STANDARD ARTICLE

Journal of Veterinary Internal Medicine

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Survival and prognostic indicators in downer dairy cows presented to a referring hospital: A retrospective study (1318 cases)

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Abstract

Background: Downer cow syndrome, a common problem in dairy cattle, represents a diagnostic and therapeutic challenge for the attending veterinarian. Identifying prognostic indicators and assessing the odds of survival may improve the accuracy of the clinician's prognosis at the time of diagnosis.

Objective: To describe a population of downer dairy cows referred to a hospital and investigate predictors of outcome.

Animals: Recumbent adult dairy cows (cows unable or unwilling to stand without help) treated at a referral hospital.

Methods: Data at the time of admission were collected from medical records of downer dairy cows treated at the Centre Hospitalier Universitaire Vétérinaire between 1994 and 2016. Simple and multivariable logistic regression analyses were performed to assess the association of predictors with the outcome.

Results: Among 1318 cows included, 727 (55%) cows were discharged, and 591 (45%) cows died or were euthanized. Cows with longer time of recumbency before referral (odds ratio [OR] = 3.6), tachycardia (100-120 beats per minute [bpm], OR = 1.93; >120 bpm, OR = 2.92), tachypnea (OR = 1.76), hypothermia (OR = 2.08), anemia (OR = 3.30), neutropenia (OR = 1.7), high aspartate aminotransferase activity (500-1000 U/L, OR = 2.16; >1000 U/L, OR = 6.69), and increased serum creatinine concentration (OR = 1.75) had higher odds of nonsurvival.

Conclusions and Clinical Importance: These findings may help the practitioner to consider treatment options and decide if referral is likely beneficial based on the odds

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of success. Early recognition of low chance of survival may facilitate an early decision for euthanasia.

KEYWORDS

cattle, nonambulatory, outcome, recumbent, ruminant

1 | INTRODUCTION

Downer cow syndrome is a common problem in dairy cattle. The incidence of downer cow syndrome, defined as cattle that are unable to stand after 24 hours of recumbency, is estimated between 1.1 and 2.1 downer cows per 100 cow years at risk.[1-3] The prognosis for downer dairy cows varies according to the definition used.

At the farm, downer dairy cows represent a diagnostic and therapeutic challenge for the attending veterinarian. Clinical examination is essential to identify the primary cause of recumbency and any secondary problems that may arise from being down. However, because of patient size, complete neurological and musculoskeletal examination of a downer cow often is challenging. Moreover, in field situations, sometimes only 1 side of the animal can be examined because of lack of space or personnel. Thus, the cause of downer cow syndrome is not always identifiable during physical examination in the field, where ancillary tests often are limited. Furthermore, regardless of the initial cause of the syndrome, with time, secondary damages, such as muscle ischemia and nerve compression (pressure damage) are inevitable.[4,5] The economic value of the animal, extent of damage, duration of recumbency, availability and cost of treatment and nursing care, and odds of successful outcome, all should be considered when making the decision of whether or not to pursue treatment on a particular case. Flotation is used to treat downer cows both in the hospital as well as on the farm.[6,7]

In previous studies, survival percentage varied from 11% to 50% when downer cows were treated at the farm.[2,7-10] For downer cows treated at a referring hospital, survival percentage was reported to be 37%.[6] Also, different clinical variables and laboratory test results have been associated with survival. Muscle enzyme activities, as well as serum urea concentration, can be used to predict survival.[11,12] Parity, days in milk, duration of recumbency, and the extent of secondary muscle damage have been shown to affect survival.[7,8,10,13] Behavior in the flotation tank and quality of care provided are important factors associated with survival.[6,10] A recent study indicated that increased serum troponin concentration and tachycardia were associated with lower survival percentage in downer dairy cows.[9]

Assessing the odds of survival of downer dairy cows and identifying prognostic indicators are useful to the attending veterinarian to recommend treatment or euthanasia. Establishing treatment and prognosis before referral may improve decision-making and allow selection of animals with reasonable likelihood of success with cost-effective treatment. Our objectives were to characterize a population of downer dairy cows referred to a veterinary hospital, to study outcome, and to evaluate the risk of treatment failure using diagnostic information collected at the time of referral.

2 | MATERIALS AND METHODS

The medical records of downer dairy cows treated at the Centre Hospitalier Universitaire Vétérinaire (CHUV) between 1994 and 2016 were retrospectively reviewed. Inclusion criteria were: recumbency (cows that were referred for recumbency or that became recumbent during hospitalization), dairy breeds, female, cows, and heifers that had already calved once. A downer cow was defined as a cow unable or unwilling to stand without help. No limit on duration of recumbency was considered. We searched all medical records for which a floating session was billed and also by all final diagnoses known to be associated with recumbency.

The following information about patient signalment was recorded: age, days in milk, and the number of days of recumbency before presentation. From clinical examination, heart rate (bpm), respiratory rate, and temperature at presentation were recorded. Cows with fatal musculoskeletal conditions evident at presentation were excluded from the study. Also, the following data from the CBC and serum biochemistry profile (SBP) were evaluated: PCV, plasma fibrinogen concentration, leukocyte count (including neutrophils, bands, metamyelocytes, and myelocytes), toxic neutrophil changes, serum aspartate aminotransferase (AST) activity, creatine kinase (CK) activity, as well as serum calcium, phosphate, potassium, total carbon dioxide (TCO_2), beta-hydroxybutyrate (BHB), urea, and creatinine concentrations. Results from the first blood samples were evaluated. Normally, all laboratory tests are performed upon arrival or <12 hours after admission for patients admitted after hours. Recorded information regarding hospitalization included: date of admission, number of days of flotation treatments, duration of hospitalization, and outcome (discharged vs died or euthanized).

Variables from patient signalment were kept continuous for descriptive statistics and then categorized for univariable and multivariable analysis. Variables from patient signalment were described as continuous and the assumption of linearity with the log odds of the outcome was assessed graphically. Given that the assumption of linearity was not met, patient signalment variables were categorized for univariable and multivariable analysis. Variable categorization was performed using 3 criteria: distribution in the dataset, normal ranges, and knowledge of pathophysiology. All variables for which normal reference ranges were available were categorized accordingly (ie, temperature, respiratory rate, PCV, plasma fibrinogen concentration, leukocyte count, neutrophil count, nonsegmented neutrophil count, toxic neutrophil changes, and serum calcium, phosphate, potassium, TCO_2, BHB, urea, and creatinine concentrations). Age, days in milk, and days of recumbency were categorized based on distribution, clinical experience, and judgment. Heart rate (bpm) was categorized using normal reference range. The cutoff of 100 bpm described in a

previous study on downer cows[9] was used as well as an additional category (>120 bpm), based on clinical experience and data distribution. Muscle enzyme activities (CK and AST) were categorized using results of previous studies[11] as well as data distribution.

Statistical analyses were performed using Stata Statistical Software (Release 15; StataCorpLP, College Station, Texas). The unit of analysis was the cow. Initially, variables were described by outcome (survivors vs nonsurvivors).

Potential clustering of cows by year of admission was explored by adding the year of admission as a random effect in a generalized linear mixed model (GLMM) and comparing this model with simple logistic regression using Akaike and Bayesian information criteria (AIC and BIC) and the likelihood ratio test. The absence of statistical difference between both models suggested no clustering of observation by year of admission ($\chi^2 = 0.49$; $P = .2$). Therefore, logistic regression was used for the analyses.

Simple logistic regression was performed to assess the association of prognostic indicators with the outcome of interest (nonsurvival). Explanatory variables with $P < .2$ in the univariable analysis were considered for inclusion in the multivariable logistic regression analysis. Collinearity between explanatory variables was identified using simple logistic regression when assessing 2 dichotomous variables (odds ratio [OR] and P value) or the χ^2 test when assessing categorical variables (P value). For dichotomous variables, collinearity was considered significant based on the magnitude of the OR (>10) and P value ($P < .05$).[14] If collinearity was observed between 2 explanatory variables, only 1 was included in the modeling based on prior scientific knowledge.

Age at admission and season of admission (winter, spring, summer, fall) were explored as potential confounders by assessing changes in the β-coefficients of the variables of the adjusted model compared to those of the nonadjusted model. However, these variables were not retained because a change >20% was not observed.[14]

Selection of the explanatory variables included in the final multivariable logistic regression model was made based on statistical considerations using a backward stepwise elimination procedure with P values for entry and removal of .2 and .25, respectively. Two-factor interactions between age of the cow, days of recumbency, and all of the independent variables of the final model were explored by adding an interaction term between each pair of variables (1 pair at the time). All possible 2-way interactions between clinicopathological (ie, AST, creatinine, PCV, neutrophil count) and clinical (ie, heart rate, respiratory rate, temperature) variables also were explored. Interaction terms were retained if $P < .05$. The goodness-of-fit of the final model was evaluated using Pearson's and Hosmer-Lemeshow statistics.[14]

3 | RESULTS

3.1 | Population included

A total of 1318 dairy cows were included in the study. Among them, 727 (55%) cows survived and were discharged from the hospital and 591 (45%) cows died or were euthanized while hospitalized. Figures 1 and 2 show the distribution of admissions over years and the months, respectively. A total of 353 downer dairy cows were admitted in winter, 396 in spring, 274 in summer, and 295 in fall.

3.2 | Patient signalment and clinical examination findings

In the study population, age of the cows ranged from 1.3 to 15.9 years (median, 5.4 years; mean, 5.5 years). Information about days in milk was available for 1113 lactating cows (median, 4 days; mean, 26.1; range, 0-500 days). The remaining 205 cows were nonlactating cows (n = 80) or the information was missing (n = 125). Before referral, cows were recumbent for an average of 2.5 days (median, 2 days; range, 0-30 days). Upon presentation, median heart rate was 100 bpm (mean, 98 bpm; range, 36-180 bpm). Median respiratory rate was 30 rpm (mean, 35 rpm; range, 8-130 rpm), and median temperature was 38.6°C (mean, 38.5°C; range, 33.1-42.2°C).

3.3 | Laboratory results

Results from blood analyses (CBC and SBP) including mean, median, and ranges are presented in the supplementary material.

3.4 | Patient hospitalization and treatment

Cows were hospitalized on average for 8 days (median, 7 days; range, 0-55 days). The mean number of floating tank sessions per cow was 3 (median, 3; range, 0-19). Table 1 presents the descriptive results of these variables for survivors and nonsurvivors.

3.5 | Categorizations and univariable analysis results

The distribution and categorization of explanatory variables by outcome category and results of univariable analysis of explanatory variables are summarized in Table 2.

3.6 | Final multivariable analysis results

Significant collinearity (OR <10 and $P < .05$ using logistic regression or $P < .05$ using χ^2) was observed between leukopenia and neutropenia (OR = 38; $P < .001$), neutropenia and toxic neutrophil changes (OR = 10; $P < .001$), nonsegmented neutrophils and toxic changes (OR = 28; $P < .001$), serum urea and creatinine concentration (OR = 23; $P < .001$), and AST and CK activity ($\chi^2 = 593.2$; $P < .001$). The best fit of the model is presented in Table 3. Time of recumbency was significantly associated with fatal outcome. Cows that were tachycardic, tachypneic,

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FIGURE 1 Distribution of admissions of 1318 downer dairy cows to the Centre Hospitalier Universitaire Vétérinaire between 1994 and 2016
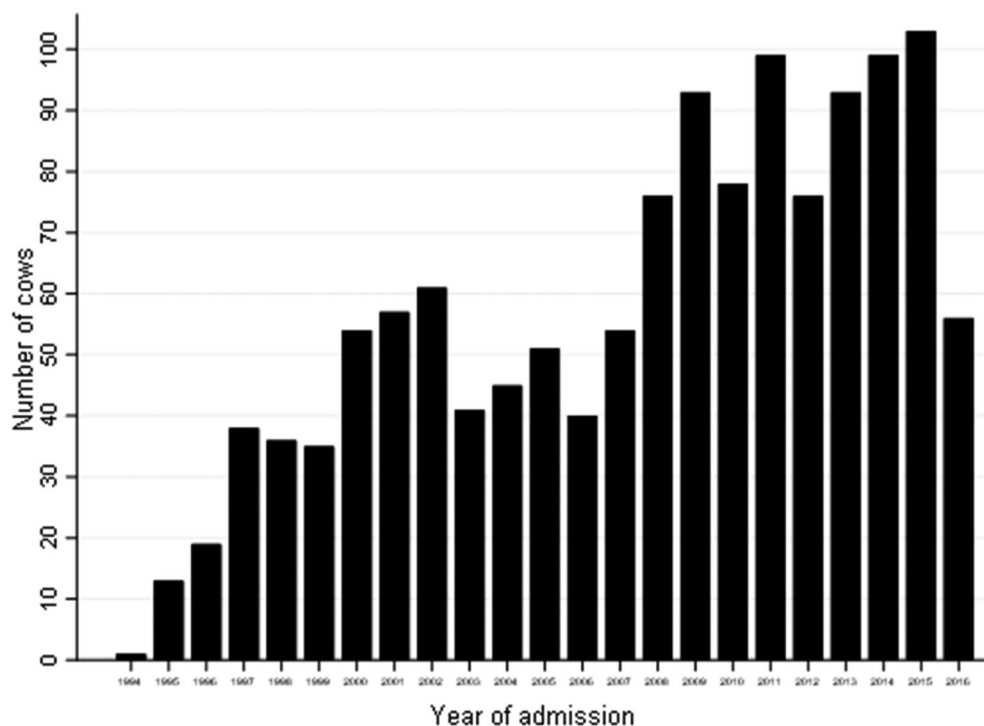
FIGURE 2 Distribution of monthly admissions of 1318 downer dairy cows to the Centre Hospitalier Universitaire Vétérinaire between 1994 and 2016
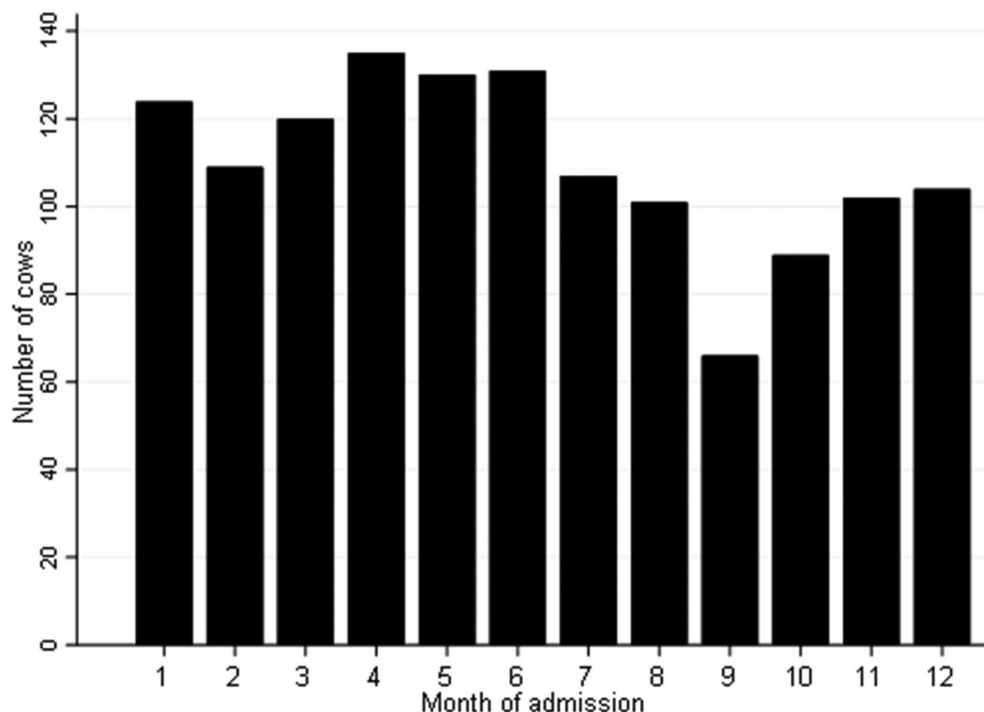
hypothermic, anemic, neutropenic, and that had high AST activity and increased serum creatinine concentration had higher odds of being euthanized or dying. None of the 2-way interactions explored was statistically significant.

The Pearson's Chi-square (χ^2 = 559.7; P = .25) and Hosmer-Lemeshow (χ^2 = 9.7; 8 degrees of freedom; P = .29) statistics suggested reasonable fit of the model.

4 | DISCUSSION

4.1 | Population and survival

Fifty-five percent of the downer dairy cows presented to the CHUV between 1994 and 2016 were discharged and had a positive outcome. The survival percentage observed in our study was higher than

TABLE 1 Patient signalment and hospitalization variables (as continuous variables) from 1318 downer dairy cows referred to the Centre Hospitalier Universitaire Vétérinaire between 1994 and 2016

Variable	Outcome	N[a]	Mean	Median	Minimum	Maximum
Age (y)	Survivors	712	5.3	5.1	1.3	14.5
	Nonsurvivors	571	5.8	5.7	1.5	15.9
Days in milk	Survivors	635	25.5	3	0	500
	Nonsurvivors	478	26.8	4	0	365
Days of recumbency	Survivors	620	2.2	2	0	12
	Nonsurvivors	509	2.8	2	0	30
Days of hospitalization	Survivors	727	10.0	9	1	54
	Nonsurvivors	591	5.5	4	0	55
Number of floating tank sessions	Survivors	723	3.2	3	0	19
	Nonsurvivors	584	2.9	3	0	18

[a]Number of cows with the information available.

the percentages reported previously.[2,6-11] Among those studies, only 1 hospital study[6] reported an overall survival percentage of 37%. One difference between our study and the previous study[6] is the number of animals included. In the previous study,[6] only 51 cows were included compared to 1318 in our study. All of the other studies were performed in a farm setting[2,7-11] and the survival percentage varied from 16% to 50%. A single study[7] reported a survival percentage of 50% when analyzing data from 34 cows that were quickly floated (<96 hours) after the onset of recumbency. In another study,[7] cows with poor or fatal prognosis were excluded. Similarly, cows with coxofemoral luxation and other fatal musculoskeletal conditions were excluded from our study. The only previous report of survival of downer dairy cows in Québec was performed on farm.

Our population is comparable to those of previous studies.[2,6-10,12] All studies were performed in dairy cattle, except 1 study[6] in which 1 of 51 cows was a Hereford. However, the definitions of downer cow in these studies differed. Some[2,7,10] included only alert downer cows whereas others[6,8,9,12] included all recumbent cows. Also, our population may have differed because it was a referral hospital population. The decision to refer or not refer a particular cow depends on several factors. The willingness of the owners to incur expense, time of transport, and hospital fees are critical. As a consequence, several recumbent cows are not referred to veterinary hospitals, creating potential bias in favor of or against some primary diagnoses. For example, some valuable cows can be referred to the hospital even if the prognosis is already considered poor at the farm. On the other hand, some simple cases of milk fever that resolve easily will not be referred. Finally, cows with traumatic injury and poor prognosis already identified by the referral veterinarian may not be referred.

4.2 | Prognostic factors associated with nonsurvival

In our study, the predictors associated with nonsurvival of downer dairy cows treated in a hospital setting were identified.

4.3 | Heart rate, respiratory rate, and temperature

Tachycardia (heart rate >100 bpm), tachypnea, and hypothermia were significantly associated with higher odds of being euthanized or dying. A previous study found an association between tachycardia and lower survival[9]; cows with heart rates >100 bpm were more likely to be eliminated from the herd than cows with lower heart rates. Tachycardia can be associated with pain, sepsis, anemia, hypovolemia, or stress. All of these conditions can be present in downer dairy cows.

To the best of our knowledge, respiratory rate and temperature have not been studied in downer cows. In our experience, tachypnea is a common finding in downer cows. Tachypnea can reflect an underlying respiratory condition or an effort to thermoregulate. Severely ill cows can spend more time in lateral recumbency, compromising their lungs. Increased temperature can be associated with difficulty in thermoregulating secondary to being recumbent. Fever can be found in cows with primary infectious diseases (eg, mastitis, metritis, pneumonia, peritonitis) or infection of wounds secondary to recumbency.

These findings emphasize the importance of accurately measuring heart rate, respiratory rate, and temperature when examining downer cows.

4.4 | Time of recumbency

More than 7 days of recumbency increased the odds (>3 times) of euthanasia or death. Time of recumbency of downer dairy cows previously has been found to be associated with the odds of being culled.[7,8,10,13] Secondary muscular damage is common in downer dairy cows[15] and is mostly related to the compartmental syndrome and pressure on peripheral nerves.[16]

4.5 | AST activity

High serum AST activity was significantly associated with lower odds of survival. Cows with AST activity between 500 and 1000 U/L had

TABLE 2   Univariable analysis to assess the association of clinical and paraclinical variables with survival

Variable	Categories	Number of survivors	Number of nonsurvivors	N	OR (95% CI)	P
Season	Winter	196	157	353	Reference	–
	Spring	231	165	396	0.9 (0.7-1.2)	.44
	Summer	143	131	274	1.1 (0.8-1.6)	.4
	Autumn	157	138	295	1.1(0.8-1.5)	.56
Age[a]	<3 y	85	64	149	Reference	—
	3 to <5 y	224	121	345	0.7 (0.5-1.1)	.1
	≥5 y	403	386	789	1.3 (0.9-1.8)	.89
Days in milk[a]	Dry cows	29	51	80	Reference	—
	≤7 d	499	338	837	0.4 (0.2-0.6)	<.01
	7-30 d	55	74	129	0.8 (0.4-1.4)	.36
	>30 d	81	66	147	0.5 (0.3-0.8)	.01
Days of recumbency[a]	<24 h	70	41	111	Reference	—
	24 to <48 h	212	143	355	1.2 (0.7-1.8)	.53
	2 d	157	114	271	1.2 (0.8-2.0)	.35
	3 d	85	78	163	1.6 (1.0-2.6)	.07
	4 d	35	44	79	2.1 (1.2-3.9)	.01
	5 d	24	30	54	2.1 (1.1-4.1)	.02
	6 d	16	18	34	1.9 (0.9-4.2)	.1
	≥7 d	21	41	62	3.3 (1.7-6.4)	<.01
Heart rate[a]	Normal (60-80 bpm)	193	91	284	Reference	—
	Bradycardia (<60 bpm)	9	6	15	1.4 (0.5-4.1)	.52
	Mild tachycardia (>80-100 bpm)	278	191	469	1.5 (1.1-2.0)	.02
	Moderate tachycardia (>100–120 bpm)	160	198	358	2.6 (1.9-3.6)	<.01
	Severe tachycardia (>120 bpm)	47	63	110	2.8 (1.8-4.5)	<.01
Respiratory rate[a]	Normal (12-36 rpm)	464	320	784	Reference	—
	Tachypnea (>36 rpm)	182	208	390	1.7 (1.3-2.1)	<.01
Temperature[a]	Normal (38.2-39.2°C)	442	274	716	Reference	—
	Hypothermia (<38.2°C)	141	159	300	1.8 (1.4-2.4)	<.01
	Hyperthermia (>39.2°C)	100	118	218	1.9 (1.4-2.6)	<.01
PCV[a]	Normal (≥26%)	673	530	1203	Reference	—
	Anemia (<26%)	17	33	50	2.5 (1.4-4.5)	<.01
Fibrinogen[a]	Normal (<6 g/L)	333	228	561	Reference	—
	Hyperfibrinogenemia (≥6 g/L)	356	335	691	1.4 (1.1-1.7)	.01
Leucocytes[a]	Normal (≥6200 cells/μL)	543	395	938	Reference	—
	Leucopenia (<6200 cells/μL)	147	168	315	1.6 (1.2-2.0)	<.01
Neutrophils[a]	Normal (≥1100 cells/μL)	665	517	1182	Reference	—
	Neutropenia (<1100 cells/μL)	24	44	68	2.4 (1.4-3.9)	<.01
Nonsegmented neutrophils[a]	Normal (≤100 cells/μL)	499	376	875	Reference	—
	Left shift (>100 cells/μL)	191	187	378	1.3 (1.02-1.7)	.03
Toxic changes on neutrophils[a]	No	487	348	835	Reference	—
	Yes	203	2015	418	1.5 (1.2-1.9)	<.01
AST[a]	<500 U/L	475	220	695	Reference	—
	≥500 to <1000 U/L	171	170	341	2.1 (1.6-2.8)	<.01
	≥1000 U/L	58	185	243	6.9 (4.9-9.6)	<.01

(Continues)

TABLE 2   (Continued)

Variable	Categories	Number of survivors	Number of nonsurvivors	N	OR (95% CI)	P
CK[a]	<10 000 U/L	450	243	693	Reference	—
	≥10 000 to <25 000 U/L	180	146	326	1.5 (1.1-2.0)	<.01
	≥25 000 U/L	74	184	258	4.6 (3.4-6.3)	<.01
Calcium	Normal (2.20-2.70 mmol/L)	347	266	613	Reference	—
	Hypocalcemia (<2.20 mmol/L)	281	246	527	1.1 (0.9-1.4)	.27
	Hypercalcemia (>2.70 mmol/L)	78	65	143	1.1 (0.8-1.6)	.66
Phosphate[a]	Normal (1.05-2.83 mmol/L)	566	460	1026	Reference	—
	Hypophosphatemia (<1.05 mmol/L)	127	87	214	0.8 (0.6-1.1)	.26
	Hyperphosphatemia (>2.83 mmol/L)	12	29	41	3.0 (1.5-5.9)	<.01
Potassium[a]	Normal (3.86-5.28 mmol/L)	388	293	681	Reference	—
	Hypokalemia (<3.86 mmol/L)	310	267	577	1.1 (0.9–1.4)	.25
	Hyperkalemia (>5.28 mmol/L)	7	17	24	3.2 (1.3-7.9)	.01
Total CO_2[a]	Normal (24-26 mmol/L)	114	89	203	Reference	—
	Hypocarbonetemia (<24 mmol/L)	91	133	224	1.9 (1.3-2.8)	<.01
	Hypercarbonetemia (>26 mmol/L)	498	353	851	0.9 (0.7-1.2)	.54
BHB	<1200 µmol/L	380	253	633	Reference	—
	≥1200 µmol/L	148	119	267	1.2 (0.9-1.6)	.2
Urea[a]	≤6.51 mmol/L	590	423	1013	Reference	—
	>6.51 mmol/L	104	143	247	1.9 (1.4-2.5)	<.01
Creatinine[a]	≤116 µmol/L	612	440	1052	Reference	—
	>116 µmol/L	91	133	224	2.0 (1.5-2.7)	<.01

Note: Estimates were obtained using a simple logistic regression on data from 1318 downer dairy cows referred to the Centre Hospitalier Universitaire Vétérinaire between 1994 and 2016.

Abbreviations: AST, aspartate aminotransferase; BHB, beta-hydroxybutyrate; bpm, beats per minute; CI, confidence interval; CK, creatinine kinase; N, number of cows with information available; OR, odds ratio; rpm, respirations per minute.

[a]Variables significantly associated with the outcome ($P < .2$).

almost twice the odds of being euthanized or dying than cows with AST activity <500 U/L. Cows with AST activity >1000 U/L had 5 times the odds of being euthanized or dying than cows with AST activity <500 U/L. Serum AST activity[11,12] previously had been found to be associated with culling in downer dairy cows. After muscle damage, AST activity usually increases and decreases slowly. Therefore, AST activity remains a good indicator of the magnitude of the initial myodegeneration without being affected substantially by time. In 1 study,[7] cows down for <7 days, with AST activity >890 UI/L had <5% of probability of survival. Similarly, cows down for <2 days with CK activity >16 300 UI/L had <5% probability of survival.[6]

4.6 | Anemia

Anemia (PCV < 26%) also was associated with increased odds (approximately 3 times) of dying or being euthanized. Anemia results from blood loss, hemolysis, or decreased erythrocyte production, and can be regenerative or nonregenerative. In downer dairy cows, anemia from abomasal ulcers secondary to chronic disease or use of nonsteroidal anti-inflammatory drugs (often used in the treatment of downer dairy cows) must be considered. Anemia was present despite the presence of dehydration, which was common as evidenced by hyperphosphatemia, increased serum creatinine concentration, and suspected endotoxemia. Clinical examination and ancillary tests results are important to establish the primary cause of anemia and the potential role of recumbency.

4.7 | Neutropenia

Downer dairy cows with neutropenia had 2.5× odds of dying or being euthanized compared to cows without neutropenia. Neutropenia often occurs with acute severe inflammatory disease and is associated with a poor prognosis if persistent.[17] A severe inflammatory response in downer dairy cows can be associated with acute puerperal metritis or mastitis. The severity of this type of systemic illness can contribute

TABLE 3 Final multivariable logistic regression model for identifying the association of clinical and paraclinical variables and not survival based on data collected from 1471 downer dairy cows referred to the Centre Hospitalier Universitaire Vétérinaire between 1994 and 2016

Variable	Category	OR	95% CI	Wald	P*
Temperature	Normal (38.2-39.2°C)	Reference	–	–	–
	Hypothermia (<38.2°C)	2.08	1.44-2.99	3.90	**<.01**
	Hyperthermia (>39.2°C)	1.01	0.66-1.55	0.04	.97
Heart rate (bpm)	Normal (60-80)	Reference	–	–	–
	<60	1.03	0.24-4.46	0.04	.97
	>80 to ≤100	1.20	0.80-1.79	0.87	.38
	>100 to ≤120	1.93	1.25-2.95	3.01	**<.01**
	>120	2.92	1.03-3.59	2.05	**.04**
Respiratory rate	Normal (12-36 rpm)	Reference	–	–	–
	Tachypnea (>36 rpm)	1.76	1.24-2.48	3.20	**<.01**
Days of recumbency	<24 h	Reference	–	–	–
	24 to <48 h	0.88	0.52-1.51	−0.45	.65
	2 d	0.76	0.43-1.34	−0.95	.34
	3 d	0.99	0.53-1.85	−0.02	.99
	4 d	1.34	0.62-2.91	0.75	.45
	5 d	1.34	0.59-3.08	0.68	.49
	6 d	1.80	0.68-4.76	1.18	.24
	≥7 d	3.61	1.64-7.94	3.19	**<.01**
AST (U/L)	<500	Reference	–	–	–
	≥500 to >1000	2.16	1.53-3.06	4.39	**<.01**
	≥1000	6.69	4.37-10.24	8.75	**<.01**
Creatinine (μmol/L)	≤116	Reference	–	–	–
	>116	1.75	1.13-2.71	2.50	**.01**
PCV (%)	Normal (≥26)	Reference	-	-	-
	Anemia (<26)	3.30	1.40-7.74	2.47	**.01**
Neutrophil count	Normal (≥1100 cells/μL)	Reference	–	–	–
	Neutropenia (<1100 cells/μL)	2.51	1.22-5.16	2.50	**.01**
Age	<3 y	Reference	–	–	–
	3 to <5 y	0.83	0.48-1.42	−0.69	.5
	≥5 y	1.51	0.92-2.47	1.64	.1
Intercept		0.15	0.07-0.31	−5.23	**<.01**

Abbreviations: AST, aspartate aminotransferase; bpm, beats per minute; CI, confidence interval; OR, odds ratio; rpm, respirations per minute.

*P value indicates pairwise comparison of each category with the reference category.

P value ≤.05 were considered significant and are indicated in bold.

to recumbency and render treatment difficult, making the prognosis poorer.

patients and potentially also from muscle damage secondary to recumbency.

4.8 | Serum creatinine concentration

Cows with increased serum creatinine concentration were less likely to survive than cows with normal serum creatinine concentration. Creatinine is produced in muscle, excreted in the kidneys by glomerular filtration, and is not normally reabsorbed in the tubules. When renal function decreases, the clearance of creatinine is disrupted resulting in azotemia. High serum creatinine concentration can result from renal damage that can occur in critically ill

4.9 | Variables associated with critically ill patients

Tachycardia, tachypnea, hypothermia, anemia, neutropenia, and renal damage associated with nonsurvival can be related to the fact that some downer cows are systemically compromised. These patients may benefit from medical treatment before being floated or helped to stand by other mechanisms. The indicated treatments for these patients are easier to provide in a hospital setting, which could explain the better prognosis observed in hospital as compared to on farm treatment.

4.10 | Correlations between variables

Among the enzymes evaluating muscle damage, AST has been shown to be most useful in predicting nonsurvival.[12] Thus, AST was chosen over the CK to build the final multivariate model. Serum urea and creatinine concentrations were found to be correlated, both evaluating renal function. Creatinine was chosen over urea to build the final multivariable model. In ruminants, creatinine is a more reliable indicator of renal failure. Urea nitrogen can be secreted in saliva and metabolized by the ruminal microflora, which frequently results in a disparity between blood urea nitrogen and creatinine concentration in ruminants with renal failure.[17] Leukocyte count, neutrophil count, left shift, and toxic neutrophil changes were correlated. Neutropenia was chosen because it is a variable often measured by point-of-care instruments (as compared to left shift and toxic changes which require evaluation of a blood smear) and is more accurate than leukocyte count (which can be affected by the lymphocyte count).

4.11 | Flotation sessions

Number of floating tank sessions reported to achieve successful outcome vary in the veterinary literature. Up to 4[7] or 13[6] floating tank sessions have been reported in previous studies. In our study, the maximum number of floating tank sessions was 19. Our population included some valuable cows for which owners were willing to spend considerable amounts of money on treatment. This factor could have influenced the overall treatment success observed in our study.

4.12 | Study limitations

Our study had several limitations. The retrospective design of the study did not allow us to assess other variables such as the clinical status of the animal and the reason for euthanasia. Prognosis could have been affected by the reason for euthanasia which could not be evaluated in our study. It would have been valuable to determine when the euthanasia was performed for economical as compared to medical reasons.

Evaluation of the clinical variables other than the heart rate, respiratory rate, and temperature, such as attitude, appetite, or presence of other problems is important when treating downer dairy cows. Other variables of clinical examination were not included in our study given that the necessary information was not always recorded in the medical records. A prospective study including other variables in the history, clinical examination, and treatment would be helpful to refine our findings. All medical records that met the inclusion criteria of the study were included. However, it is possible that some records were not found, and thus were not included.

4.13 | Contribution of the study

Our results help direct treatment of downer dairy cows in at least 2 clinical situations. On farm, the findings can help the practitioner consider treatment options and decide if referral is a reasonable choice based on the odds of success. In the hospital, the results can be used to identify animals with high odds of recovery, to estimate expected progress, and to facilitate discussing the cost of the treatment with owners.

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.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.