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ABSTRACT

Downer cows as a syndrome was first reported in the 1950ies and have been a challenge for veterinarians ever since. A cow that is recumbent for too long may develop soft and nerve tissue lesions because of her recumbency. The pathophysiology and blood biochemistry related to downer cows have been studied by others. An important step in the treatment of a recumbent cow is to help her stand. Many inventions have been created in order achieve this. In this study flotation therapy, where buoyancy from water is used as a supportive force, as treatment was evaluated. A retrospective study of all cases that spent at least one day in the flotation tank at the Large Animal Clinic at the Faculté de Médecine Vétérinaire at Université de Montréal between the 12th of June 2006 and the 4th of April 2011 was conducted. The aim was to get a deeper understanding of the treatment and to identify factors that can be used to predict the outcome. The results indicate that flotation therapy for downer cows can greatly increase the recovery rate and save cases that otherwise would have a guarded prognosis. The results also indicate that infectious, musculoskeletal and nerve lesions are the most common diagnose of recumbent cows. For creatine kinase activity (CK) and aspartat aminotransferase activity (AST) there were statistically significant differences between survivors and non-survivors indicating that these muscle enzymes can be used to predict the outcome.

SAMMANFATTNING

Långliggande kor (Downer cows) som ett syndrom är beskrivet sedan mitten av 1950-talet. Det finns inte någon entydig definition av syndromet. Olika författare har alla haft sin egen definition som har varierat över tid men även inom och mellan länder. I denna text används den enkla definitionen; en ko som inte kan resa sig trots att djurägaren försökt hjälpa henne att resa sig.

Det finns flera anledningar till att en ko blir en långliggare, ofta är det en ko med kalvningsförlamning som inte svarar på behandlingen men infektioner, muskeloskelettala skador och tumörer kan också vara en anledning. En ko som blir liggande för länge på samma sida kan utveckla trycknekroser och ischemiska skador i mjukvävnaden och på perifiera nerver. Ett experimentellt nedsövningsförsök visade att en ko kan utveckla irreversibla skador efter att ha legat på samma sida i sex timmar. En viktig del av behandlingen av en långliggande ko är hjälpa henne att stå. Det finns många uppfinningar för att hjälpa en ko att stå, den kanske mest kända i Sverige är en uppblåsbar ballong som placeras under kon och sedan fylls med luft. Detta arbete handlar om en alternativ teknik som utnyttjar vattnets flytkraft, flotationsteknik. Tekniken uppfanns av en dansk i slutet på 1970-talet och använder sig av en liten container med avtagbara bak- och framdörrar. Kon läggs på en matta och dras in i containern och när dörrarna stängts fylls den med vatten. Studier på andra djurslag har visat på en avsevärd reducering i vikt som individen måste bära då den står i vatten.

Flotation som behandling av långliggande kor har används vid stordjurskliniken vid Fakulteten för veterinärmedicin vid Montreals Universitet i Saint-Hyacinthe i Québec Canada sedan mitten av 1990-talet. Kliniken tar emot ca 1000 nötkreatur per år. Data därifrån har används för att göra en retrospektiv studie, där målet var att utvärdera behandlingseffekten av flotationstekniken samt undersöka om man kan använda blodprover för att förutsäga prognosen.

Journaldata från alla patienter som behandlats med flotationsteknik mellan 12 juni 2006 och 4 april 2011 sammanfattades i en datafil och bearbetades statistiskt. Resultaten visar att flotation är en effektiv behandling till långliggande kor och kan användas med gott resultat till fall som annars skulle ha en avvaktande prognos. De vanligaste diagnoserna på fall som behandlades med flotation var relaterade till infektion, muskeloskelettala skador och nervskador. Det var ingen statistiskt signifikant skillnad i calcium-, kalium- eller fosfornivåer mellan överlevare och icke-överlevare. För CK och AST fanns det en statistiskt signifikant skillnad mellan överlevare och icke-överlevare vilket indikerar att dessa muskelenzymer kan användas för att förutsäga prognosen.

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INTRODUCTION

This Degree Project is a part of the curriculum for Swedish veterinary students. The data for the retrospective study comes from the Bovine section of the Large Animal Clinic at the Faculté de Médicine Vétérinaire at Université de Montréal in Saint-Hyacinthe Québec, Canada where downer cows have been treated with flotation therapy since the middle of the 1990ies. Being the largest bovine clinic in the province of Quebec receiving about 1000 cases per year and having a good reputation cows are being referred to the hospital from all over the province and from neighbouring regions. The frequent use of the flotation tank at the hospital and the years of experience have resulted in a large archive with medical records from cows treated with flotation therapy giving good conditions for a retrospective study.

BACKGROUND AND LITERATURE REVIEW

Definition

The term downer cow syndrome and the shorter expression downer cow have been used since the 1950ies (Cox 1988) but a universally accepted definition is still not available. Different authors have all used their own definition and the definition has varied within countries, between countries and over the years. Björsell and Holtenius from Sweden defined a “downer” as a milk fever cow that had not risen within 24 hours after calcium treatment (Bjorsell et al. 1969). Fenwick from Australia defined a “downer” as any cow that did not rise within 10 min after calcium treatment (Fenwick 1969). Cox from the University of Minnesota, USA, who performed much research on downers, defined a downer cow as a cow that has been in sternal recumbency for 24 hours after initial recumbency (Cox 1988). In the textbook Large Animal Internal Medicine by Smith a downer cow is described as an alert cow that is unable to rise to a standing position but will eat and drink (Smith 2002). Another definition of a downer cow is a cow that has been recumbent for 12 hours or more and is unable or unwilling to stand (Burton et al. 2009). In none of the textbooks Veterinary Medicine (Radostits et al. 2007) or The Merck Veterinary Manual (Merck 2010) have the authors defined a downer cow. This may be due to the difficulties in finding a clear and precise definition. Instead the authors in these textbooks focus on the clinical signs, the causes and the consequences.

A complicating factor is that downer cows can be divided into different groups; alert and non-alert downers. Alert downers eat and drink and have a normal behavior except for the fact that they are unable to rise. Non-alert downers have abnormal vital signs and/or altered mental awareness (Smith et al. 1997; Burton et al. 2009).

All attempts to define a downer cow have contained one or two behavioural units (“unable to rise” and “alert/non-alert”), a time unit and sometimes a cause and/or response unit. The behavioural unit “unable to rise” is a part of all definitions, whereas the alert/non-alert behaviour has not always been used. Time is included in many definitions but has varied. The response unit (e.g. risen within 24 hours of calcium treatment) and the cause unit (milk fever) was important in the earlier definitions of a downer cow but have now become part of the syndrome and not the definition of it.

From a strict theoretical point of view one could argue that the definition of a downer cow is an alert cow that eats and have a normal mental awareness that is unable or unwilling to rise and have been recumbent for 12 hours or more. That is a definition that a lot of people would agree with and the literature supports. However, the problem with such a definition is that a lot of down animals are being excluded. The excluded animals are still down and deserve attention.

In the continuation of this text a downer cow will be a cow that is unable to stand despite receiving assistance from the farmer.

Incidence of downer cow syndrome

The incidence of downer cows is not easy to estimate partly due to the variation in definition and partly due to the fact that a downer cow per se is not a diagnose. In a questionnaire investigation from Minnesota in 1986 where the definition was a cow recumbent on the sternum for more than 24 hours for no obvious reason, the incidence of downer cows was estimated to 21.4/1000 cow years at risk (Cox et al. 1986). When alert downer cows are expressed as percentage of milk fever cases, 3.8 to 28 per cent have been reported (Cox 1988). Non-alert downer cows occurred in 1.9 – 3.4 per cent of milk fever cases (Fenwick et al. 1986). In a study from New York the cumulative incidence rate was 1.1% for cows in their first 30 days if lactation (Correa et al. 1993).

Risk factors associated with downer cow syndrome

Attempts to identify risk factors for the downer cow syndrome have been made. Correa et al. (1993) concluded in their study that hypocalcaemia and stillbirth increased the risk of having a downer cow fivefold. There was also a correlation between retained placenta and dystocia and downer cows. These results support the results from the Minnesota survey where 58% of the downer cows became recumbent 1 day post partum and only 5% of the downer cows became recumbent after 100 days of milking (Cox et al. 1986). A study of 1822 farms with one or more cases of downer cows in 2004 compared with 151 farms without downer cow cases revealed that total mixed ration, an average milk production of more than 9090 kg/cow/year, not having pasture as the predominant flooring for lactating cows during winter and a herd size of more than 100 cows increased the risk of having a downer cow (Green et al. 2008). A summary of factors from the articles by Correa et al. (1993) and Green et al. (2008) that increase the risk of having a downer can be found in Table 1.

Table 1: Factors on herd and individual levels that increase the odds of having a downer cow. Compiled from Green et al. (2008) [a] and Correa et al. (1993) [b].

Herd level			Individual level	
Factor	Odds ratio		Factor	Odds ratio
Feeding TMR[a]	2.0		Stillbirth[b]	4.9
Producing >9090kg[a]	2.8		Clinical hypocalcemia[b]	5.6
Herd size >100 cows[a]	3.7			
Flooring not pasture[a]	4.7			

Pathophysiology

While examining a downer cow one must always bear in mind that there are often more than one possible diagnose. The primary diagnose is the reason the cow became recumbent, this can be anything from sepsis and endotoxemia to muscle damage and external trauma. The secondary diagnose is related to injuries and lesions that the cow has developed because of her recumbency.

To this day, the publication that best describes the pathophysiology, injuries and lesions related to recumbency was published by Cox et al. in 1982. Sixteen cows were experimentally anesthetised on a 14 mm rubber mat with the right hind leg under the body in a sternal position for 6, 9 or 12 hours. Creatine kinase activity (CK) was measured at 0, 3, 6, 9, 12, 24, 48, 96 and 144 hours after the start of the anaesthesia. Eight of the cows became non-ambulatory downer cows after the anaesthesia, there was no difference in how long the cows had been anaesthetised (6, 9 or 12 hours). CK started to rise after 12 hours and peaked at 24 hours for the ambulatory group and at 48 hours for the non-ambulatory group. There was a significant difference in the CK levels between the ambulatory group and the non-ambulatory group at 48 and 96 hours. While being helped to stand one day post anaesthesia all cows in the non-ambulatory group displayed fetlock flexion indicating peroneal paralysis. Necropsy was performed on non-ambulatory cows 10 to 14 days after the anaesthesia and revealed damage to the ischiadicus nerve caudal to the proximal end of femur, discoloration of the nerve and proliferation of connective tissue surrounding it. The nerve was impossible to separate from muscles in the area. Muscles in the right hind limb were pale necrotic and foul smelling, most affected were the *Musculus semitendinosus* and *Musculus gluteus*.

In the discussion of the study (Cox et al. 1982) and in a later article (Cox 1988) pressure damage and compartment syndrome are suggested as likely explanations to why some cows became downers. The term “compartment syndrome” refers to pressure damage within an osteofascial compartment. An osteofascial compartment is a group of muscles that are surrounded by a thick fascia, innerved by the same nerve and performing the same action. In species where the osteofascial compartments have been described they are best developed in the proximal part of the extremities. Increased pressure within an osteofascial compartment can be the result of either external or internal pressure or a combination of the two. External pressure can cause vessel compression, ischemia, leaking vessels and post-compression swelling which leads to increased internal pressure. The pressure within a compartment can be measured with a fluid filled catheter that is connected to a pressure recording device. During the anaesthesia of the previously mentioned cows, pressure was measured in the hamstring muscles the maximum pressure varied from 70 to 90 mm Hg to be compared with the aortic diastolic pressure of 60-80 mmHg. Depending of the position and inclination of the pelvis in relation to the floor the pressure within the muscles varied greatly. For cows in lateral recumbency the pressure in the hamstring muscles were close to zero. The differences in the internal pressure of the hamstring muscles attributed to the position and inclination of the pelvis would be a logical explanation to why some cows became recumbent after the anaesthesia (Cox 1988).

The necropsy findings of a damaged sciatic nerve on non-ambulatory cows could explain the difficulties for the downer cows to rise. The semimembranosus muscle that is innervated by the sciatic nerve is large, has adductor and hip extension function. The muscle is important in the locomotion apparatus of the cow. Experimental bilateral transection of the obturator nerve (innervating the adductor muscle) and the L6 root of the ischiadic nerve (second largest root of three in the ischiadic nerve) produced an extremely ataxic cow and recumbency, while a transection of the obturator nerve did not make the cow recumbent as long as she was on a non-slippery surface (Cox et al. 1975; Cox 1988).

Different materials have different capacity to absorb and even out the pressure from a recumbent cow. In a case report Cox et al. (1992) reported on sand as bedding for an alert recumbent cow that was down completely for 4 days and unwilling to rise for 40 days. At necropsy the cow did not have any signs of pressure damage and her CK levels during early recumbency did not indicate any muscle damage. Likewise Fenwick et al. (1986) reported on seven non-alert downer cows that had been recumbent on pasture. None of the five that went to autopsy displayed any macroscopic lesions to the muscles behind the stifle. The authors concluded that the lack of lesions was due to the lateral recumbency. An alternative explanation for the lack of lesions could be due to the pasture. Less apparent evidence of pasture as a good bedding for downer cows can be found in the Minnesota survey (Cox et al. 1986). The fact that fewer cases of downer cows occurred during the months when the cows are on pasture indicates that pasture is good bedding for downers.

Biochemistry of downer cows

To use biochemical analyses to evaluate muscle damage and pressure damage in a downer cow is appealing. However results from studies that have evaluated aspartate aminotransferase activity (AST) and CK in downer cows have showed it to be a useful but blunt tool. In Cox experimental study of the pathogenesis of downer cows (Cox et al 1982) there was no significant difference in CK level between the ambulatory and the non-ambulatory group at 24 hours, mean 36 610 and 39 640 U/L respectively. However, there was a significant difference between the ambulatory group and the non-ambulatory group at 48 and 96 hours after anaesthesia, mean at 48 h 12 800 and 41 640 U/L, mean at 96 h 2160 and 16 160 U/L respectively. A New Zealand study of 433 periparturient recumbent cows concludes that CK and AST together with urea and day of sampling are the best combination to predict the recovery of an animal (Clark et al. 1987). This information was used in a model they created to calculate the probability of recovery. They found that CK levels must be correlated to day of recumbency but are only useful between day one and seven. They calculated a 95% critical value for CK and AST. An animal that had a CK or AST value over the 95% critical value had less than 5% chance of survival. Their 95% critical values for CK to predicting the outcome of recumbency are displayed in Table 2. For AST the 95% critical value was 890 U/L for the first seven days (normal range 25-120 U/L). They did point out that AST must be evaluated together with liver enzymes or CK to avoid misinterpretation since hepatocellular damage also will lead to increased serum AST levels (Clark et al. 1987).

Many countries including Sweden are using the SI-unit of katal/L instead of U/L; providing that the conditions are the same i.e. the analysing method is using the same substrate, pH and temperature one U/L equals 0.0167 µkat/L and reversed one µkat/L equals 60 U/L.

A German study of 770 recumbent cows with hypocalcemia from five different regions one day before calving to two days post partum concluded that CK and AST are not good indicators to predict the outcome of the treatment (Gelfert et al. 2007). They used CK and AST to calculate positive and negative predictive values since CK and AST were the only parameters that differed significantly in all five regions. The result was a low positive predictive value and a high negative predictive value.

Another attempt to create cut off points, in order to help veterinarians predict the prognostics comes from an Israeli study (Shpigel et el. 2003). They looked at CK, AST and lactate dehydrogenase activity (LDH) on day 1 to 4 of recumbency on 262 downer cows and evaluated the enzymes capacity to predict the outcome. The conclusions they made was that after four days none of the muscle enzymes were good predictors of the outcome. AST was the muscle enzyme that best predicted the outcome, with a cut off value for AST at 171 U/L. The positive predictive value (proportion of subjects with a positive result who are correctly diagnosed) and the negative predictive value (proportion of subjects with a negative test result who are correctly diagnosed) were 85% and 80% respectively when the failure to recover was 37%. Indicating that a downer cow with a value under 171 U/L would have 85% likelihood to recover, and a downer cow with a value over 171 U/L would have 80% likelihood not to recover. The predictive values vary with the disease prevalence (or the recovery prevalence if you only look at downer cows) and need to be corrected for local conditions (Shpigel et al. 2003).

Table2: Critical CK values for recumbent cows modified from Clark et al. 1987. A CK value over the critical value for a specific day indicates less than 5% chance of survival.

	95% Critical CK value	
Days down	U/L	µkat/l
1	18600	310.6
2	16300	272.2
3	14000	233.8
4	10900	182.0
5	8500	142.0
6	6200	103.5
7	3900	65.1

Treatment of downer cows

Supportive care for a downer cow is essential. It will not only prevent further pressure damage and secondary lesions but will also be an important step towards having a standing cow. However one must stress that obvious reasons for recumbency must be treated before assisted standing is performed. Often the primary diagnose and the secondary lesions need to be treated simultaneously. Green et al. (2008) concluded in their study that recumbency for less than 24 hours, treatment with calcium, potassium or phosphorus and cases that not received treatment by a veterinarian before recumbency were more likely to recover. A surprising finding in their study was that repositioning did not increase the likelihood to recover; the authors assumed that the lack of benefit is because the repositioning was initiated too late, or that repositioning was only performed on the most severe cases. Thus their negative results of repositioning should not be interpreted as a negative effect. An overview of important steps when treating a recumbent cow can be found in Figure 1.

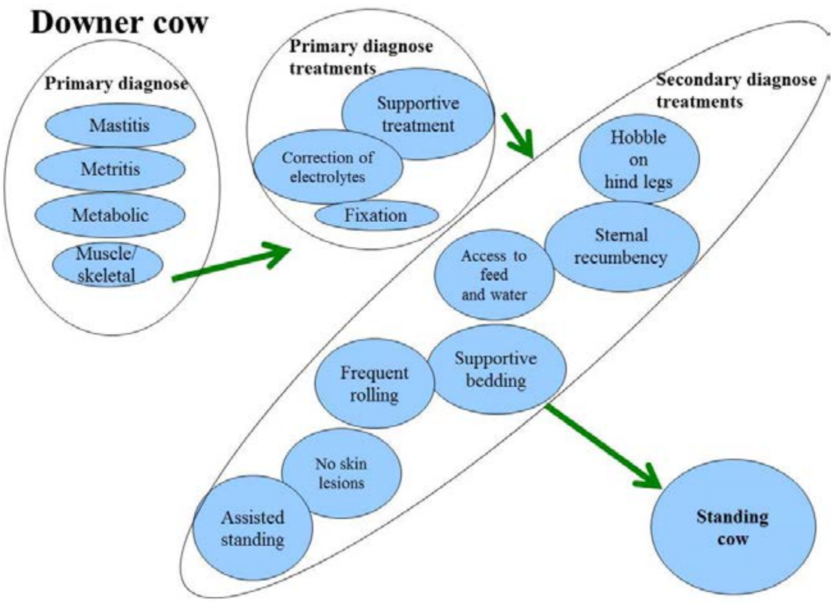


Figure 1: Important steps when treating a downer cow. Primary and secondary diagnose treatments often need to be performed simultaneously and some steps repeated.

LIFTING TECHNIQUES AND DEVICES

There are various techniques and devices used to assist a dower cow to stand; hip lifters, inflatable balloons, different types of slings and flotation therapy. Unfortunately very few of these techniques have been evaluated scientifically. Since there are very few articles written about the techniques, a brief explanation will be given and positive and negative effects will be pointed out bases on the authors own experience. A comparison of the different techniques based on the same information is given in Table 3.

Hip Lifters

The hip lifter or hip clamp consists of a straight extendable bar and have two metallic rings attached to each end of it. The rings are placed over the tuber coxae of the recumbent cow and then tightened. The hip lifter is then lifted together with the cow. In the Minnesota survey 75% of the farmers expressed that they had experience with hip lifters and 71% found them useful (Cox et al. 1986). Advantages with a hip lifter are that it is small, easy to use and supports the hind legs that a downer cow normally has difficulties with. A disadvantage is the fixation on the cow. There is a lot of pressure on a small area. If it is attached to hard it can damage the muscle and bones around the tuber coxae. If it is attached too loose the cow will rise a few centimetres but then fall out of the hip lifter with serious skin lesions. In the US patent application for the Aqua Cow tank, Johan Lastein claims that hip lifters have been forbidden because of the terrible injuries to the hip muscle (Lastein 1995) although this claim have not been possible to confirm. The use of hip lifters varies in different part of the world, in Sweden and the Scandinavian countries they are hardly used at all. In North America and Australia hip lifters are commonly used.

Air bag

Inflatable air bag, inflatable balloon or a Cow Jack are all different names for lifting devises working with the same principle. It consists of a large cylinder shaped inflatable devise that is being placed under the cow and then inflated. As the pressure in the bag increases the cow rises. An advantage of the air bag is that it is much softer on the animal and not causing any muscle damage. The negative effect of the airbag is that they support the comparatively soft abdomen of the animal leading to compression of the internal organs and the diaphragm, having a negative effect on the respiration (Cox 1988). The author of this text does not have any personal experience with an inflatable air bag but have understood that it is hard to make the animal stand comfortably and that the animal has a tendency to bounce making it hazardous for the people treating it.

Both the hip lifter and the inflatable air bag have the same problem, they don't give enough support for a large cow. In the last 30 years the size of dairy cows have increased significantly resulting in much more weight to be lifted, increasing the risk of damages and suffering for the animal while treated.

Sling

Supportive slings for cows come in various different shapes and sizes. The principle behind it is a mesh or a net that together with straps can be placed under the whole ventral part of the animal, supporting not just the abdomen but also the cranial and caudal part of the body. The sling is then attached to a front end loader or an overhead attachment; there are models that attach to a movable freestanding structure. An advantage is that it gives a better support for the animal and the weight is spread out over a larger surface. A negative aspect of the sling is that it is difficult to install on the animal. There are a lot of straps to fit. The authors experience is limited; the overall impression is that straps work well but the animal does not appear as comfortable in reality as in theory.

Flotation

Flotation as a technique to help downer cows was developed in the late 1970ies by the Dane Johan Lastein after that he himself had undergone a treatment based on the same principles (Down-Cow) (Figure 2 and 3). To get the recumbent cow in to the flotation tank she is rolled up on a mat that is dragged in to a tank with removable front and rear doors, the doors are then sealed and water is put into the tank (Down-Cow; Smith et al. 1997). Even though the technique is fairly new, first reported by a veterinarian in 1982 there have been several publications made (Smith et al. 1997; Burton et al. 2009; Giudice and Gianesella 2010) reporting 37-46% positive result. Negative aspects of the technique is the difficulty to get the cow in to the tank, the large amount of warm water that is needed and the risk of creating hyperthermia or hypothermia in the animal. The advantage is that the cow can stand comfortably for a long period and the flotation force created by the water is evenly spread.

Table 3: Comparison of different lifting devises for downer cows, DC indicates downer cow.

	Hip lifter	Air bag	Sling	Flotation
Cost	+	++	+	+++
Effect on marginal DC	++	+	++	+++
Effect on severe DC	+	+	+	++
Animal comfort	+	+	++	+++
Easy to install	+++	++	+	+
Time demanded	+	++	++	++
Movable	+++	++	+++	++
Easy to use	+++	++	++	++

IN DEPTH DESCRIPTION OF FLOTATION

A flotation tank resembles a small container on wheels with removable front and rear doors (Figure 2). The tank volume is about 3000 L and the dimension is roughly; length 2.5 m, height 1.25 m and width 1.25 m. The first obstacle is to get the cow into the tank. That is usually done by rolling her onto a mat that can be pulled or winched into the tank with the doors removed. The doors are then put in place and seal with a rubber gasket. When the cow is in the tank her head should be held tightly to prevent that she inhales water or tries to rise too early. Injuries to the tail should also be avoided. The water needs to be put in rapidly otherwise there is risk for injuries if the cow tries to rise too early. It will take approximately 2500 L of water to float a cow. The water temperature is important lukewarm water is recommended. If the water is too warm the cow will develop hyperthermia and if the water is too cold she may develop hypothermia. When the tank is half to 2/3 full the cow can be encouraged to rise. If she rises too early there will not be enough buoyancy when she stands. When the cow stands it is important to evaluate her comfort and standing behaviour. A cow that is not standing comfortably might suffer from untreatable injuries, e.g. hip-luxation, severe neurological injuries or fracture. A cow that have been recumbent for a day or two might find it physical demanding to stand and won't be able to stand long. Clinical signs like trembling or discomfort in a previously comfortable cow can be signs of fatigue. As long as the cow is comfortable she can stay in the water for 6 to 8 hours. Flotation therapy for longer periods (up to 24 hours) has been reported (Smith et al. 1997). However concidering the normal behaviour of a cow flotation for more than 8 hours is not physiological. After treatment it is essential that the cow exits the flotation tank slowly on a non-slippery surface. Hobblers on the hind legs to prevent to cow from slipping are always recommended on downer cows and important to prevent accidental injuries especially when exiting the flotation tank.

The supportive force that is acting on a body in water is the buoyancy. Buoyancy is the upward thrust from the water that is creating an apparent decrease in the weight while the body is immersed. Archimedes principle states that, the upward thrust is equal to the weight of the fluid displaced. The amount of displaced water depends on the density of the body relative to the density of water. There have been studies on dogs on the amount of bodyweight born by the animal when immersed in water as a percentage of the bodyweight on land. When the water was at the level of the lateral condyl (distally) on the femur the dog carried 85% if its bodyweight, and when it was in level with the greater trochanter (proximal) of femur the dog carried 38% of its bodyweight (Millis et al. 2004; Levine et al. 2010).

A cow that is standing in a flotation tank has approximately half the femur below the water level, depending on the size of the cow. With the assumption that the bovine body has the same density as the canine body it implicates an apparent 15-62% reduction in weight for the animal to carry.

Figure 2 and 3: A flotation tank from Aqua Cow Rise System and a cow standing in a flotation tank. With permission from Aqua Cow Rise System.

AIMS

The aim of this retrospective study was to use medical records from downer cows treated with flotation therapy at the Large Animal Clinic at the Faculté de Médecine Vétérinaire at Université de Montréal to evaluate the efficiency of the treatment and what factors that can be used to predict the outcome for cows treated with flotation therapy.

MATERIALS AND METHODS

With the help from the billing system records of all patients that had spent at least one day in the flotation tank between the 12th of June 2006 and the 4th of April 2011 were retrieved from the archive. This gave 368 medical records; out of these 13 contained no information about the patient.

The medical records from recumbent cows that spent at least one day in the flotation tank were summarised in a dataset containing: medical record number, date of arrival to the clinic, day of departure from the clinic, number of days at the clinic, number of days treated with flotation therapy, cost for the client, if an autopsy report is available, diagnose /diagnoses, if a complete blood count at arrival is available, if a biochemistry report at arrival is available, the values of AST, CK, calcium (Ca), potassium (K), phosphorus (P), carbon dioxide (CO_2) and betahydroxybutyrate (BHB) at arrival, days recumbent before arrival and if the cow had been lifted with another lifting device before arrival. All haematology and biochemistry analyses were performed at the University laboratory. An illustration of the dataset is given in Table 4.

Table 4; Example of information from the dataset, containing a summary of the medical record for cows treated with flotation therapy between the 12th of June 2006 and the 4th April 2011.

Patient no	Date of arrival DD/MM/YYYY	Date of departure DD/MM/YYYY	No of days in the hospital	No of days in flotation tank	Cost for client CAD
12345	15/03/2011	17/03/2011	3	2	694.96
12346	17/01/2011	17/01/2011	1	1	432.61

Survivor/ non-survivor	Necropsy report available Y/N	Days down before arrival	Method of lifting at the farm	Diagnose
S	N	2	Hip-lifter	Mastitis Q4, myosite
N	Y			Metritis, peroneal paralysis

CBC at arrival Y/N	Biochemistry at arrival Y/N	AST U/L	CK U/L	Ca mmol/L	P mmol/L	K mmol/L	CO_2 Total mmol/L	BHB umol/L
Y	Y	3587	148 309	1.72	2.09	3.18	29.4	2745
Y	Y	2460	106 484	4.24	3.87	7.08	11.9	748

RESULTS

In total 368 cows were treated with flotation therapy for at least one day during the study period. The numbers of cases treated varied from 54 cases in 2007 to 91 cases in 2009, with an average of 76 cases per year for the four whole calendar years where data were available.

The overall survival rate for recumbent cows treated with flotation therapy during the study period was 57%; varying from 43% to 70% over the years (Figure 4).

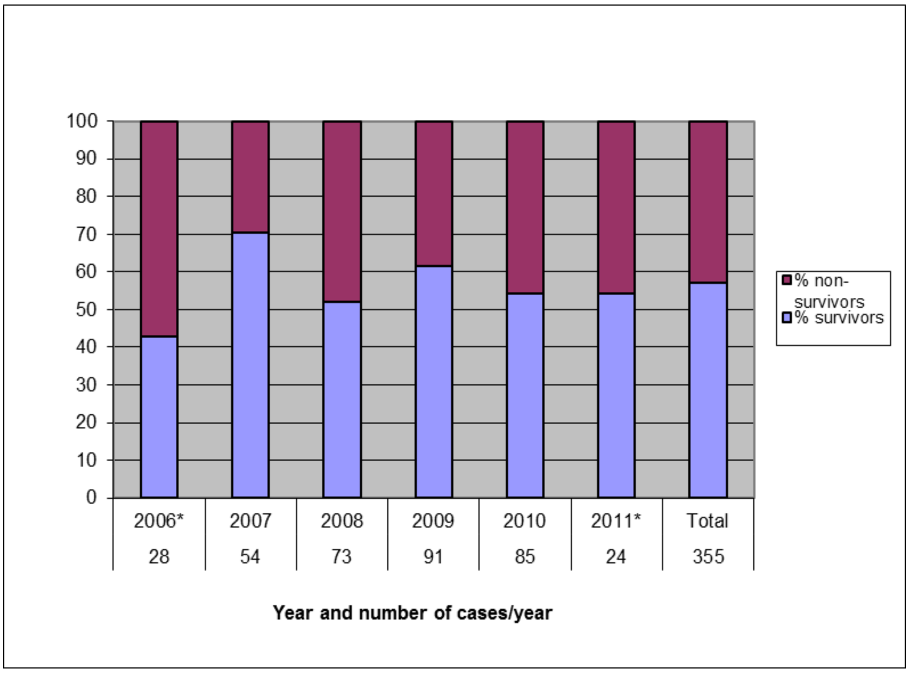


Figure 4: Survival rates and number of cases treated per year with flotation therapy for at least one day between the 12th of June 2006 and the 4th of April 2011.
**data for the whole year not available.*

Recumbent cows treated with flotation therapy for at least one day between the 12th of June 2006 and the 4th of April 2011 were presented to the clinic over the whole year; the distribution is given in Figure 5. There was a variation in the number of cases presented to the clinic per month and the survival rate varied from 47% to 70% per month.

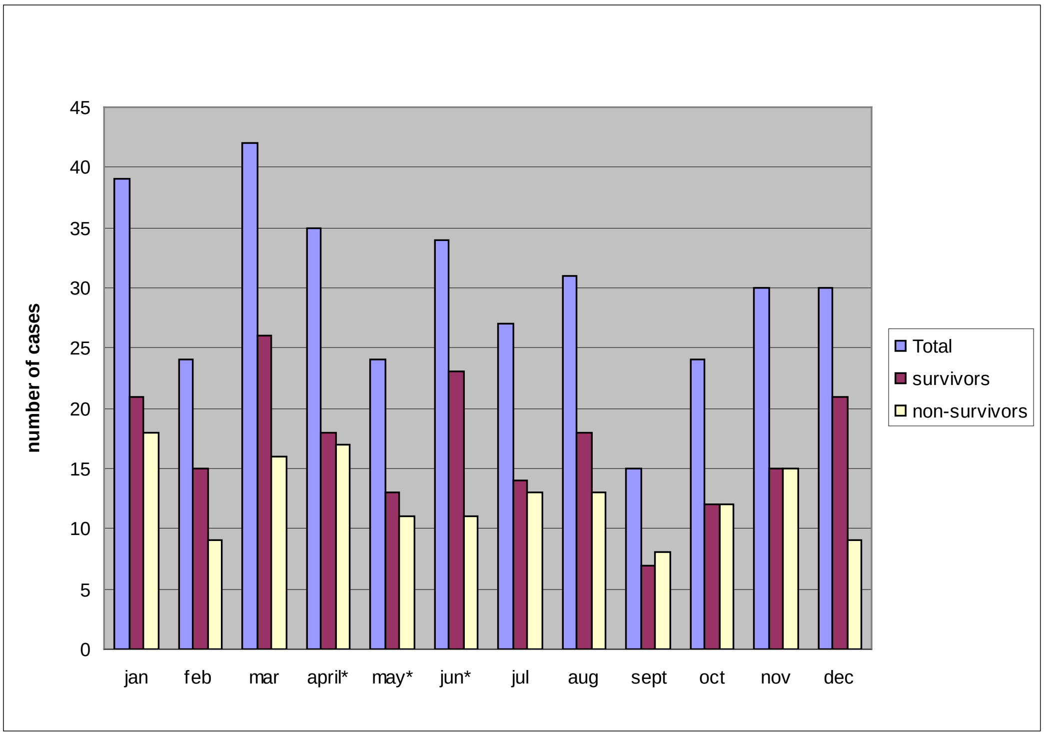


*Figure 5: Distribution of total number of cases, survivors and non-survivors per month for 355 cases that received at least one day of flotation therapy between the 12th of June 2006 and the 4th of April 2011. *data for the whole month not available for six years.*

The majority of cases, 67%, received ≤ 3 days of flotation therapy. Information about number of days of flotation therapy needed and survival rate per day is given in Table 5. One hundred and one cases (28%) needed only one day of flotation therapy before they either rose and stood on their own or were diagnosed non treatable. Only 18 cases (5%) were treated with flotation therapy for more than seven days. There was some variation in survival rate for cows treated with flotation therapy for less than seven days. For cows treated with flotation therapy for seven days or more there was a larger variation in survival rate, most likely due to the small number of animals. None of the animals that were treated with flotation therapy for more than 10 days survived.

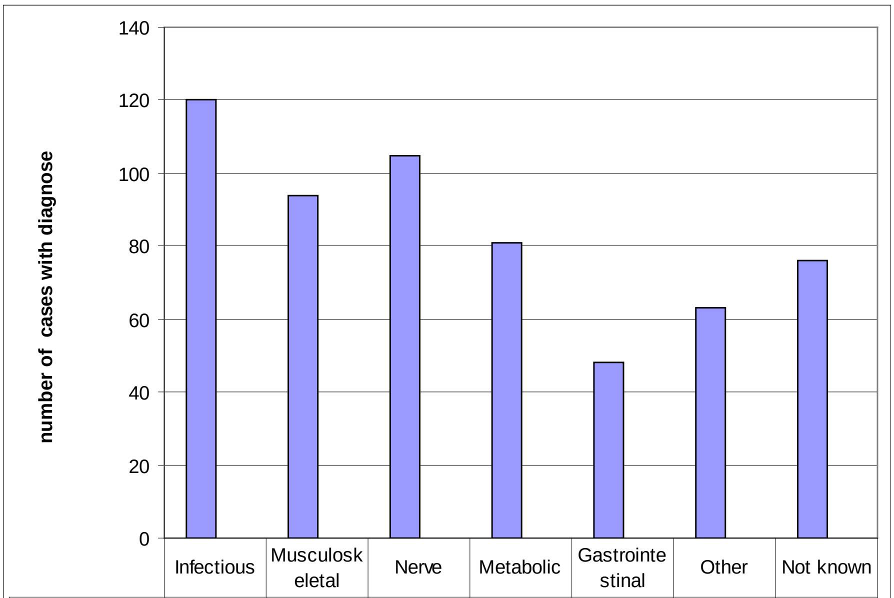
Table 5: Days of flotation therapy received, number of survivors and survival rates for 355 cases treated at the clinic between the 12th of June 2006 and the 4th of April 2011.

Days treated with flotation therapy	Number of cases	Number of survivors	Survival rate in %
1	101	55	54.5
2	71	40	56.3
3	66	46	69.7
4	44	24	54.5
5	29	16	55.2
6	14	9	64.3
7	12	4	33.3
8	7	5	71.4
9	4	2	50.0
10	2	2	100.0
>10	5	0	
Total	355	203	57.2

For 155 cases information on the length of recumbency before arrival to the hospital was available. The majority of these, 66% had been recumbent for less than four days and less than 5 % had been recumbent for more than seven days. There was an apparent decrease in survival rate with increasing number of days recumbent, although this difference was not statistically significant ($p > 0.05$; Chi square test). There was a large variation in survival rate for cows that have been recumbent for more than seven days, probably due to the small number of cases that had been recumbent so long.

In order to make the diagnoses visible they were categorised into seven different categories; infectious, musculoskeletal, nerve, metabolic, gastrointestinal, other and not known. The infectious category includes cases that were diagnosed with mastitis, metritis or an infective process elsewhere. The musculoskeletal category contains cases that suffer from hip-luxation, fracture, arthritis, myosite, myopathy and similar lesions. Nerve injuries such as nerve paralysis and nerve paresis that does not origin from the central nervous system were categorised under nerve. The metabolic category contains cases with a metabolic disorder that create a measurable change in the peripheral blood composition such as hypocalecemia, acetonemia and electrolyte alterations. The gastrointestinal category contains cases that were diagnosed with displaced abomasum, diarrhea, abomasal ulcers and similar diagnoses. The category with other includes cases that did not fit in any of the other categories. Examples of diagnoses in the category other are; dermatological problems, retained placenta, teat fibrosis and lymphoma. Cases with no diagnose noted in the medical record and cases with an uncertain diagnose were categorised under not known. The number of cases in each category and the survival rate for each category are shown in Figure 6.

Many cases had several diagnoses and were subsequently divided into several categories. In total the 355 cases had 587 different diagnoses. 199 cases were placed in one category, 95 cases were places in two different categories, 48 cases were placed in three different categories, 11 cases were placed in four different categories and two cases were placed in five different categories. A case was never placed twice in the same category.



	Infectious	Musculoskeletal	Nerve	Metabolic	Gastrointestinal	Other	Not known
Number of cases	120	94	105	81	48	63	76
Survival rate in %	67	36	68	73	46	48	58

Figure 6: Categories of diagnoses for 355 cases with 578 different diagnoses and survival rate for each category. The cases were treated with flotation therapy for at least one day between the 12th of June 206 and the 4th of April 2011.

For 342 cases a serum biochemical analysis, including AST, CK, Ca, P, K, CO_2 and BHB, was made upon arrival. The Ca, P and K values for survivors and non-survivors are shown in a box plot in Figure 7. There was no significant difference between survivors and non-survivors in relation to their Ca, P and K values (P-values 0.85, 0.30 and 0.76, respectively, in two sided t-tests.

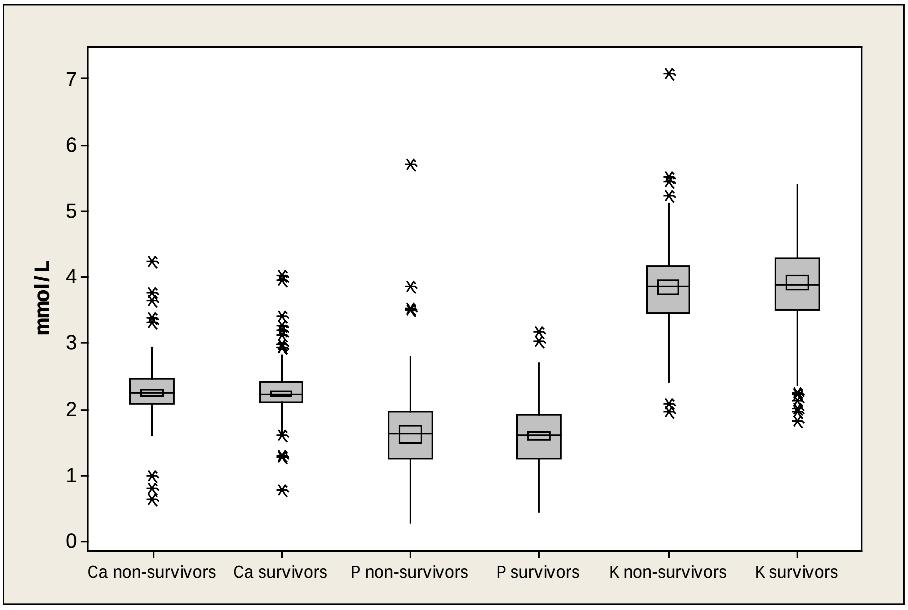


Figure 7: Box plot of Ca, P and K values at arrival for survivors and non-survivors for 342 cases treated with at least one day of flotation therapy between the 12th of June 2006 and the 4th of April 2011. Showing the median, confidence interval for the median, first quartile and third quartile in the box, max and min values as whiskers and outliers as stars.

The CK and AST values were not normally distributed and where therefore logarithmically transformed before being analyzed. A box plot of the log-CK values at arrival for survivors and non-survivors is shown in Figure 8. A two-sided t-test of the data gave a T-value of 4.72 and a P-value of < 0.001 indicating a significant difference between survivors and non-survivors.

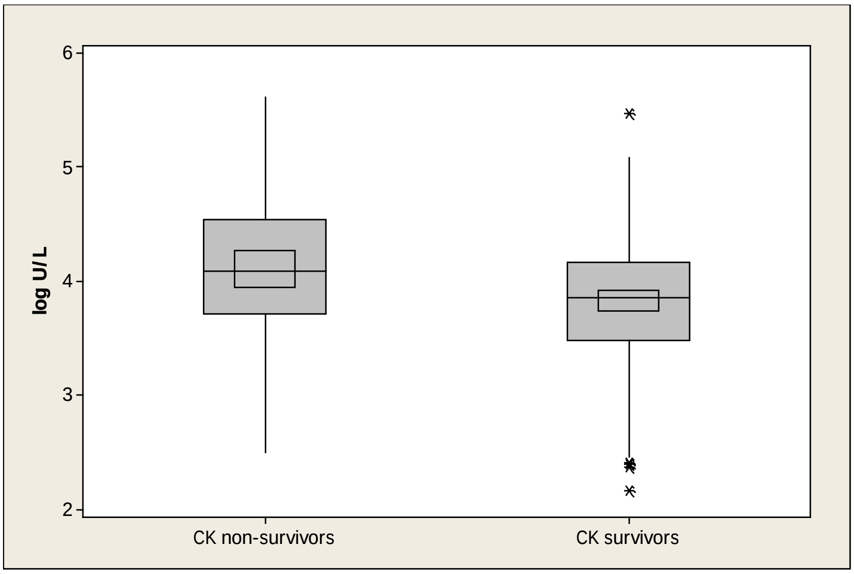


Figure 8: Box plot of CK values at arrival for survivors and non-survivors for 342 cases treated with at least one day of flotation therapy between June 2006 and April 2011. Showing the median, confidence interval for the median, first quartile and third quartile in the box, max and min values as whiskers and outliers as stars.

A box plot of the log-AST values at arrival for survivors and non-survivors are shown in Figure 9. A two-sided t-test for the data gave a T-value of 4.90 and a P-value of < 0.001 indicating a significant difference between survivors and non-survivors.

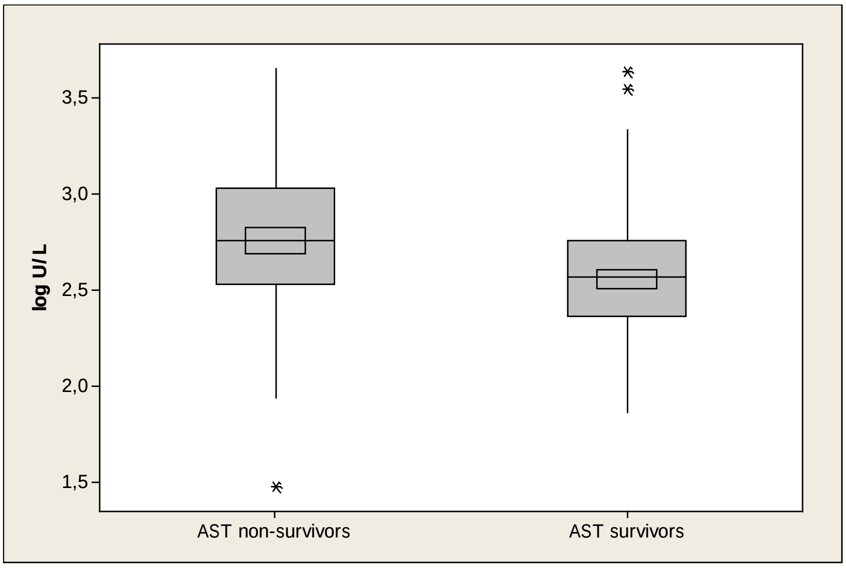


Figure 9: Box plot of AST values at arrival for survivors and non-survivors for 342 cases treated with at least one day of flotation therapy between the 12th of June 2006 and the 4th of April 2011. Showing the median, confidence interval for the median, first quartile and third quartile in the box, max and min values as whiskers and outliers as stars.

DISCUSSION

The overall survival rate for recumbent cows treated with at least one day of flotation therapy at the Large Animal Clinic at the Faculté de Médecine Vétérinaire during the time period for this study was 57%. This can be compared with the 33% survival rate for downer cows reported in the Minnesota survey (Cox et al. 1986) and 39% survival rate reported from New Zealand (Clark et al. 1987). When those studies were done flotation therapy was not available as a treatment technique. Previous reports on recovery rates for cases treated with flotation therapy are 46% and 37% (Smith et al. 1997; Burton et al. 2009). Considering that the survival rate 2007 was 70% and the fact that the non-recovery rate for the first day in the tank was 45% draw attention to the importance of a complete clinical examination before assisting the cow to stand. Doing a complete clinical examination of a recumbent cow can be challenging but is extremely important in order to save the animal from the suffering of a futile rising attempt and to initiate adequate treatment.

As previously described the fact that a cow stays recumbent can induce pressure damage and make her recovery impossible. Therefore, a recumbent cow should be helped to her feet as soon as her general condition allows. Even though Cox et al. (1992) showed that a recumbent cow on good bedding (sand) doesn't get pressure damage one could easily argue that the longer the cow stays recumbent the greater is the risk of developing pressure damages. The recovery rate for recumbent cows decreased from 76% on day one to 19% on day four in the study by Shpigel et al. (2003). Although there was an apparent decrease in survival rate with increasing days recumbent before arrival in the present study, this was not statistically significant. One reason for this might be that the patients were treated at a hospital and only the more severe cases are being referred. Another explanation can be that too few cases were included in the study.

Organizing diagnoses into categories is a useful way of visualising what the patients are suffering from. However, one should be careful when drawing conclusions from this type of data. Although it is not uncommon that a recumbent cow has several diagnoses, it should be noted that the cases included in the present study were treated in a university hospital. The patients received several clinical examinations per day from students and veterinarians which might explain why so many different diagnoses were identified. Some of the diagnoses were probably direct related to the recumbency while others were not.

In this study infectious, musculoskeletal and nerve injuries were the most common diagnose categories. Approximately one third of all the cases had a musculoskeletal or a nerve injury and 26% of all the cases were diagnosed with an infectious process. As a comparison, the three most common primary diagnoses from the study of recumbent cows by Shpiegel et al. (2003) were milk fever, dystocia and mastitis. Supposedly most cases in the nerve category have developed their lesions as a sequel to recumbency, however drawing these conclusions without information from an autopsy report is perilous. For the infectious and musculoskeletal category it is impossible to draw conclusions about the reason for the injuries, whether the cow is recumbent because of an infection or if the infection have developed because of the recumbency.

Survival rate for the different categories varied from 36% for the musculoskeletal category to 73% survival rate for the metabolic category. These survival rates could be expected for large animals, a metabolic disturbance is relatively easy to adjust with intravenous injections while a musculoskeletal injury in one limb greatly increase the weight borne by the other limbs and thus making it more difficult for the cow to rise.

In the metabolic category 57 out of the 81 cases had an electrolyte disturbance, representing 70% of the cases in that category and 16% of all cases. A possible explanation to the small percentage of cases with electrolyte disturbances could be that they were treated in a referring hospital; cases with electrolyte disturbance may have received treatment on farm by the local veterinarian and only being referred when not responding to treatment.

Metabolic disorders and recumbent cows is not an unusual combination. Milk fever is one of the most common reasons for cows to become recumbent. There are indications that milk fever cases with less severe hypocalcaemia, serum calcium levels of $\geq$ 1.7 mmol/L, have higher risk of becoming downer cows (Ménard and Thompson 2007). Clark et al. had a similar result in their study, recumbent cows with blood calcium levels within or close to the reference range were less likely to recover (Clark et al. 1987). Ménard and Thompson argued that apparent milk fever cases with normal Ca levels actually might have suffered from unobserved trauma around parturition. Hypokalemia as a reason for recumbency has been reported e.g. by Peek et al. (2000) and has been associated with muscle weakness (Sattler et al. 1998).

Hypophosphatemia has been reported as a complicating factor for milk fever cases. Results from Ménard et al. (Ménard and Thompson 2007) indicate that milk fever cases with hypophosphatemia have a higher risk of becoming downer cows. In contrast to their results Clark et al. found a reversed correlation between serum phosphorus levels and likelihood to recover in periparturient recumbent cows, cases with low serum phosphate levels were more likely to recover (Clark et al. 1987). Burton et al. had result similar to those from Clark et al. in their study of downer cows treated with flotation therapy, non-survivors had higher serum phosphate concentration; this was however only true for the group that were less than two weeks post partum (Burton et al. 2009). In this study there was no significant statistical difference in blood Ca, P or K values between survivors and non-survivors. A possible explanation for this can be that there was a variation in time after calving among the cows; information on days in milking was not available in the dataset.

Creatine kinase is found primarily in heart and muscle tissue and the serum levels increase rapidly after muscle damage. This makes it a potential indicator for pressure damage and predictor for the outcome of recumbency. One problem with CK as a predictor is the short half life of CK in serum, an estimated half life of two to four hours have been reported (Clark et al. 1987). Another problem is that an elevated CK activity can be the result of heart disease. Normal parturition and even more in the case of dystocia also result in increased serum CK. The serum CK values after a complicated calving are normally not higher than the reference value. The potential use of CK as a predictor for recumbency has been explored by others. In the induced recumbency experiment by Cox et al. the authors did not promote CK as a predictor for the outcome (Cox et al. 1982). In their study the CK values were highly variable at 12 and 24 hours after anaesthesia and a statistically significant difference between ambulatory and non-ambulatory cases occurred only at 48 and 96 hours after anaesthesia. They concluded that muscle damage alone was not the reason for recumbency and therefore CK should not be used to predict the outcome. Clark et al. did use CK as a potential predictor for recumbency (Clark et al. 1987). For CK to be useful as a predictor they stressed that the CK value have to be put in correlation with day of recumbency, and that after seven days down no biochemical analysis is good as a predictor. Shpigel et al. also used CK to predict the outcome of recumbent cows (Shpigel et al. 2003). They had a critical CK value of 34 305 U/L in their study and no animal with a higher value survived, they also had a 95% critical value of 16 000 U/L indicating that an animal with a higher CK value have 5% chance of survival. In the present study time did not allow to calculate a predictive value for CK but the significant difference that do exist between survivors an non-survivors suggests that the data can be used to calculate cut-off and a predictive values. Making the data interesting since it would be the first publication of a predictive value for cows treated with flotation therapy.

Aspartat aminotransferase is, like CK, a useful enzyme to evaluate muscle damage. It is however not as muscle specific as CK and hepatocellular damage can also result in increased serum activity. AST has been explored as a potential outcome predictor for recumbent cows. Being both positive and negative factors are the slow release of AST from damaged muscle cells and the long half life, the slow release from damaged cells implies that a sample taken too early could be misinterpreted. Results for AST from Shpigel et al. have been described previously in this paper; in short they showed that with serum activity higher than 171 U/L the cow had 80% likelihood not to recover. They also had a critical value of 694 U/L and no cow with a higher value recovered. Their predictive value for AST was significantly better at predicting the outcome compared to the CK and LDH predictive values (Shpigel et al. 2003). Clark et al. calculated a 95% critical value for AST to 890 U/L for the first seven days of recumbency in their study of periparturient recumbent cows, indicating that a cow with a higher value only had 5% chance of survival (Clark et al. 1987).

In the present study there were 68 cows that had AST values over 890 U/L upon arrival and 23 of them survived giving a survival rate of 34%. Likewise 110 cases had a CK value over 16 000 U/L at arrival and 44 of these survived giving a survival rate of 40%, 15 survivors had a CK value over 35 000 U/L at arrival to be compared with the maximal cut of value of 34 305 U/L reported by Shpigel et al. (2003). This shows that flotation therapy can be used to save cases that otherwise would have a guarded prognosis.

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