Received: 17 March 2022 | Accepted: 17 November 2022
DOI: 10.1111/jvim.16599

STANDARD ARTICLE

Journal of Veterinary Internal Medicine Open Access
ACVIM American College of Veterinary Internal Medicine

Prognostic indicators for survival of downer cattle treated using a flotation tank in a referral hospital: 190 cases (2000-2020)

Chelsea L. Holschbach[1] | Sarah M. Raabis[2] | Simon F. Peek[1]

[1]Department of Medical Sciences, School of Veterinary Medicine, University of Wisconsin-Madison, Madison, Wisconsin, USA

[2]Department of Clinical Sciences, School of Veterinary Medicine, Colorado State University, Fort Collins, Colorado, USA

Correspondence
Chelsea L. Holschbach, Department of Medical Sciences, School of Veterinary Medicine, University of Wisconsin-Madison, 2015 Linden Drive, Madison, WI 53706, USA.
Email: cholschbach@wisc.edu

Abstract

Background: Nonambulatory cattle present therapeutic challenges in addition to animal welfare concerns. Flotation therapy is a treatment option, but more information regarding prognostic indicators for survival is needed to guide use of this modality.

Hypothesis/Objectives: Evaluate historical and clinical variables assessed during hospitalization as prognostic indicators for survival in recumbent cattle undergoing flotation treatment in a referral hospital.

Animals: A total of 190 nonambulatory dairy cattle.

Methods: Retrospective case series. Medical records were analyzed from cattle undergoing flotation between 2000 and 2020. Univariable and multivariable logistic regression analyses were performed to assess the association of clinical variables with survival to discharge.

Results: Eighty-nine of 190 (47%) recumbent cattle survived to discharge. For each additional day of hospitalization, cattle were 1.10 (95% confidence interval [CI], 1.02, 1.21) times more likely to survive. Cattle unable to walk out of the tank after their first float session were 0.11 (95% CI, 0.04, 0.28) times less likely to survive compared to cattle that could and inappetent cattle were 0.22 (95% CI, 0.07, 0.63) times less likely to survive compared to cattle with normal appetites. Cattle diagnosed with coxofemoral luxation or toxemia were 0.11 (95% CI, 0.02, 0.65) and 0.16 (95% CI, 0.02, 0.90) times less likely to survive, respectively, compared to cattle with causes of recumbency that were undetermined.

Conclusions and Clinical Importance: Walking out of the tank after the first float session, appetite, diagnosis, and days of hospitalization are associated with outcome in nonambulatory dairy cattle treated by flotation. These findings can be used to determine likely outcome and guide treatment, referral, or euthanasia decisions.

KEYWORDS
behavior, coxofemoral luxation, dairy cattle, nonambulatory

Abbreviations: AST, aspartate aminotransferase; CK, creatine kinase; ROC, receiver operating characteristic curve.

1 | INTRODUCTION

Nonambulatory adult cattle, unable or unwilling to stand, are commonly referred to as downers.[1-3] Whatever the primary reason for recumbency, the risk of myopathy, neuropathy and complications associated with repeated, unsuccessful attempts to rise are well documented.[1-7] Over the last 2 decades, flotation tanks have become more widely available for the management of nonambulatory cattle, especially in dairy-dense areas of the United States. Their appeal lies in the buoyant, evenly distributed support that the water provides.[3-5,8] By assisting cattle to stand through flotation, a previous study reported 37% survival and adult cattle that were able to stand after the first flotation event were almost 5 times as likely to survive than those that could not stand after the first flotation event.[4] If they were able to stand normally on all 4 feet during the first flotation event they were also more likely (2.9 times) to survive.[4] A more recent retrospective identified an overall survival rate to discharge of 55% in a referral population of 1318 dairy cows treated by flotation, and the odds of nonsurvival increased with longer recumbency before referral, tachycardia, hypothermia, anemia and high aspartate aminotransferase activity and serum creatinine concentration.[3] Although these studies did not endorse flotation tank use versus other mechanical devices, veterinary literature reporting the deteriorating prognosis for cattle that remain recumbent beyond 24 hours emphasizes the need for prompt attempts at well-tolerated, effective and nontraumatic methods of assisting down cattle to stand.[3-5,8,9]

Of considerable relevance to the topic of nonambulatory cattle are concerns over animal welfare.[2,9,10] The 2014 National Animal Health Monitoring System survey on health and management practices highlighted that whereas approximately 76% of all dairy operations had at least 1 down cow per year, the proportion increased with size of operation and 70% of cattle recumbent for >24 hours failed to survive,[11] consistent with other studies identifying recumbency as a significant contributor to culling losses.[5,11,12]

With larger farms and the more commonplace use of flotation tanks, there is a clear need for information on factors that influence outcome and survival to improve decision making regarding flotation of cattle nonambulatory for any reason, and at any age. Previous veterinary literature has focused on flotation of adult cattle in early lactation. Our primary objective was to identify differences between survivors and nonsurvivors for multiple clinical, behavioral and clinicopathologic variables from retrospective data on a large number of down dairy cattle, distributed across all stages of lactation and ages presented to the University of Wisconsin-Madison Veterinary Teaching Hospital over an approximately 20-year period.

2 | MATERIALS AND METHODS

2.1 | Case selection

All dairy cattle, ≥9 months of age admitted to the University of Wisconsin-Madison Veterinary Teaching Hospital between 1 January 2000 and 31 December 2020 for which a flotation tank (Aqua Cow Rise System, Aqua Cow Rise System North America, Inc) was used at least once for treatment of recumbency were eligible for inclusion in the study. Cattle that were unable to stand at the time of admission to the hospital and those that became nonambulatory during hospitalization were included.

2.2 | Patient signalment and hospital management

Data obtained from the medical records included age, sex, breed, duration of hospitalization, number of flotation sessions, final clinical diagnosis, and whether or not the cow survived to discharge. Cattle were further categorized by diagnosis based on the most common causes of recumbency (i.e., coxofemoral luxation, metabolic disorder, toxemia, calving paralysis, other musculoskeletal injury, and lymphosarcoma). Cattle in the metabolic category were those that had primary clinical and biochemical evidence of hypocalcemia, hypokalemia, or hypophosphatemia. Toxemia refers to cattle with clinical evidence of metritis, mastitis, enteritis, or peritonitis, or those with clinicopathologic evidence of endotoxemia, including leukopenia or a left shift. Cattle with calving paralysis were postparturient, typically with a history of dystocia, that had evidence of obturator, femoral, or sciatic nerve damage or some combination of these. Other musculoskeletal injuries included stifle and hock injuries, septic joints, vertebral body fractures leading to compressive myelopathies, peripheral neuropathies, myopathies, and fractures. In cases with multiple diagnoses, cattle were categorized based on the clinician's ranked order of problems pertinent to the case. The first problem on the clinician's list was used to categorize cases. A typical flotation session was 8 hours in duration, with some variance depending on patient temperament. Cattle typically were floated twice in a 24-hour period, with 2, 4-hour rest periods between the float sessions (Figure 1A). Cattle were maintained in a sling, attached to a hoist and I-beam, which extended the entire length of the stall. This design facilitated movement into and out of the tank, ensuring cows could be lifted for physical examination and to access their udder for milking (Figure 1B). Cattle first were encouraged to stand without sling assistance, but if unable to rise, the sling was hoisted up far enough to allow the animals' legs to extend and bear weight. The sling was not used to support the weight of the cows in the flotation tank, and therefore did not influence standing behavior. Hobbles were commonly applied to the cows' hindlimbs to prevent them from splaying out. For lactating dairy cattle, days in milk were recorded. Cattle then were categorized into early (0-3 months), mid- (4-6 months), and late lactation (7-14 months or dry) for analysis. Information regarding duration of recumbency before hospital flotation therapy was documented (<6 hours, 6-12 hours, 13-18 hours, or >24 hours) as was any prior on-farm flotation tank use or other mechanical means used to encourage the cow to stand (e.g., hip lifts or slings). Data regarding the animal's behavior during the first flotation session also were obtained. These data included tank behavior during first flotation (i.e., standing on front- and hindlimbs, partial standing on front- or hindlimbs, or unable to stand), and behavior at the end of the first flotation session, once water was drained (i.e., stand on all limbs and walk out, stand on all limbs but unable to walk out, or unable to stand or walk). Appetite was rated as normal, decreased, or absent. The offered diets (type of feed and amounts) were based upon the owner's account at admission of what the cow was eating on the farm before the current illness (i.e., hay, grain, total mixed ration). Specifically, cows in the decreased appetite category consumed less feed in hospital than what they typically would consume on farm in a healthy state. Clinicians, technicians, and students recorded feed intake in a semiquantitative manner, basing intakes on proportion of feed consumed compared to what was offered, but did not explicitly weigh refused food.

2.3 | Laboratory and necropsy data

Laboratory data collected for each animal included admission serum potassium and ionized calcium concentrations and creatine kinase (CK) activity as well as the highest CK activity during hospitalization. Serum potassium and ionized calcium concentrations were measured on a blood gas analyzer (ABL90 FLEX analyzer, Radiometer America, Inc), whereas CK activity was obtained from a serum biochemistry profile. If the cow died or was euthanized and necropsy was performed, specific pathology associated with the coxofemoral joints, hindlimb musculature and any other pertinent findings were recorded.

2.4 | Case outcome

Our outcome of interest was survival to discharge. Survivors were defined as animals that were ambulatory at the time of discharge from the hospital, and nonsurvivors were those cattle that died or were euthanized.

2.5 | Statistical analysis

Statistical analyses were performed using RStudio Version 1.2.5033 (RStudio, Inc, Boston, MA) and GraphPad Prism version 9.2.0 (GraphPad Software, San Diego, CA). Categorical and continuous variables were analyzed using univariable logistic regression to assess the association between recorded clinical data and case outcome (ie, discharge or euthanasia). Continuous variables were plotted against the log odds of the outcome variable to ensure the relationship was linear. Relevant 2-way interactions between variables were investigated. Wald chi-squared tests were performed to evaluate the impact of individual categorical variables on the associations between clinical data and case outcome. Variables with $P < .2$ were entered into a multivariable logistic regression model. Multicollinearity among continuous variables was assessed by calculating variance inflation factor ratios. Lasso regression, a regularization method that decreases overfitting of multivariable models, was used to determine the final predictive multivariable logistic model using the glmnet package.[13-15] The final model fit was evaluated with an analysis of deviance table using chi-squared tests. Additionally, a receiver operator characteristic (ROC) curve was plotted and the area under the curve was calculated for the final multivariable model using the ROCit package.[16] Continuous variables also were assessed for normality by evaluating histograms. Variables with a parametric distribution were reported as mean ± SD and were compared between outcome groups using a Student's *t* test. Variables with a nonparametric distribution were reported as median (interquartile range [IQR]) and were compared between groups using a Wilcoxon rank sum test. Statistical significance was set at $P < .05$.

3 | RESULTS

3.1 | Patient signalment

One hundred ninety-six cattle met the inclusion criteria for the study, but 6 animals were excluded from analysis because they were discharged from the hospital alive, but still recumbent. Seven dairy breeds were represented with the majority being Holsteins (n = 166, red and white and black and white combined), followed by Guernseys (n = 10), Jerseys (n = 7), Brown Swiss (n = 3), Ayrshires (n = 2), and

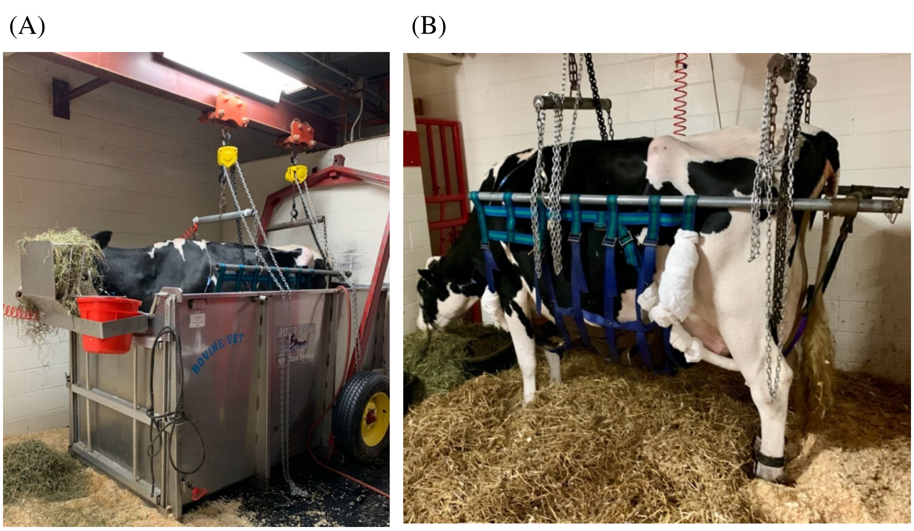

FIGURE 1 (A) Photograph of float tank setup. Note that the cow is in the sling, which is attached to a hoist system that runs the entire length of the stall. This arrangement facilitates movement of recumbent cattle in and out of the tank. (B) Photograph of previously recumbent patient that was able to walk out of tank. Note that sling remains in place, although not supporting the patient's weight. Towels are used to pad the straps and prevent pressure sores. The patient also is wearing hobbles

TABLE 1 Univariable logistic regression analysis for prediction of survival in 190 dairy cattle treated at a referral hospital for recumbency with use of a flotation tank

Variable	Survivors (n = 89)	Nonsurvivors (n = 101)	OR (95% CI)	P
Age (y)	4 (0.75, 11)	4 (1, 17)	0.95 (0.84, 1.07)	.42
Days in milk (reported for 164/177)				
Unknown (n = 13) or N/A (n = 2 males and n = 11 nonlactating heifers)	15/26 (58%)	11/26 (42%)	Reference	–
Early (0-3 mo)	59/118 (50%)	59/118 (50%)	0.73 (0.30, 1.72)	.47
Mid (4-6 mo)	3/8 (38%)	5/8 (63%)	0.44 (0.10, 2.18)	.32
Late (7-14 mo or dry)	12/38 (32%)	26/38 (68%)	0.33 (0.11, 0.94)	.04
Hours down (reported for 183/190)				
Unknown	2/7 (29%)	5/7 (71%)	Reference	–
<6 h	27/60 (45%)	33/60 (55%)	2.05 (0.40, 15.07)	.41
6-12 h	17/36 (47%)	19/36 (53%)	2.24 (0.42, 17.07)	.37
13-24 h	9/13 (69%)	4/13 (31%)	5.63 (0.83, 53.43)	.09
>24 h	34/74 (46%)	40/74 (54%)	2.12 (0.43, 15.50)	.39
Farm manipulation				
None reported	73/144 (51%)	71/144 (49%)	Reference	–
Float tank	10/30 (33%)	20/30 (67%)	0.48 (0.21, 1.09)	.09
Hip lift or sling	6/16 (38%)	10/16 (63%)	0.58 (0.19, 1.65)	.32
Diagnosis				
Cause of recumbency undetermined	11/16 (69%)	5/16 (31%)	Reference	–
Coxofemoral luxation	6/23 (26%)	17/23 (74%)	0.16 (0.04, 0.62)	.01
Metabolic	30/42 (71%)	12/42 (29%)	1.14 (0.31, 3.90	.84
Toxemias	8/26 (31%)	18/26 (69%)	0.20 (0.05, 0.74)	.02
Calving paralysis	5/10 (50%)	5/10 (50%)	0.45 (0.08, 2.31)	.34
Other musculoskeletal injury	28/68 (41%)	40/68 (59%)	0.32 (0.09, 0.97)	.05
Lymphosarcoma	1/5 (20%)	4/5 (80%)	0.11 (0.01, 1.01)	.08
Days of hospitalization	7 (5, 10)	4 (2, 6)	1.12 (1.05, 1.20)	.001
Number of flotation sessions	4 (2, 7)	5 (2, 6.5)	0.99 (0.93, 1.06)	.89
Behavior during first flotation (reported for 183/190)				
Stood on front and hindlimbs	68/103 (66%)	35/103 (34%)	Reference	–
Partial standing on front or hindlimbs	8/33 (24%)	25/33 (76%)	0.16 (0.06, 0.39)	<.001
Unable to stand	9/47 (19%)	38/47 (81%)	0.12 (0.05, 0.27)	<.001
Undetermined	4/7 (57%)	3/7 (43%)	0.69 (0.14, 3.64)	.63
Behavior at end of first flotation, water drained (reported for 169/190)				
Stand on all limbs and walk out of tank	51/64 (80%)	13/64 (20%)	Reference	–
Stand on all limbs, unable to walk out	6/9 (67%)	3/9 (33%)	0.51 (0.12, 2.66)	.38
Unable to stand or walk	21/96 (22%)	75/96 (78%)	0.07 (0.03, 0.15)	<.001
Undetermined	11/21 (52%)	10/21 (48%)	0.28 (0.10, 0.80)	.02
Appetite				
Normal	36/55 (66%)	19/55 (35%)	Reference	–
Decreased	31/48 (65%)	17/48 (35%)	0.96 (0.43, 2.18)	.92
Inappetent	22/87 (25%)	65/87 (75%)	0.18 (0.08, 0.37)	<.001

Note: Median (IQR) and count (%) of variables for patients that subsequently survived to discharge or were euthanized (survivors and nonsurvivors, respectively).

Milking Shorthorns (n = 2). One hundred eighty-eight were female (99%) and 2 were male (1%). Days in milk were known for 93% (164/177) of the female cattle, excluding 11 nonlactating heifers (6%). Of 164 cows, 141 were lactating (86%) and 23 were dry (14%). For the lactating cows, median (IQR) days in milk was 53 (2, 54). The median age of all cattle was 4 years (range, 9 months to 17 years). Eighty-nine cattle survived (47%) and 101 died or were euthanized (53%).

3.2 | Laboratory and necropsy data

A total of 176/190 (93%) patient records included serum potassium concentration from admission laboratory testing. The mean serum potassium concentration was not different between survivors (3.66 mEq/L ± 0.80) and nonsurvivors (3.63 mEq/L ± 0.83; *P* = .78).

Ionized calcium concentrations were obtained from 66/190 (35%) patient records. The mean ionized calcium concentration at admission was not different between survivors (1.21 mmol/L ± 0.18) and nonsurvivors (1.27 mmol/L ± 0.19; *P* = .2).

Additionally, 173/190 (91%) patients had CK activity measured at admission and at least once more during hospitalization. The CK activities were highly variable and not normally distributed. Admission CK median activity was numerically lower for survivors (4209 U/L [1154, 11 587]) compared to nonsurvivors (5034 U/L [1273, 13 761]), but a statistically significant difference was not found between the groups (*P* = .9). Similarly, when comparing the highest CK activity measured during hospitalization, survivors had lower median CK activity (5472 U/L [1369, 14 008]) compared to nonsurvivors (7952 U/L [2411, 24 247]), but this difference did not lead to a significant difference in outcome (*P* = .49).

TABLE 2 Final multiple logistic regression analysis for prediction of survival in 190 dairy cattle treated at a referral hospital for recumbency with use of a flotation tank

Variable	OR (95% CI)	*P*
Days hospitalized	1.10 (1.02, 1.21)	.03
Diagnosis		
Undetermined	Reference	–
Coxofemoral luxation	0.11 (0.02, 0.65)	.02
Metabolic	2.29 (0.45, 11.40)	.30
Toxemias	0.16 (0.02, 0.90)	.04
Calving paralysis	0.79 (0.09, 6.46)	.82
Other musculoskeletal injury	0.29 (0.06, 1.17)	.09
Lymphosarcoma	0.09 (0.003, 1.10)	.08
Behavior (end of first flotation, water drained)		
Stand on all limbs and walk out	Reference	–
Stand on all limbs, no walking	0.62 (0.10, 4.87)	.62
Unable to stand or walk	0.11 (0.04, 0.28)	<.001
Undetermined	0.44 (0.11, 1.72)	.23
Appetite during float sessions		
Normal	Reference	–
Decreased	2.10 (0.70, 6.40)	.20
Inappetent	0.22 (0.07, 0.63)	.006

Eighty of the 101 (79%) cows that did not survive had necropsies performed. Thirty-four of the 80 animals (42%) had unilateral or bilateral coxofemoral joint pathology. The most common lesions were rupture of the ligament of the head of the femur (n = 17) followed by coxofemoral joint luxation (n = 15). The majority (47%, n = 7) of coxofemoral joint luxations were caudoventral. Six of the 7 caudoventral luxations occurred in cows that had closed reduction performed antemortem and reluxated in hospital. Of the 46 cows with normal coxofemoral joints, 19 had moderate to severe generalized myonecrosis of their hindlimb musculature. Other notable pathology included 6 cases of vertebral body fractures, 2 cases of extradural spinal cord abscesses leading to compressive myelopathy, and 2 cases of spinal cord lymphosarcoma. Many of the cattle had peripheral nerve injury, varying from perineural edema and hemorrhage to rupture. Stifle joint injuries leading to ruptured cranial and caudal cruciate ligaments and collateral ligaments were appreciated in 2 cases. Only 1 case of long bone fracture (tibia and femur) was identified, and had been diagnosed antemortem. The cause of death in 10 animals was determined by pathologists to be sepsis based on evidence of multiple body cavity or organ system infections at necropsy.

3.3 | Univariable analysis results

The distribution and categorization of variables by outcome category and results of the univariable analysis are presented in Table 1.

3.4 | Final multivariable analysis results

The ability to walk out of the tank after the first float session, appetite, diagnosis, and days of hospitalization were retained in the final model (Table 2). The area under the ROC curve was 0.89

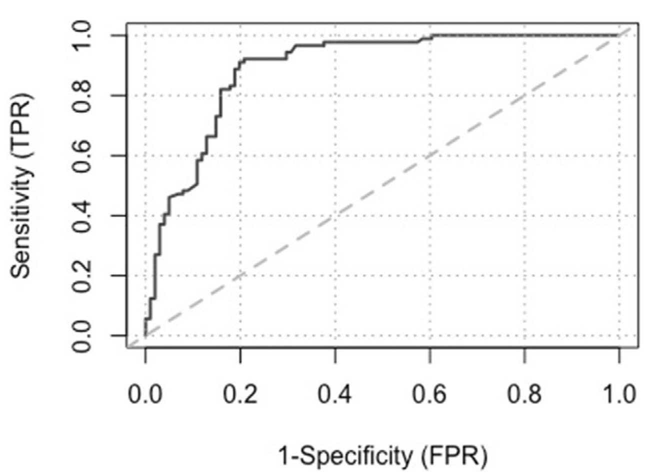

FIGURE 2 Receiver operator characteristic curve from final multiple logistic regression model. The estimated AUC (area under the curve) of the final model is 0.89 (95% CI, 0.84, 0.94). The sensitivity of the model was 0.84 and the specificity of the model was 0.76

(sensitivity, 84%; specificity, 76%), indicating accurate classification of outcome by the final model (Figure 2).

4 | DISCUSSION

4.1 | Population and outcome

Forty-seven percent of recumbent cattle treated by flotation therapy at the University of Wisconsin-Madison Veterinary Teaching Hospital between 2000 and 2020 survived to discharge. The survival percentage in our study was higher than that of a previous hospital study conducted in the United States,[4] which reported a survival rate of 37%, but slightly less than that reported from a more recent study in Québec[3] where survival reached 55%. Differences in the cattle population studied previously[3] (cattle with coxofemoral luxation excluded) and the population used in our study (cattle with coxofemoral luxation included) may have contributed to the difference in success rates. Cattle in our study that were recumbent because of coxofemoral luxation were significantly less likely to survive compared to cattle for which cause of recumbency was undetermined. As a consequence, our overall survival rate would have been considerably higher if we had similarly excluded individuals with coxofemoral luxation from our analysis (n = 23). Of particular clinical interest, 14 of the 15 cattle with coxofemoral joint luxation identified during necropsy had been diagnosed antemortem by radiography. Fifty percent (n = 7) of these cows had closed reduction of the coxofemoral joint that failed, whereas the other 50% were euthanized promptly after diagnosis. Additionally, a subset of cows (17/80) had only orthopedic pathology (ruptured ligament of the head of the femur) at the time of necropsy. It is likely that this pathology played a role in recumbency in these cattle, but little veterinary literature is available describing this lesion as a primary cause of recumbency. Further research is needed to determine the clinical relevance of this condition as well as techniques for antemortem diagnosis. Increased use of high frequency musculoskeletal ultrasound, already a diagnostic modality used for identifying coxofemoral luxations,[17] may prove useful for identifying soft tissue lesions associated with the joint. Results of a comprehensive physical examination are always important, however challenging they can be to perform in a nonambulatory mature cow, and must include evaluation for catastrophic musculoskeletal injuries before referral so as to avoid unnecessary suffering. Simultaneous distal limb manipulation and external palpation over the upper femur and coxofemoral region are important physical diagnostic procedures to include on every down cow in hopes of identifying upper limb fractures and luxations, especially craniodorsal abnormalities, and substantial subluxations. Similarly, rectal palpation while the limb is being advanced, retracted and abducted by an assistant can be helpful in identifying some cases of ventral luxation where the femoral head dislocates into the obturator foramen. As was identified at necropsy in several cases in our study however, substantial ligamentous damage to the coxofemoral region can be present but elusive to repeated physical examination in recumbent individuals, and can contribute to continued inability to rise.

The referral population from which our retrospective cases were drawn was unique. Most of the cattle in our study were highly valuable, whether for genetic or show reasons, and in many instances were referred directly from farms without prior veterinary examination. The owners generally were willing to incur the expense associated with transport, examination, diagnostic testing, and flotation treatment, at least initially, without knowing much about the prognosis. This situation might be different for commercial grade cattle, but with increasing availability of mobile flotation tank services and private veterinary practices with haul-in flotation tank set-ups, our findings along with those of other studies[3,4] are still highly relevant to both producers and ambulatory veterinarians alike.

4.2 | Patient signalment and outcome

The median age of cattle receiving flotation tank treatment was slightly lower than previously reported,[3,4] because we included cattle <1 year of age. Age however was not a prognostic indicator for survival. These findings are in agreement with results from other studies[3,4] and remain an important finding because there is a tendency for producers and veterinarians to associate a worse prognosis for survival in older, recumbent cattle.

Most commonly, cattle become recumbent during the peri- or postparturient period secondary to metabolic derangements, systemic infections, toxemia, or dystocia.[1,5] However, in our study, only 43% (82/190) of cattle were ≤2 weeks postpartum. This finding is in contrast with other studies with 63% lactating cattle <14 days in milk[4] and 85% lactating cattle, a median of 4 days in milk.[3] Our dairy clientele and referring veterinarians are highly skilled in treating common early postparturient diseases of cattle, and therefore our referrals in early lactation likely represent refractory cases, requiring more intensive treatment. Those in our later categories of mid- and late lactation were more likely to represent cattle with nonmetabolic, nondystocia-related causes of recumbency, a greater proportion of which include trauma and musculoskeletal injury cases. In interpreting our results, the influence of these observations must be considered. Early lactation cases are typically refractory metabolic cases whereas the later lactation cases are more often trauma cases. Regardless, days in milk was not associated with outcome in our study.

Surprisingly, prior on-farm manipulation and hours down before flotation treatment were not associated with outcome in our study. Neither previous on-farm flotation nor the use of hip lifters or slings influenced outcome in cattle in our study after referral for flotation. The fact that prior use of hip lifters (16 cases, 6 of which survived) did not substantially impair survival should not be taken as tacit approval of this form of assistance to stand, because these devices can be extremely traumatic if used inappropriately or repeatedly. A previous report found that the odds of successful flotation treatment of nonambulatory cattle decreased with every additional hour that the animal was recumbent before treatment was initiated.[5] Another study found that >7 days of recumbency before flotation treatment increased the odds of euthanasia or death 3-fold,[3] whereas another study did not find duration of recumbency before first float treatment to be a prognostic indicator for survival.[4] Clinicians at our teaching hospital historically have given clients a more guarded prognosis for survival if a cow has been recumbent for >24 hours, based on previous findings.[9] Time down before flotation may not have been a prognostic indicator for survival in our study because the majority of cattle (60%) received their first flotation treatment within 24 hours of the onset of recumbency. Secondary muscle and nerve damage occurs rapidly in downer cattle,[4] and therefore urgency exists for producers to seek flotation treatment immediately for high value cattle.

4.3 | Laboratory results and outcome

Hypocalcemia is a well-documented cause of recumbency in periparturient cattle.[2,4,6] Severe hypokalemia (usually <2 mEq/L), although much less common, also can cause recumbency.[6] Ionized calcium (the biologically active form of calcium) and serum potassium concentrations are easily measured using stall-side point-of-care instruments, and were of particular interest to us. Our results showed no significant differences in serum concentrations of ionized calcium or potassium at admission between survivors and nonsurvivors, similar to the results of a previous study.[4] Additionally, these mean electrolyte concentrations were within normal reference ranges (serum ionized calcium reference range, 1.16-1.33 mmol/L and serum potassium reference range, 3.2-4.7 mEq/L). The lack of difference in calcium concentrations between the 2 groups most likely is because of the fact that the initial treatment for most recumbent cattle on farms is at least 1 bottle of 23% calcium gluconate. Only 3/190 (< 2%) cows in our study were diagnosed with hypocalcemia as the sole cause of recumbency. Serum potassium concentrations are influenced by dry matter intake, concurrent metabolic disease, specific drug treatments, and acid-base status.[6] Only 4/190 (2%) cows had severe hypokalemia (<2 mEq/L). All 4 cows had concurrent infections, specifically coliform mastitis or salmonellosis. An inciting cause of hypokalemia, documented in 2 cows without concurrent systemic infection, was repeated dosing of isoflupredone acetate.

Serum activity of CK can provide insight into the extent of muscle damage, but the veterinary literature is conflicting on the prognostic accuracy of these results.[3,6] Consequently, we wanted to compare admission serum CK activity and highest CK activity measured during hospitalization between survivors and nonsurvivors. In our analysis, CK activity was not a useful prognostic indicator for survival to discharge. Two previous studies also corroborate this finding.[3,4]

4.4 | Patient behavior and outcome

In agreement with a previous study,[4] cattle that could walk out of the tank after the first flotation session, or that had a normal appetite, were more likely to survive to discharge compared to individuals that were unable walk out of the tank or were inappetent. These behaviors within the first 24 hours of hospitalization proved to be important prognostic indicators for survival to discharge in our study, whereas the measured laboratory variables that we analyzed were not. The fact that we did not identify improved survival to discharge in association with any clinicopathologic variable is different from some previous studies. Recently, a study identified high aspartate aminotransferase (AST) activity, increased serum creatinine concentration and anemia as increasing the odds of nonsurvival[3]; high AST activity also has been shown to be associated with increased culling in previous studies.[18,19] Unfortunately, AST activity was inconsistently available in our study patients, challenging our ability to analyze this variable and its utility as a prognostic indicator.

One of the most common questions asked by owners when treating recumbent cattle using flotation is, "If a cow does not stand during her first flotation treatment, how many more attempts should she be given before making the decision to euthanize?" In our study, the number of flotation sessions was not a prognostic indicator of survival to discharge, and therefore we cannot comment on either an ideal number of float treatments or an upper limit on the total number of flotation sessions to recommend. Increased days of hospitalization did lead to an increase in likelihood of survival. The disparity in outcome between these 2 variables (number of float treatments and days of hospitalization) can be explained by the fact that cows often were hospitalized for continued treatment of the condition which led to recumbency, but they did not warrant flotation for the duration of their hospital stay. For owners, it is often a financial decision coupled with a cow's clinical diagnosis. It may be more pertinent to make decisions on duration of treatment or euthanasia based on the diagnosed cause of recumbency, response to first flotation treatment, and appetite.

4.5 | Study limitations

The retrospective nature of our study was a main limitation. There were other variables we would have liked to analyze, (e.g., blood lactate and beta-hydroxybutyrate concentrations) but these diagnostic tests were not routinely performed in recumbent cattle during the past 20 years with the same regularity as they are in our in-patient population today. Similarly, the inconsistent measurement of AST activity hindered our ability to investigate this analyte and its potential prognostic value (as indicated by some other studies) in our study population. Other studies have identified hospital-based clinicopathologic variables such as increased serum cardiac troponin I (cTnI)[20] and serum creatinine concentrations and AST activity,[3] as well as anemia and neutropenia,[3] as being negatively associated with survival in downer cattle. Although several of these variables (e.g., creatinine, AST) are commonly available, cTnI is not, and therefore its prognostic utility will not be available to most ambulatory veterinarians. We also realize that some of our clinical findings (e.g., appetite) are subjective and may not carry the same weight as more objective findings. We believe however that historical and clinical variables are crucial to assess when attempting to prognosticate survival in recumbent cattle. For a prospective study, it would be important to document whether the decision to euthanize was made for medical or financial reasons.

Additionally, the results of our multivariable logistic regression analysis should be interpreted with caution, given that some variables analyzed in our study population included missing data (i.e., unknown categories for variables). Consequently, we reanalyzed the multivariable logistic regression model with all cows that had any unknown variables removed (n = 42). After lasso regression, ability to walk out during the first float session and appetite were retained in the model despite the suspected loss of study power from decreased sample size. Cattle that were unable to stand or walk at the end of the first float session were 0.07 (0.03, 0.15) times less likely to survive to discharge compared to cattle that could walk out of the tank successfully ($P < .0001$).

4.6 | Conclusion

The ability to walk out of the tank after the first float session, appetite, diagnosis, and days of hospitalization were associated with outcome in nonambulatory dairy cattle treated by flotation. Walking out of the tank after the first float session was associated with outcome after exclusion of cows that had missing data for the categorical variables analyzed. Additionally, some variables that have been considered poor prognostic indicators for survival (e.g., duration of recumbency before first flotation tank treatment) did not differ between survivors and nonsurvivors. These findings can be used to determine likely case outcome and assist producers with decisions concerning treatment, referral, or euthanasia.

ACKNOWLEDGMENT

No funding was received for this study.

CONFLICT OF INTEREST DECLARATION

Authors declare no conflict of interest.

OFF-LABEL ANTIMICROBIAL DECLARATION

Authors declare no off-label use of antimicrobials.

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) OR OTHER APPROVAL DECLARATION

Authors declare no IACUC or other approval was needed.

HUMAN ETHICS APPROVAL DECLARATION

Authors declare human ethics approval was not needed for this study.

ORCID

Chelsea L. Holschbach https://orcid.org/0000-0001-5173-5240

REFERENCES

1. Cox VS, McGrath CJ, Jorgensen SE. The role of pressure damage in pathogenesis of the downer cow syndrome. *Am J Vet Res*. 1982;43:26-31.
2. Fenwick DC. The downer cow syndrome. *Aust Vet J*. 1969;45(4):123-126.
3. Puerto-Parada M, Bilodeau ME, Francoz D, et al. Survival and prognostic indicators in downer dairy cows presented to a referring hospital: a retrospective study (1318 cases). *J Vet Intern Med*. 2021;35:2534-2543.
4. Burton AJ, Nydam DV, Ollivett TO, et al. Prognostic indicators for non-ambulatory cattle treated by use of a flotation tank system in a referral hospital: 51 cases (1997-2008). *J Am Vet Med Assoc*. 2009;234(9):1177-1182.
5. Stojkov J, Weary DM, von Keyserlingk MAG. Nonambulatory cows: duration of recumbency and quality of nursing care affect outcome of flotation therapy. *J Dairy Sci*. 2016;99(3):2076-2085.
6. Guard CL, Peek SF, Fecteau G. Musculoskeletal disorders. In: Peek SF, Divers TJ, eds. *Rebhun's Diseases of Dairy Cattle*. 3rd ed. St Louis: Elsevier; 2017:553-605.
7. Fenwick DC. Parturient paresis of cows. I. Response to treatment and the effect of the duration of symptoms. *Aust Vet J*. 1969;45(4):111-113.
8. Zanolari P, Monnard R, Hirsbrunner G. Lifting techniques in bovine recumbency. *Schweiz Arch Tierheilkd*. 2019;161(10):619-625.
9. Green AL, Lombard JE, Garber JE, et al. Factors associated with occurrence and recovery of non-ambulatory cows in the United States. *J Dairy Sci*. 2008;91:2275-2283.
10. Stull CL, Payne MA, Berry SL, Reynolds JP. A review of the causes, prevention, and welfare of nonambulatory cattle. *J Am Vet Med Assoc*. 2007;231:227-234.
11. USDA. Dairy 2014. Health and Management Practices on U.S. Dairy Operations 2014, Report 3, USDA-APHIS:VS, CEAH, National Animal Health Monitoring Systems, Fort Collins, CO; February 2018. #696.0218. https://www.aphis.usda.gov/animal_health/nahms/dairy/downloads/dairy14/Dairy14_dr_PartIII.pdf. Accessed June 30, 2021.
12. Cook NB. Symposium review: The impact of management and facilities on cow culling rates. *J Dairy Sci*. 2020;103(4):3846-3855.
13. Hastie T, Tibshirani R, Wainwritght M. *Statistical Learning with Sparsity: The Lasso and Generalizations*. 1st ed. New York: CRC Press Taylor and Francis Group; 2015.
14. Friedman J, Hastie T, Tibshirani R, et al. *Lasso and Elastic-Net Regularized Generalized Linear Models*; 2021. https://cran.r-project.org/web/packages/glmnet/glmnet.pdf. Accessed November 30, 2022.
15. Luethy DL, Feldman R, Stefanovski D, Aitken MR. Risk factors for laminitis and nonsurvival in acute colitis: retrospective study of 85 hospitalized horses (2011-2019). *J Vet Intern Med*. 2021;35:2019-2025.
16. Khan RA. *ROCit: An R Package for Performance Assessment of Binary Classifier With Visualization*; 2020. https://cran.r-project.org/web/packages/ROCit/vignettes/my-vignette.html. Accessed November 30, 2022.
17. Taguchi K, Kudo K, Suzuki T, et al. Ultrasonographic appearance of bovine coxofemoral luxation in different directions. *J Vet Sci Technol*. 2011;S3(3):1-4.
18. Clark RG, Henderson HV, Hoggard GK, Ellison RS, Young BJ. The ability of biochemical and haematological tests to predict recovery in periparturient recumbent cows. *N Z Vet J*. 1987;35:126-133.
19. Shpigel NY, Avidar Y, Bogin E. Value of measurements of the serum activities of creatine phosphokinase, aspartate aminotransferase and lactate dehydrogenase for predicting whether recumbent dairy cows will recover. *Vet Rec*. 2003;152:773-776.
20. Labonte J, Dubuc J, Roy JP, et al. Prognostic value of cardiac troponin I and L-lactate in blood of dairy cows affected by downer cow syndrome. *J Vet Intern Med*. 2018;32:484-490.

How to cite this article: Holschbach CL, Raabis SM, Peek SF. Prognostic indicators for survival of downer cattle treated using a flotation tank in a referral hospital: 190 cases (2000-2020). *J Vet Intern Med*. 2023;37(1):366-373. doi:10.1111/jvim.16599