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Evaluation of central venous pressure in ruminants

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ABSTRACT

Central venous pressure is determined by complex interactions of blood volume, cardiac pumping action and alteration in vascular bed. The CVP was measured in 10 sheep, 10 goats and 13 cattle of both sexes. Animals were clinically healthy and measurement was made through jugular vein in standing position (sheep, goat and cattle) and right lateral recumbency (sheep and goat). The sternal manubrium and scapulo-humeral joint were used as zero reference point in lateral recumbency and standing position, respectively. Each measurement was repeated three times. Measured CVP was significantly higher in sheep (3.40 ± 0.15 cm H_2O) compared to cattle (2.31 ± 0.15 cm H_2O) and goat (1.25 ± 0.14 cm H_2O). The interspecies difference was also significant. The CVP was significantly higher in female animals ($P<0.05$). No significant difference was found between lateral recumbency and standing position. CVP measurement in animals suffering from dehydration or heart failure has provided useful information regarding disease status. Approximately 40 jugular catheterizations were performed in this study without any side effects or complications. CVP measurement is a simple procedure and requires no sophisticated equipment. It can provide information regarding cardiovascular disease, evaluation of treatment and prognosis.

Key words: central venous pressure, sheep, goat, cattle

Introduction

Central venous pressure (CVP) is an estimate of luminal pressure of intrathoracic vena cava, which reflects right atrial pressure. CVP depends on the interaction of cardiac function, intravascular blood volume, venous compliance and intrathoracic pressure. Peripheral venous pressure is variably higher than CVP and is not a reliable indicator of CVP (HASKINS, 1999). Monitoring of CVP has been used as a guide for estimating intravascular volume deficit during fluid therapy and can prevent fluid overload in patients requiring massive fluid or blood replacement. It can also provide useful information

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about the haemodynamic status of critically ill patients (shock, heart failure and during anaesthesia). It should be noted that continuous CVP monitoring rather than single value provides the most important information (KAPLAN, 1992).

In veterinary patients the CVP is commonly measured in cranial vena cava (via jugular vein). However, CVP measurement from the abdominal caudal vena cava has been reported (MACHON et al., 1995). The monitoring system should be zeroed at the level of the right atrium since it is right atrial pressure that is to be monitored. If patient positioning and zero reference point remain constant, changes in CVP of greater than 5 cm H_2O are considered significant. The real value in CVP measurement is in monitoring for trends and not in single readings (SHAFFRAN, 1994).

Normal values for CVP are 0 to 5 cm H_2O in dogs and cats (KAPLAN, 1992) and +5 to +10 cm H_2O in horses. A low or negative CVP value indicates depleted blood volume (hypovolemia), vasodilation or high cardiac output, while a high CVP (over 10-12 cm H_2O) indicates either excessive/too rapid fluid administration, venoconstriction, right heart failure, pericardial tamponade or pulmonary hypertension (HASKINS, 1999). Alteration in body position can affect CVP, particularly in large animals (KLEIN and SHERMAN, 1977). CVP may drop 10-15 cm H_2O when a horse is rolled from lateral to dorsal recumbency (SCHATZMANN and BATTIER, 1986-87).

All factors causing high intrathoracic pressure (positive pressure ventilation, positive end-expiratory pressure, abdominal distension, diaphragmatic hernia and pneumothorax) can increase CVP (BENNETT et al., 1989; KAPLAN, 1992; SHAFFRAN 1994; ROSENTHAL et al., 1998). It has been reported that increased intra-ruminal pressure results in high CVP in calves (SHARMA et al., 1998). Since CVP decreases during spontaneous inspiration and increases during expiration, the measurement is usually taken at the end of expiration in order to standardise the effect of intrathoracic pressure. CVP changes are reversed during positive pressure ventilation.

High CVP has been reported in dogs with heartworm disease (dirofilariasis) due to tricuspid valve insufficiency (KITAGAWA et al., 1985). The level of CVP decreases significantly after heartworm removal. Portal vein occlusion or propranolol (β-adrenergic blocking agent) injection significantly decreases CVP in dogs (SWALEC et al., 1991). Experimental pleural effusion has been associated with high CVP in cats (GOOKIN and ATKINS, 1999).

The objective of this study was to determine normal range of CVP values in ruminants in different positions (i.e., standing versus right lateral recumbency) and both sexes. The animals received no medication prior to experiment. The CVP values have also been reported in some clinical cases.

Materials and methods

Ten healthy Iranian fat-tailed sheep, 1-3 years old, weighing 29-55 kg (mean ± SEM = 36.61 ± 2.44 kg), ten goats, 1-5 years old, weighing 19-57 kg (mean ± SEM= 34.30 ± 4.60 kg), and thirteen Holstein cattle, 6 months to 5 years old, weighing 120-450 kg (mean ± SEM = 240 ± 27.74 kg), were used in this study. On the basis of physical findings animals were determined to be free of cardiopulmonary disease and in good health. Food was not withheld prior to commencement of the study. The experiment was performed in the morning to avoid any circadian effects.

After infiltration of the skin and subcutaneous tissues with 2% lidocaine hydrochloride[1] (without epinephrine) a small skin incision was made in jugular furrow. Using aseptic technique, a long catheter 20-30 cm, 18 gauge[2] (sheep and goat) or 60 cm, 14 gauge[3] (cattle) was inserted into the left jugular vein and the tip advanced to the level of the right atrium. Correct position of catheter tip was verified by lateral thoracic radiograph (sheep and goats), and the oscillation of fluid level in the column with breathing (in cattle). Contact with the endocardium of the right atrium should be avoided, since this may stimulate cardiac arrhythmia. The catheter was connected via saline-filled tubing to an open-ended vertical column of saline with cm gradation[4].

The CVP was measured in standing position (sheep, goat and cattle) and right lateral recumbency (sheep and goat). The sternal manubrium and scapulo-humeral joint were used as zero reference point in lateral recumbency and standing position, respectively. In order to avoid the effects of intrathoracic pressure, all measurements were taken at the end of expiration and were repeated 3 times at one-minute intervals. Heart (HR) and respiratory (RR) rate were recorded before and during CVP measurement. The pressure was measured only when heart rate was in the resting range in order to eliminate the effects of stress. No fluids or sedatives were given before or during this experiment.

CVP measurement was also performed in three cows suspected of traumatic reticulo-peritonitis (TRP), two calves and one lamb with diarrhoea and one sheep under halothane anaesthesia. TRP cases were confirmed following exploratory laparotomy (presence of penetrating foreign body and adhesion between reticulum and diaphragm).

Statistical analysis of data was performed using one-way analysis of variance (ANOVA) followed by independent sample t-test, or Duncan when appropriate. All results are expressed as mean ± SEM and differences were considered significant at $P \leq 0.05$.

(Footnotes)

[1] Lidocaine 2%, Pasteur Institute of Iran

[2] E-Z CATH®, Desert Pharmaceutical CO, Utah USA

[3] Intrcath®, Becton Dickinson, Utah, USA

[4] CVP-Manometer, Espergaerde, Denmark

Results

There were no significant differences between male and female animals for weight, HR and RR (Table 1.) Measured CVP was significantly higher in sheep (3.4 ± 0.15 cm H_2O) compared to cattle (2.31 ± 0.15 cm H_2O) and goat (1.25 ± 0.14 cm H_2O). The difference between cattle and goat was also significant ($P<0.05$). The CVP was significantly higher in female animals. No significant difference was found between right lateral recumbency and standing position in sheep and goats (Table 2.) CVP values for clinical cases have been reported in Table 3. CVP measurement in animals suffering from dehydration (diarrhoea) or heart failure (TRP) was considerably lower and higher than values in normal animals, respectively.

No adverse reactions or complications (thrombophlebitis, septicemia, air embolism, and vascular endothelial damage) were encountered after performance of approximately 40 jugular catheterizations in this study.

Table 1. Physiological variables measured in sheep, goats and cattle (mean ± SEM)

	HR (beats/min)		RR (breaths/min)	
	Male	Female	Male	Female
Sheep	75.25 ± 4.24	76.64 ± 3.29	35.00 ± 5.82	34.72 ± 5.06
Goat	68.25 ± 1.2	71.50 ± 0.42	28.58 ± 0.77	30.12 ± 0.35
Cattle	70 ± 2.58	68.33 ± 0.93	28.50 ± 4.42	28.00 ± 1.49

HR = heart rate; RR = respiratory rate

Table 2. CVP values (cm H_2O) measured in sheep, goats and cattle (mean ± SEM)

	Sex		Position		Total
	Male	Female	Standing	L.L.R.	
Sheep	3.02 ± 0.16*	3.66 ± 0.22	3.14 ± 0.23	3.62 ± 0.19	3.40 ± 0.15♣
Goat	0.80 ± 0.11*	1.9 ± 0.26	1.35 ± 0.24	1.15 ± 0.15	1.25 ± 0.14
Cattle	1.45 ± 0.25*	2.70 ± 0.15	2.31 ± 0.15	-	2.31 ± 0.15

L.L.R.= left lateral recumbency

* significant difference between male and female ($P<0.05$)

♣ significant difference from goat and cattle ($P<0.05$)

Table 3. CVP (cm H_2O) values in clinical cases (mean ± SEM)

Species	Position	CVP (cm H_2O)
Cow (TRP)	Standing	20-21
Cow (TRP)	Standing	10-11
Cow (TRP)	Standing	9-10
Sheep (halothane anaesthesia)	RLR	7.2-7.5
Calf (diarrhoea)	Standing	-3.5 to - 3.0
Calf (diarrhoea)	Standing	0.5 - 0.7
Lamb (diarrhoea)	RLR	-0.5 to - 0.2

TRP = traumatic reticulo-peritonitis; RLR = right lateral recumbency

Discussion

Placement of central venous catheter can be performed easily and safely in standing or recumbent animals. Central venous catheter is also useful for long-term intravenous feeding and administration of highly irritant solutions. The measurement of CVP can provide diagnostic information in both heart disease and circulating blood volume deficit. It has been shown that during haemorrhage, CVP reduction occurs before changes in mean arterial blood pressure (HALL and NIGAM, 1975). Comparative study of normal CVP values in unsedated conscious ruminants has not been reported previously.

The results of this study have demonstrated significant differences in CVP values between ruminants; sheep and goats had highest and lowest CVP, respectively. Cattle had intermediate values compared to sheep and goats. CVP measurement was taken only when the animal was calm and free of stress based on resting heart rate. CISSICK et al. (1991) reported that pregnant sheep under light halothane anaesthesia have CVP values of 0-1.47cm H_2O. Previous studies reported CVP values of 4 ± 3.4 mm Hg (2.94 cm H_2O) and -1.4 ± 3.5 mm Hg (-1.03 cm H_2O) in unsedated standing cattle (NUYTTEN et al., 1985; AMORY et al., 1992). In both studies the scapulo-humeral joint has been used as zero reference point. No data was available on CVP in goats.

CVP was significantly higher in female animals ($P<0.05$). The reason for this discrepancy is unknown. No significant difference was found between lateral recumbency and standing position in sheep and goats. CVP was higher in lateral recumbency (under general anaesthesia) than standing in horses (KLEIN and SHERMAN, 1977; HALL and NIGAM, 1975). Increased intrathoracic pressure due to forward displacement of diaphragm can explain the rise in CVP in lateral recumbency. However, it should be mentioned that these animals had received sedative and anaesthetic drugs, which can affect CVP values. Phenothiazines decrease and xylazine (an α-agonist agent) decreases CVP in horses

(SCHATZMANN and BATTIER, 1986-87). KLEIN and SHERMAN (1977) reported no changes in CVP following intramuscular xylazine injection, but administration of acepromazine (IV/IM) induced significant reduction in CVP. A steep rise in CVP has been shown in horses following administration of high concentration (11%) of halothane (SHERIDAN et al., 1972). Higher CVP in anesthetized sheep in the present study may be due to depressant effect of halothane on myocardial contractility.

It has been reported that the catheter size (gauge) or left versus right lateral recumbency has no effect on CVP values in dogs under isoflurane anaesthesia (OAKLEY et al., 1997). The water manometer was more accurate than strain-gauge transducer. A highly significant correlation between CVP and bodyweight has been reported in horses (HALL and NIGAM, 1975).

SHARMA et al. (1998) reported that increased intra-ruminal pressure results in high CVP in calves. Although food and water were not withheld prior to each trial in this study, since the duration of lateral recumbency was short (15-20 minutes) no sign of ruminal tympany or bloat was observed in sheep and goats. In case of prolonged recumbency it may be necessary to withdraw food and water in order to reduce gas production in rumen. As expected, CVP was high in TRP cases. Exploratory laparotomy confirmed the presence of a penetrating foreign body between reticulum and diaphragm. CVP measurement in these cases can provide useful information regarding the severity of heart failure. Comparison of pre- and post-operative (following foreign body removal) CVP in TRP cases may be used to evaluate the prognosis.

Conclusion

CVP measurement can be performed easily and safely in ruminants. Continuous monitoring of CVP is used as an indicator of successful treatment as CVP readings return to normal. In animals suffering from dehydration or heart failure (acquired or congenital), CVP measurement has provided useful information regarding disease status. Determination of normal CVP values in different species is necessary for interpretation of CVP changes in clinical situations.

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SAŽETAK

Centralni venski tlak (CVT) određen je složenim djelovanjem između volumena krvi, akcije srčane pumpe i promjenama u krvožilnom spletu. Mjerenje centralnog venskog tlaka obavljeno je u 10 ovaca, 10 koza i 13 goveda oba spola. Životinje su bile klinički zdrave, a mjerenje je provedeno kroz jugularnu venu u stojećem položaju (ovce, koze i goveda) te u desnom postranom ležećem (ovce i koze). Manubrium prsne kosti i lopatično-humeralni zglob rabljeni su kao početne točke u postranom ležećem i stojećem položaju. Svako mjerenje ponovljeno je tri puta. Utvrđen CVT bio je značajno veći u ovaca (3,40 ± 0,15 cm H_20) u usporedbi s govedima (2,31 ± 0,15 cm H_20) i kozama (1,25 ± 0,14 cm H_20). Razlike i unutar životinja iste vrste bile su značajne. CVP bio je značajno veći u ženskih životinja (P<0,05). Razlike između postranog ležećeg i stojećeg položaja nisu bile statistički značajne. CVT mjerenja u životinja koje pate od dehidracije ili srčanog zastoja pružila su korisne informacije o stanju bolesti. Približno 40 jugularnih kateterizacija učinjeno je u ovom istraživanju bez ikakvih nuzpojava ili komplikacija. CVT mjerenje je jednostavna metoda koja ne traži specijalnu opremu, a može pružiti informacije o kardiovaskularnim bolestima, procjeni liječenja i prognozi.

Ključne riječi: centalni venski tlak, ovca, koza, govedo