Assessment of lithium dilution cardiac output as a technique for measurement of cardiac output in dogs

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Objectives—To determine agreement of cardiac output determined by use of lithium dilution cardiac output (LiDCO) and thermodilution cardiac output (TDCO) techniques 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 techniques. 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 LiDCO and TDCO. LiDCO determinations were pooled, ICC was 0.9894. When all LiDCO determinations were pooled, ICC was 0.9896. For determinations of cardiac output < 5.0 L/min, ICC was 0.9730. Mean ± SD of the differences of TDCO minus LiDCO was -0.084 ± 0.465 L/min, and mean of TDCO minus LiDCO for cardiac outputs < 5.0 L/min was -0.002 ± 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 and could increase use of cardiac output monitoring, which may improve management of cardiovascularly unstable animals. (Am J Vet Res 2001;62:1255–1261)

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 all are 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. It belongs to the group of cardiac output measurements known as indicator dilution methods. The other 2 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 amount of dilution of this indicator is measured over time, using samples obtained from an arterial site that is distant from the site of injection.

The 2 previously used 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. The technique for injection of indocyanine green is not currently used clinically in humans because of the potential for allergic reactions to the indicator. Other noninvasive methods of measuring cardiac output have not proven to be as accurate, reliable, simple, or inexpensive as TDCO. 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 a blood sample obtained from a peripheral arterial site, using a sensor that is selective for lithium. The lithium sensor is monitored by a LiDCO computer that ana...
lyzes the dilution curve and determines cardiac output. The LiDCO method has been validated as being accurate, compared with values for TDCO, in horses, and pigs. In the study involving the use of pigs, LiDCO also was compared with cardiac output measured by use of an electromagnetic flow meter; those investigators found that LiDCO was more accurate than TDCO. In all those reports, 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. 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 techniques in dogs and to determine the agreement of values between these techniques. Another objective was to evaluate cardiac output determination with the LiDCO system when using a high and low dose of lithium chloride and to compare values of each with results for TDCO.

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 (0.4 mg/kg of body weight, IM). Anesthetic induction was accomplished by use of thiopental sodium (20 mg/kg, IV), and dogs then were intubated and initially maintained on halothane at 1.5%. Dogs were ventilated 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 placed percutaneously in the dorsal pedal artery; a 22-F 80-cm occlusion catheter 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 inserted in a jugular vein and advanced to the level of the pulmonary artery, and a 6-F 65-cm straight flush catheter 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 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 powered up. Prior to placement, the Swan-Ganz catheter was attached to the side port of a 3-way valve that was connected to the catheter inserted in the dorsal pedal artery. The sensor was prepared as described in the operation manual. 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 it 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. 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 mM. 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, 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 mM.

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 (5 to 10 mg/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 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 CO₂ concentration. All variables were recorded from an automated unit that was calibrated prior to beginning the experiment on each dog. A disposable pressure transducer 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 PCO₂ was maintained within the range of 30 to 45 mm Hg. To accomplish this, ventilation rate was increased when PCO₂ was > 45 mm Hg and decreased when PCO₂ was < 30 mm Hg.

At each rate of cardiac output, a 15-step protocol for data collection 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. 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 determination (3 consecutive measurements of cardiac output; values differed by ≤ 10%). Step 4 was to perform an initial LiDCO determination (LiDCOa). The dose of lithium chloride (low or high) used for LiDCOa was determined randomly. Step 6 was to perform another LiDCO determination with the alternate dose of lithium chloride from step 4 (LiDCOb). 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, 10 and 12, and 14 and 14.

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 (ie, hemodynamic instability 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, using a statistical software program. Data analysis was used to develop an intraclass correlation coefficient (ICC) for the true reliability between LiDCO and TDCO. 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. 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.

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 9 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 (ie, 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. 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.

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 (Fig 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 (Fig 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 (Fig 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 (Fig 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; Fig 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. The ICC is defined as the ratio of variance between dogs (this refers to all variance except that attributable to the test) 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.

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 12.80 L/min, compared with cardiac output that ranged from 1.10 to 12.80 L/min (Fig 1 and 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 revealed that LiDCO had more reliability than TDCO 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 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. This increased serum lithium concentration could interfere with subsequent determinations, because LiDCO would be less able 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 we were concerned that the background threshold serum lithium concentration (0.2 mmol/L) would be surpassed as a result of additional LiDCO measurements that would be required.

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 (Fig 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 for the remaining 6 dogs after completion of data collection for 2 rates of cardiac output. 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 (Fig 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. 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. Thus, there is not a limitation of animal size for the LiDCO, but a technical limitation exists in the technical 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. Lithium has a narrow therapeutic index 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. 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. Gastrointestinal tract signs, cardiovascular signs, neutropenia, lymphopenia, skin lesions, and signs of renal dysfunction may be evident. These signs mainly have been reported in humans, but there have been 2 reported cases of lithium toxicosis in dogs. Both of these dogs had been drinking water from a swimming pool that had been chlorinated with lithium hypochlorite. We did not detect 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 mM for the LiDCO. 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 mM/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 mM/L, and the theoretic upper limit for serum lithium concentration is 0.2 mM/L. None of the 10 dogs reported here reached a serum lithium concentration of 0.2 mM/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, compared with TDCO measurements.

References


