  | I 1.0 E 0.9 |  | I 1.0 E 0.9 | 8 |  | I 1.0 E 0.9 |  | I 1.0 E 0.9 |  | I 1.0 E 0.9 | 8 |  | I 1.0 E 0.9 |
| ET CO2 | 34 | 9 |  | 34 |  | 35 |  | 34 | 9 |  | 35 |  | 35 |  | 36 | 9 |  | 35 |
| Hb | 10.8 | 10 |  |  |  |  |  |  | 10 |  |  |  |  |  |  | 10 |  |  |
| Na++ | 139 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Time | 4:27 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 4:50 |
| Li [ ] | 0.38 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.42 |

* peak concentration below recommended level for the device

Analyzed in chapter 3.

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# Appendix 5: Summary of Data Used for Analysis in Chapters 2 and 3, Which Were Extracted From Appendix 4

**Appendix 5.0:**     **Index of abbreviations**

| | |
|---|---|
| 3a | Chapter 3 - primary objective |
| 3b | Chapter 3 – secondary objective |
| Analyzed in chapter | Indicates which chapters and objectives the data were used for |
| H | High rate of cardiac output - dobutamine |
| LiDCO-HD | Lithium dilution cardiac output – high dose of lithium chloride |
| LiDCO-LD | Lithium dilution cardiac output – low dose of lithium chloride |
| Method | The method used to produce a rate of cardiac output |
| ML | Mildly low rate of cardiac output – moderately deep anesthesia |
| N | Normal rate of cardiac output – light anesthesia |
| Rate | The ordered number in which the cardiac output rates occurred |
| TDCO | Thermodilution cardiac output |
| VL | Very low rate of cardiac output – occlusion catheter or markedly deep anesthesia |

**Appendix 5.1**      **Dog 1**

| Rate / Method | Analyzed in Chapter | TDCO | LiDCO-LD | TDCO | LiDCO-HD | TDCO | LiDCO-HD | TDCO | LiDCO-LD |
|---|---|---|---|---|---|---|---|---|---|
| 1 / ML | 2,3a,3b | 1.39 | 1.21 | 1.46 | 1.32 | 1.46 | 1.47 | 1.52 | 1.48 |
| 2 / H | 3b | 5.54 | 5.63 | 5.50 | 5.75 | 5.50 | 5.77 | 5.55 | NR |
| 3 / VL | 3b | 0.74 | 0.70 | 0.70 | 0.81 | 0.70 | 0.81 | 0.70 | 0.81 |
| 4 / N | 3b | 4.50 | NR | 4.00 | 6.65 | 4.00 | 7.06 | 3.74 | 6.91 |

**Appendix 5.2**      **Dog 2**

| Rate / Method | Analyzed in Chapter | TDCO | LiDCO-LD | TDCO | LiDCO-HD | TDCO | LiDCO-HD | TDCO | LiDCO-LD |
|---|---|---|---|---|---|---|---|---|---|
| 2 / H | 2,3b | 10.97 | 11.83 | 12.43 | 12.75 | 12.43 | 13.16 | 11.87 | 12.58 |
| 3 / ML | 3b | 0.96 | 1.02 | 0.72 | 0.92 | 0.72 | 0.68 | 0.86 | 0.49 |
| 4 / N | 3b | 4.40 | 4.76 | 4.57 | 5.00 | 4.57 | 5.10 | 4.57 | 5.11 |
| 5 / N | 3b | 4.46 | 4.66 | 4.36 | 5.01 | 4.36 | 5.09 | 4.51 | 4.97 |
| 6 / N | 3b | 4.74 | 5.06 | 4.83 | 5.09 | 4.83 | 5.85 | 4.98 | 5.64 |
| 7 / N | 3b | 4.83 | 5.33 | 4.82 | 5.94 | 4.82 | 5.44 | 5.08 | 5.80 |

| | | TDCO | LiDCO-HD | TDCO | LiDCO-LD | TDCO | LiDCO-LD | TDCO | LiDCO-HD |
|---|---|---|---|---|---|---|---|---|---|
| 1 / VL | 3b | 0.57 | 0.44 | 0.59 | 0.49 | 0.59 | 0.52 | 0.76 | 0.63 |
| 8 / N | 3b | 4.91 | 5.61 | 4.34 | 5.22 | 4.34 | 5.05 | 4.33 | 5.38 |

**Appendix 5.3**      **Dog 3**

| Rate / Method | Analyzed in Chapter | TDCO | LiDCO-LD | TDCO | LiDCO-HD | TDCO | LiDCO-HD | TDCO | LiDCO-LD |
|---|---|---|---|---|---|---|---|---|---|
| 4 / VL | 3b | 0.56 | 0.94 | 0.59 | 0.94 | 0.59 | 0.90 | 0.66 | 1.02 |
| 5 / N | 3b | 3.60 | 5.86 | 3.74 | 6.59 | 3.74 | 6.84 | 3.66 | 7.17 |
| 6 / N | 3a,3b | 3.34 | 4.05 | 3.59 | 4.11 | 3.59 | 5.41 | 3.26 | 4.15 |

| | | TDCO | LiDCO-HD | TDCO | LiDCO-LD | TDCO | LiDCO-LD | TDCO | LiDCO-HD |
|---|---|---|---|---|---|---|---|---|---|
| 1 / N | 2,3a,3b | 2.00 | 2.02 | 2.02 | 1.92 | 2.02 | 2.14 | 2.12 | 2.36 |
| 2 / ML | 2,3a,3b | 1.07 | 1.13 | 1.09 | 1.23 | 1.09 | 1.24 | 1.12 | 1.35 |
| 3 / H | 3b | 3.98 | 5.25 | 4.82 | 5.86 | 4.82 | 7.42 | 4.79 | 7.33 |

## Appendix 5.4        Dog 4

| Rate / Method | Analyzed in Chapter | TDCO | LiDCO-LD | TDCO | LiDCO-HD | TDCO | LiDCO-HD | TDCO | LiDCO-LD |
|---|---|---|---|---|---|---|---|---|---|
| 1 / H | 2,3b | 8.32 | 9.52 | 9.07 | 9.69 | 9.07 | 9.46 | 9.37 | 10.05 |
| 4 / N | 3b | 2.49 | 3.14 | 3.23 | 3.29 | 3.23 | 4.32 | 2.97 | 4.02 |
| 5 / N | 3a,3b | 2.64 | 3.19 | 2.98 | 3.34 | 2.98 | 3.97 | 2.94 | 3.46 |
| 6 / N | 3a,3b | 2.76 | 3.41 | 3.04 | 3.48 | 3.04 | 3.96 | 2.96 | 4.05 |
| 7 / N | 3b | 2.65 | 3.42 | 2.91 | 3.67 | 2.91 | 3.98 | 2.99 | 4.11 |

| | | TDCO | LiDCO-HD | TDCO | LiDCO-LD | TDCO | LiDCO-LD | TDCO | LiDCO-HD |
|---|---|---|---|---|---|---|---|---|---|
| 2 / VL | 3b | 1.00 | 0.62 | 0.77 | 0.56 | 0.77 | 0.80 | 0.79 | 0.78 |
| 3 / ML | 3b | 1.43 | 1.68 | 1.59 | 1.77 | 1.59 | 1.82 | 1.64 | 1.94 |

## Appendix 5.5        Dog 5

| Rate / Method | Analyzed in Chapter | TDCO | LiDCO-LD | TDCO | LiDCO-HD | TDCO | LiDCO-HD | TDCO | LiDCO-LD |
|---|---|---|---|---|---|---|---|---|---|
| 1 / N | 2,3a,3b | 1.96 | 1.85 | 2.11 | 1.95 | 2.11 | 2.19 | 2.26 | 2.24 |
| 2 / H | 2,3b | 9.44 | 9.54 | 9.17 | 8.95 | 9.17 | 8.79 | 9.41 | 8.68 |
| 3 / VL | 2,3a,3b | 1.33 | 0.89 | 1.44 | 1.17 | 1.44 | 1.25 | 1.41 | 1.30 |

## Appendix 5.6        Dog 6

| Rate / Method | Analyzed in Chapter | TDCO | LiDCO-LD | TDCO | LiDCO-HD | TDCO | LiDCO-HD | TDCO | LiDCO-LD |
|---|---|---|---|---|---|---|---|---|---|
| 5 / N | 3a,3b | 2.53 | 2.79 | 2.82 | 2.86 | 2.82 | 3.15 | 2.90 | 2.94 |
| 6 / N | 3b | 2.42 | 2.57 | 2.92 | 2.83 | 2.92 | 3.28 | 3.03 | 3.03 |
| 9 / N | 3a,3b | 2.88 | 3.18 | 3.03 | 2.95 | 3.03 | 3.42 | 3.13 | 3.18 |

| | | TDCO | LiDCO-HD | TDCO | LiDCO-LD | TDCO | LiDCO-LD | TDCO | LiDCO-HD |
|---|---|---|---|---|---|---|---|---|---|
| 1 / VL | 2,3a,3b | 1.37 | 1.35 | 1.58 | 0.95 | 1.58 | 1.37 | 1.52 | 1.39 |
| 2 / ML | 2,3a,3b | 1.31 | 1.30 | 1.15 | 1.18 | 1.15 | 1.33 | 1.11 | 1.19 |
| 3 / H | 2,3b | 4.50 | 4.91 | 4.61 | 4.58 | 4.61 | 5.20 | 4.78 | 5.62 |
| 4 / N | 2,3a,3b | 2.92 | 2.94 | 2.88 | 2.92 | 2.88 | 3.40 | 2.96 | 3.46 |
| 7 / N | 3a,3b | 2.71 | 2.85 | 2.89 | 2.67 | 2.89 | 2.56 | 3.03 | 2.99 |
| 8 / N | 3b | 2.47 | 3.42 | 3.55 | 3.49 | 3.55 | 3.51 | 3.48 | 3.71 |
| 10 / N | 3a,3b | 2.82 | 3.03 | 2.97 | 2.87 | 2.97 | 3.24 | 3.09 | 3.27 |

**Appendix 5.7**    **Dog 7**

| Rate / Method | Analyzed in Chapter | TDCO | LiDCO-LD | TDCO | LiDCO-HD | TDCO | LiDCO-HD | TDCO | LiDCO-LD |
|---|---|---|---|---|---|---|---|---|---|
| 2 / VL | 2,3a,3b | 1.49 | 0.98 | 1.47 | 1.22 | 1.47 | 1.27 | 1.55 | 1.13 |
| 6 / N | 3a,3b | 2.91 | 3.06 | 2.97 | 3.58 | 2.97 | 3.79 | 2.93 | 4.11 |
| 9 / N | 3a,3b | 2.69 | 2.48 | 2.73 | 2.86 | 2.73 | 3.04 | 2.86 | 2.94 |
|  |  | TDCO | LiDCO-HD | TDCO | LiDCO-LD | TDCO | LiDCO-LD | TDCO | LiDCO-HD |
| 1 / H | 2,3b | 7.20 | 7.21 | 7.71 | 6.45 | 7.71 | 7.00 | 7.86 | 7.41 |
| 3 / N | 2,3a,3b | 2.77 | 2.74 | 3.08 | 2.92 | 3.08 | 3.02 | 3.24 | 3.13 |
| 4 / ML | 2,3a,3b | 2.09 | 1.85 | 1.86 | 1.83 | 1.86 | 1.69 | 1.77 | 1.84 |
| 5 / N | 3a,3b | 2.40 | 2.52 | 2.64 | 2.59 | 2.64 | 2.89 | 2.67 | 3.15 |
| 7 / N | 3a,3b | 2.73 | 2.80 | 2.82 | 3.04 | 2.82 | 3.07 | 2.84 | 3.11 |
| 8 / N | 3a,3b | 2.68 | 2.97 | 2.82 | 3.06 | 2.82 | 3.27 | 2.89 | 3.42 |

**Appendix 5.8**    **Dog 8**

| Rate / Method | Analyzed in Chapter | TDCO | LiDCO-LD | TDCO | LiDCO-HD | TDCO | LiDCO-HD | TDCO | LiDCO-LD |
|---|---|---|---|---|---|---|---|---|---|
| 2 / VL | 3b | 0.80 | 0.71 | 0.79 | 0.77 | 0.79 | 0.77 | NR | 0.48 |
| 5 / N | 3a,3b | 3.27 | 3.20 | 3.25 | 3.50 | 3.25 | 3.62 | 3.12 | 3.44 |
| 9 / N | 3a,3b | 2.46 | 2.73 | 2.97 | 2.94 | 2.97 | 3.56 | 3.00 | 3.11 |
|  |  | TDCO | LiDCO-HD | TDCO | LiDCO-LD | TDCO | LiDCO-LD | TDCO | LiDCO-HD |
| 1 / ML | 3b | 2.23 | 3.13 | 2.43 | 2.69 | 2.43 | 2.48 | 2.52 | 2.20 |
| 3 / N | 2,3a,3b | 4.32 | 4.31 | 4.27 | 4.25 | 4.27 | 4.28 | 4.48 | 4.55 |
| 4 / H | 3b | 5.40 | 6.68 | 5.25 | 6.60 | 5.25 | 8.02 | 5.86 | 7.49 |
| 6 / N | 3a,3b | 2.70 | 3.06 | 2.89 | 3.23 | 2.89 | 3.28 | 2.77 | 3.37 |
| 7 / N | 3a,3b | 2.62 | 2.71 | 2.64 | 3.04 | 2.64 | 3.16 | 2.57 | 3.20 |
| 8 / N | 3a,3b | 2.47 | 3.02 | 2.58 | 3.06 | 2.58 | 3.16 | 2.64 | 3.47 |

**Appendix 5.9**        **Dog 9**

| Rate / Method | Analyzed in Chapter | TDCO | LiDCO-LD | TDCO | LiDCO-HD | TDCO | LiDCO-HD | TDCO | LiDCO-LD |
|---|---|---|---|---|---|---|---|---|---|
| 1 / N | 2,3a,3b | 3.37 | 3.05 | 3.38 | 3.21 | 3.38 | 3.44 | 3.12 | 2.79 |
| 3 / ML | 2,3a,3b | 2.28 | 2.42 | 2.19 | 2.73 | 2.19 | 2.75 | 2.24 | 2.66 |
| 4 / VL | 2,3a,3b | 1.53 | 1.36 | 1.39 | 1.53 | 1.39 | 1.53 | 1.28 | 1.46 |
| 5 / N | 3a,3b | 2.20 | 2.21 | 2.29 | 2.44 | 2.29 | 2.51 | 2.20 | 2.38 |
| 6 / N | 3a,3b | 2.09 | 2.22 | 2.28 | 2.55 | 2.28 | 2.64 | 2.32 | 2.49 |
| 8 / N | 3a,3b | 2.28 | 2.65 | 2.34 | 3.02 | 2.34 | 3.00 | 2.40 | 3.14 |
| | | TDCO | LiDCO-HD | TDCO | LiDCO-LD | TDCO | LiDCO-LD | TDCO | LiDCO-HD |
| 2 / H | 2,3b | 7.13 | 8.55 | 7.12 | 7.33 | 7.12 | 8.05 | 7.06 | 8.33 |
| 7 / N | 3a,3b | 2.32 | 2.72 | 2.33 | 2.62 | 2.33 | 2.61 | 2.31 | 2.94 |
| 9 / N | 3a,3b | 2.40 | 3.12 | 2.49 | 2.71 | 2.49 | 3.12 | 2.46 | 3.34 |

**Appendix 5.10**        **Dog 10**

| Rate / Method | Analyzed in Chapter | TDCO | LiDCO-LD | TDCO | LiDCO-HD | TDCO | LiDCO-HD | TDCO | LiDCO-LD |
|---|---|---|---|---|---|---|---|---|---|
| 1 / ML | 2,3a,3b | 1.34 | 1.28 | 1.54 | 1.48 | 1.54 | 1.67 | 1.67 | 1.46 |
| 2 / N | 2,3a,3b | 1.79 | 1.77 | 1.90 | 2.28 | 1.90 | 2.12 | 1.86 | 1.87 |
| 6 / N | 3a,3b | 2.42 | 2.58 | 2.65 | 3.07 | 2.65 | 3.18 | 2.66 | 3.16 |
| 7 / N | 3a,3b | 2.24 | 2.56 | 2.48 | 2.87 | 2.48 | 2.99 | 2.56 | 2.87 |
| 9 / N | 3a,3b | 2.28 | 2.82 | 2.52 | 3.00 | 2.52 | 3.21 | 2.57 | 3.03 |
| | | TDCO | LiDCO-HD | TDCO | LiDCO-LD | TDCO | LiDCO-LD | TDCO | LiDCO-HD |
| 3 / H | 3b | 4.89 | 5.56 | 6.28 | 5.74 | 6.28 | 6.56 | 7.61 | 8.38 |
| 4 / VL | 3b | 1.04 | 1.20 | 0.73 | 0.97 | 0.73 | 0.87 | 0.79 | 0.97 |
| 5 / N | 3a,3b | 2.46 | 2.82 | 2.64 | 2.76 | 2.64 | 2.83 | 2.78 | 3.09 |
| 8 / N | 3a,3b | 2.36 | 2.49 | 2.39 | 2.39 | 2.39 | 2.85 | 2.45 | 2.90 |

# Appendix 6: Experimental Protocol for a Rate of Cardiac Output in Chapter 3 with Paired Observations Indicated

\* TDCO \* LiDCOa \* LiDCOb \* TDCO \* LiDCOb \* LiDCOa \* TDCO \*

∪ - Encompasses the paired cardiac output observations used for analysis

\* - Collect hemodynamic and respiratory parameters, which included heart rate, respiratory rate, systemic arterial systolic, diastolic and mean pressures, pulmonary arterial systolic, diastolic and mean pressures, inspired and expired halothane concentrations, end-tidal $CO_2$ and body temperature.

TDCO - thermodilution cardiac output, three observations within 10% of each other were collected and averaged

LiDCO - lithium dilution cardiac output

LiDCOa - was randomly selected to be either the high dose or the low dose of lithium chloride

LiDCOb - was determined to be the opposite dose to LiDCOa

**Appendix 7:**     **Coefficient of Variation of the Serum Lithium Determinations Performed with an IL 943 Flame Photometer***

|  | Low Control | High Control |
|---|---|---|
|  | 0.70 mmol/L | 2.15 mmol/L |
|  | 0.70 mmol/L | 2.13 mmol/L |
|  | 0.69 mmol/L | 2.15 mmol/L |
|  | 0.69 mmol/L | 2.15 mmol/L |
|  | 0.69 mmol/L | 2.14 mmol/L |
|  | 0.67 mmol/L | 2.11 mmol/L |
|  | 0.68 mmol/L | 2.08 mmol/L |
|  | 0.67 mmol/L | 2.09 mmol/L |
|  | 0.68 mmol/L | 2.10 mmol/L |
|  | 0.69 mmol/L | 2.12 mmol/L |
|  |  |  |
| Total sample number | 10 | 10 |
| Mean value | 0.686 mmol/L | 2.122 mmol/L |
| Standard deviation | 0.011 | 0.026 |
|  |  |  |
| Coefficient of variation | 1.56 or 2 % | 1.23 or 1 % |

Each pair of control determinations was performed on separate days.

* IL 943 flame photometer, Instrumentation Laboratories, Lexington, MA

## Appendix 8: Experimental Protocol for Chapter 4 with Paired Observations Indicated

Sensor 1          Sensor 2

C    P    C    P    C    P         P    C    P    C    P    C
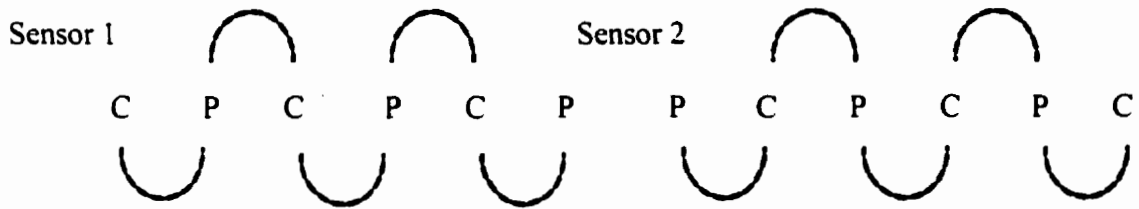
$\cup$ or $\cap$ - Encompasses the paired cardiac output observations used for analysis

C  –  Central venous injection of lithium chloride for lithium dilution cardiac output determination

P  –  Peripheral venous injection of lithium chloride for lithium dilution cardiac output determination

Sensor – Indicate the sequence of lithium sensors used in the experimental protocol

# Appendix 9: Complete Data Collected from Peripheral Venous Versus Central Venous Lithium Dilution Cardiac Output Experiment

## Appendix 9.0: Index of abbreviations

C          central lithium dilution cardiac output (L/min)

Hb         hemoglobin (g/L)

ID         identification

IM         intramuscular

IV         intravenous

kg         kilogram

LiCl       lithium chloride

LiDCO      lithium dilution cardiac output (L/min)

ml         milliliters

Na         sodium (mmol/L)

P          peripheral lithium dilution cardiac output (L/min)

S/N        signal amplitude of the indicator curve

**Appendix 9.1:** **Data Collected for Peripheral Venous vs. Central Venous Lithium Dilution Cardiac Output for Dog 1**

Date: November 16, 1999

LiCl dosage used: 1 ml (0.15 mmol/ml)

Animal ID: Dog # 1

Pre-med: Butorphanol 0.4 mg/kg IM

Weight: 11.3 kg

Induction: Thiopental 10 mg/kg IV

Arterial Hb.: 126 g/L

Maintenance: Halothane

Na: 140 mmol/L

LiDCO sensor #1                                          LiDCO sensor #2

|   | Time | LiDCO | S/N |   | Time | LiDCO | S/N |
|---|------|-------|-----|---|------|-------|-----|
| C | 14:05 | 1.74 | >0.6 | P | 14:35 | 2.49 | >0.6 |
| P | 14:07 | 1.92 | >0.6 | C | 14:37 | 2.44 | >0.6 |
| C | 14:08 | 2.12 | >0.6 | P | 14:40 | 2.13 | 0.55 |
| P | 14:09 | 2.00 | >0.6 | C | 14:42 | 2.25 | >0.6 |
| C | 14:11 | 2.30 | >0.6 | P | 14:43 | 2.76 | >0.6 |
| P | 14:12 | 2.18 | 0.6 | C | 14:45 | 2.46 | >0.6 |

| Time | Serum Lithium Concentration (mmol/L) |
|------|-------------------------------------|
| 14:00 | 0.00 |
| 14:16 | 0.35 |
| 14:47 | 0.85 |

**Appendix 9.2:**      **Data Collected for Peripheral Venous vs. Central Venous Lithium Dilution Cardiac Output for Dog 2**

Date: November 16, 1999

LiCl dosage used: 1 ml (0.15 mmol/ml)

Animal ID: Dog # 2

Pre-med: Butorphanol 0.4 mg/kg IM

Weight: 10.1 kg

Induction: Thiopental 10 mg/kg IV

Arterial Hb.: 128 g/L

Maintenance: Halothane

Na: 141 mmol/L

LiDCO sensor #1                                      LiDCO sensor #2

|   | Time | LiDCO | S/N |   | Time | LiDCO | S/N |
|---|------|-------|-----|---|------|-------|-----|
| C | 15:17 | 2.00 | >0.6 | P | 15:30 | 2.05 | >0.6 |
| P | 15:19 | 1.76 | >0.6 | C | 15:31 | 2.21 | >0.6 |
| C | 15:21 | 2.11 | >0.6 | P | 15:33 | 2.16 | >0.6 |
| P | 15:22 | 2.02 | >0.6 | C | 15:36 | 2.50 | >0.6 |
| C | 15:25 | 2.28 | >0.6 | P | 15:37 | 2.32 | >0.6 |
| P | 15:26 | 2.16 | >0.6 | C | 15:39 | 2.43 | >0.6 |

| Time | Serum Lithium Concentration (mmol/L) |
|------|--------------------------------------|
| 15:00 | 0.00 |
| 15:28 | 0.51 |

**Appendix 9.3:**     **Data Collected for Peripheral Venous vs. Central Venous Lithium Dilution Cardiac Output for Dog 3**

Date: November 30, 1999            LiCl dosage used: 1 ml (0.15 mmol/ml)

Animal ID: Dog # 3                 Pre-med: Butorphanol 0.4 mg/kg IM

Weight: 9.8 kg                     Induction: Thiopental 10 mg/kg IV

Arterial Hb.: 107 g/L              Maintenance: Halothane

Na: 141 mmol/L

LiDCO sensor #1                                    LiDCO sensor #2

|   | Time | LiDCO | S/N |   | Time | LiDCO | S/N |
|---|------|-------|-----|---|------|-------|-----|
| C | 12:43 | 1.61 | >0.6 | P | 13:00 | 1.91 | >0.6 |
| P | 12:45 | 1.76 | >0.6 | C | 13:01 | 2.15 | >0.6 |
| C | 12:48 | 1.82 | >0.6 | P | 13:02 | 2.22 | >0.6 |
| P | 12:50 | 1.82 | >0.6 | C | 13:04 | 2.48 | >0.6 |
| C | 12:52 | 1.89 | >0.6 | P | 13:07 | 2.36 | >0.6 |
| P | 12:54 | 1.85 | >0.6 | C | 13:09 | 2.56 | >0.6 |

| Time | Serum Lithium Concentration (mmol/L) |
|------|--------------------------------------|
| 12:37 | 0.00 |
| 12:55 | 0.55 |
| 13:11 | 0.64 |

**Appendix 9.4:**     **Data Collected for Peripheral Venous vs. Central Venous Lithium Dilution Cardiac Output for Dog 4**

Date: November 30, 1999

Animal ID: Dog # 4

Weight: 10.8 kg

Arterial Hb.: 120 g/L

Na: 141 mmol/L

LiCl dosage used: 1 ml (0.15 mmol/ml)

Pre-med: Butorphanol 0.4 mg/kg IM

Induction: Thiopental 10 mg/kg IV

Maintenance: Halothane

LiDCO sensor #1                                           LiDCO sensor #2

|   | Time | LiDCO | S/N |   | Time | LiDCO | S/N |
|---|------|-------|-----|---|------|-------|-----|
| C | 13:41 | 1.49 | >0.6 | P | 13:57 | 2.11 | >0.6 |
| P | 13:43 | 1.58 | >0.6 | C | 13:59 | 1.55 | >0.6 |
| C | 13:45 | 1.61 | >0.6 | P | 14:01 | 1.50 | >0.6 |
| P | 13:47 | 1.71 | >0.6 | C | 14:03 | 1.48 | >0.6 |
| C | 13:50 | 1.73 | >0.6 | P | 14:05 | 1.47 | >0.6 |
| P | 13:51 | 1.68 | >0.6 | C | 14:07 | 1.52 | >0.6 |

| Time | Serum Lithium Concentration (mmol/L) |
|------|--------------------------------------|
| 13:38 | 0.00 |
| 13:54 | 0.41 |
| 14:10 | 0.78 |

**Appendix 9.5:**   **Data Collected for Peripheral Venous vs. Central Venous Lithium Dilution Cardiac Output for Dog 5**

Date: November 30, 1999                    LiCl dosage used: 1 ml (0.15 mmol/ml)

Animal ID: Dog # 5                         Pre-med: Butorphanol 0.4 mg/kg IM

Weight: 11.8 kg                            Induction: Thiopental 10 mg/kg IV

Arterial Hb.: 126 g/L                      Maintenance: Halothane

Na: 142 mmol/L

LiDCO sensor #1                                                LiDCO sensor #2

|   | Time  | LiDCO | S/N  |   | Time  | LiDCO | S/N  |
|---|-------|-------|------|---|-------|-------|------|
| C | 14:39 | 1.11  | >0.6 | P | 14:53 | 1.50  | >0.6 |
| P | 14:40 | 1.31  | >0.6 | C | 14:55 | 1.46  | >0.6 |
| C | 14:42 | 1.42  | >0.6 | P | 14:57 | 1.55  | >0.6 |
| P | 14:44 | 1.67  | >0.6 | C | 15:00 | 1.60  | >0.6 |
| C | 14:46 | 1.79  | >0.6 | P | 15:01 | 1.75  | >0.6 |
| P | 14:48 | 1.95  | >0.6 | C | 15:03 | 1.66  | >0.6 |

| Time  | Serum Lithium Concentration (mmol/L) |
|-------|--------------------------------------|
| 14:35 | 0.00 |
| 14:50 | 0.51 |
| 15:06 | 0.94 |