Nonambulatory cows: Duration of recumbency and quality of nursing care affect outcome of flotation therapy

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ABSTRACT

Cows that are unable or unwilling to stand and remain recumbent for ≥ 12 h are defined as nonambulatory. Care and management of nonambulatory cattle is considered a major animal welfare concern facing the livestock industry, particularly the dairy sector. Flotation therapy has gained interest as a means to promote recovery in nonambulatory cows and is based on the concept that by floating the cow in warm water, secondary pressure damage to muscles and nerves will be reduced. The objective of this study was to assess the physiological responses to stress related to the flotation therapy and to evaluate the effect of recumbency duration and nursing care on the outcome of the flotation therapy. The outcomes of 34 nonambulatory Holstein dairy cows were analyzed after they were subjected to flotation therapy. The duration of recumbency and quality of nursing care provided before initiation of the flotation treatment were assessed based on producer responses to survey questions, and from on-site observations by the researchers. A veterinarian examined all cows before flotation therapy began. The treatment was divided into 5 phases: baseline (before filling), manipulation (placing the cow into the tank), filling (the tank was filled with water), flotation (the cow was confined in the filled tank), and draining (water was removed from the tank). Stress responses to the procedure, excluding the manipulation portion, were assessed using heart rate variability. The high-frequency component (HF normalized units) decreased during the filling and draining phases (2.8 ± 0.3 and 2.8 ± 0.4 , respectively) compared with the baseline and floating phase (4.7 ± 0.5 and 4.7 ± 0.3 , respectively). These results indicate that the stress related to the flotation therapy is greatest during the filling and draining phases of the treatment, when cows likely have to exert increased effort to transition to a standing position. The flotation therapy was less likely to be successful on cows that

had been recumbent for longer periods (odds ratio = 0.96; 95% CI = 0.93–0.99, for every 1-h increase in time recumbent before the therapy began). Higher quality of nursing care provided to nonambulatory cows increased the chance of recovery. In conclusion, cows subjected to flotation therapy were more likely to recover if they were treated at early stage of recumbency and if good nursing care was provided while recumbent.

Key words: flotation tank, nonambulatory cow management, hydrotherapy

INTRODUCTION

Cows are at greatest risk of disease and death in the weeks just after calving. Risks include metabolic illnesses such as hypocalcemia and ketosis, infectious diseases such as mastitis and metritis, and other maladies such as dystocia and hoof and leg injuries that cause lameness. Unfortunately, some cows become so compromised that they become nonambulatory, others are at high risk for becoming nonambulatory, and all experience poor welfare. The challenges described above, as well as the potential risks associated with dairy cows having to interact with equipment such as manure scrapers and the milking parlor, likely explains why dairy cows are at much higher risk than beef cattle of arriving at auction and slaughter facilities unable to stand or walk (Doonan et al., 2003; Green et al., 2008). The National Animal Health Monitoring Survey (NAHMS) estimated that about 234,000 dairy cows of the approximately 9 million lactating cows in the United States became nonambulatory in 2013, of which approximately 18% (42,000) died naturally on farm (i.e., were not euthanized; Adams et al., 2015).

Nonambulatory cows are unable or unwilling to stand (Fenwick, 1969; Cox, 1988) and remain recumbent for ≥ 12 h (Burton et al., 2009). Regardless of cause, an extended period of recumbency initiates secondary damage to the muscles and nerve tissue, causing a condition described as secondary recumbency (Cox, 1982), which in turn increases the risk of compartmentalization and crushing syndrome (Cox, 1988). Nonambulatory cows that struggle to stand are also susceptible to muscle

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and ligament damage resulting in permanent or terminal recumbency. The severity of the nonambulatory cow condition is affected by both the original cause and the duration of recumbency.

The care and handling of nonambulatory cows is a major challenge for dairy producers and veterinarians (Stull et al., 2007), but to date has been the subject of little research. For example, there is currently no scientific basis for recommendations for when nonambulatory cows should be euthanized versus treated. Current evidence suggests that cows that are recumbent for >24 h can develop muscle and nerve tissue lesions, greatly hindering their ability to recover (Green et al., 2008). Given the risks associated with extended periods of recumbency, standard industry practice on many farms is to force cows to stand using devices such as hip lifters, slings, air bags, and more recently, flotation therapy (Stull et al., 2007; Burton et al., 2009). These procedures likely expose the cow to distress, but there is little scientific guidance available to judge which cows are likely to recover, and which procedures are most effective.

Flotation therapy has recently received some attention (Burton et al., 2009). Floating the cow in warm water reduces secondary pressure damage to muscles and nerves and positions the cow in a standing position for when the water is eventually drained. To our knowledge, no previous study has assessed the stress associated with flotation treatment or determined the conditions under which cows are most likely to recover following this treatment. The objectives of the current study were (1) to assess the physiological responses to stress using heart rate variability (HRV) measures taken before, during, and after the flotation treatment, and (2) to evaluate the effects of recumbency duration and nursing care provided to the nonambulatory cow on the outcome of the flotation treatment. We hypothesized that flotation would induce a stress response in cows, and that cows that had spent little time recumbent and received good nursing care during recumbency would have a greater chance for recovery.

MATERIALS AND METHODS

Animals, Housing, and Management

Cases were recruited from 27 commercial dairy farms in the Fraser Valley region of British Columbia, Canada, from February to August 2015. A total of 36 Holstein dairy cows having a mean ($\pm$ SD) parity of 3.4 ± 1.4 , identified by a veterinarian as nonambulatory cows (see below for criteria), were enrolled in the study. All farms but one used freestall housing; the exception used tie-stalls.

Data Collection

Commercial farms that reported a nonambulatory cow were visited by a veterinarian who performed a detailed physical examination to establish eligibility for flotation treatment (see Table 1 for inclusion and exclusion criteria). Eligible cows were subjected to flotation therapy on-farm. General information about the cow and data regarding the medical history, recumbency duration, treatment, and management of the recumbent cow were collected (see Table 2). The duration of recumbency was defined as the time (as identified by the farmer or farm worker) from when the cow was discovered down until the flotation treatment was initiated. Information from the 5 questions regarding the nonambulatory cow management practices used on their farms was combined with the subjective on-site evaluation made by the veterinarian, and used to assign a cumulative “nursing care” score (ranging from 0 to 5) before treatment was initiated. This information was then used to assign a binary variable: good care was assigned when the score was ≥ 3 versus poor care when the score was ≤ 2 , describing the overall quality of nursing care provided to the nonambulatory cow before the flotation therapy was initiated (see Table 2 for more details). Cows subjected to flotation therapy were diagnosed as having metabolic disorders (16), musculoskeletal injuries (4), or a combination of metabolic disorders and infectious disease (3), metabolic disorders and musculoskeletal injuries (7), or having experienced a difficult calving followed by a metabolic disorder (4). Recumbent cows were provided treatment based on the primary cause of recumbency before flotation was initiated. For instance, cows diagnosed with metabolic disorders received supplement therapy and nonsteroidal anti-inflammatory drugs (NSAID), cows with infectious diseases received antibiotic therapy and an NSAID, cows with musculoskeletal injuries and dystocia received an NSAID. Between flotation treatments, 3 cows received additional antibiotics as part of their treatment plan, 5 cows received another dose of NSAID, and 4 cows received additional supplemental therapy.

Before any manipulation of the nonambulatory cows was initiated, a heart rate monitor (HRM; Polar Equine RS800CX or V800, Polar Electro Oy, Kempele, Finland) was attached to the cow's chest. The HRM was set to record each interbeat interval (R-R recording rate) during the baseline period and the entire flotation treatment. The Polar HRM was previously validated for use in cows (Hopster and Blokhuis, 1994). Each HRM consists of an elastic strap, Wearlink transmitter, and watch receiver. The elastic strap had 2 incorporated electrodes and removable Wearlink transmitter

Table 1. Description of conditions that were used as exclusion and inclusion criteria when selecting nonambulatory cows for flotation treatment

Inclusion criteria ¹	Exclusion criteria ²
Metabolic disorders (e.g., hypocalcaemia, hypophosphatemia)	Nonalert cows
Infection diseases (e.g., endotoxic mastitis, septic metritis)	Maintained lateral recumbency
Difficult calving (e.g., malpresentation, fetal disproportion)	Fracture on a limb or the spine
Minor musculoskeletal injuries (not detectable during physical exam)	Arthritis on multiple joints
	Major musculoskeletal injuries
	Poor body condition (BCS of 2.0 or less) ³

¹Alert cows with apparently normal mental state that maintained sternal recumbency, were willing to eat, showed initiative to stand up (reported by the farmer and assessed by the veterinarian), and had one or more conditions from the inclusion criteria were recommended for treatment.

²Cows that showed at least one of the symptoms described in the exclusion criteria were not recommended for treatment.

³Scoring was according to the chart for body condition scoring of Holstein dairy cows (1–5), where 1 was severe under-conditioning (emaciated) and 5 was severe over-conditioning (Edmonson et al., 1989).

attached. The cow's body was gently tilted toward one side and the strap placed underneath the cow's sternum and pushed toward the opposite side. The cow was then tilted gently toward the opposite side until the strap was visible, at which time it was pulled and then adjusted accordingly. Before fitting the HRM around cow's chest, the 2 electrodes incorporated on the strap were lubricated with gel (EcoGel 100, Eco-Med Pharmaceutical Inc., Mississauga, ON, Canada) to improve conductivity between the electrodes and the cow's body. The upper electrode was located behind the left shoulder blade and the lower electrode placed near the sternum. After placing the elastic strap around the cow's chest, the watch was started. Previous studies have reported a period of 5 to 10 min as sufficient for animals to acclimate to the HRM equipment (Mohr et al., 2002; von Borell et al., 2007; Stojkov et al., 2015). In this study, cows were allowed to habituate to the equipment for approximately 10 min before recording was initiated. The recording was continued throughout the flotation procedure. The researcher marked each phase of the flotation treatment by recording the time and duration of each phase.

Flotation Treatment Description

The flotation treatment consisted of 5 phases: baseline (before filling), manipulation (placing the cow into the tank), filling (the tank was filled with water), flotation (the cow was confined in the filled tank), and draining (water was removed from the tank). All cows were floated in the same flotation tank (length 2.4 m, height 1.37 m, and width 1.32 m; Aqua Cow Rise System, Kirby Manufacturing Inc., Merced, CA) filled with 2,400 L of water. During the first phase (baseline), the recumbent cow was fitted with an HRM and was left undisturbed for 20 min (10 min for adaptation to the equipment and 10 min for recording the baseline HRV values). The cow was then placed on a rubber mat that required the involvement of at least 3 individuals. The cow was transitioned from sternal recumbency to a lateral position. While the front and the hind legs were slightly elevated by 2 individuals, the third person slid the rubber mat under the cow. All cows were able to achieve sternal recumbency on their own or with minimal assistance. Using a manual winch or machinery, the mat was then pulled into the float

Table 2. Description and assessment of on-farm nonambulatory cow management practices, based on survey questions and the on-site assessment by the attending veterinarian¹

Nonambulatory cow management practices	Assessment criteria
Bedding	Assessed lying surface and bedding type, depth, and cleanliness: scored as +1 if the bedding was clean and deep or cows were housed on pasture with shade provided; otherwise scored as 0.
Access to feed and water	Frequency of monitoring of feed and water and proximity to cow: scored as +1 if feed and water were offered to the cow 3 or more times per day and placed within reach of the cow; otherwise scored as 0.
Housing conditions	Housing of the nonambulatory cow: scored as +1 if the cow was housed in a sick pen with no more than 2 other cows; otherwise scored as 0.
Relocation of the down cow	Relocation of the nonambulatory cow from the pen: scored as +1 if relocated using a loader bucket or placing on a pallet and pulled to the desired location; otherwise scored as 0.
Repositioning	Number of visits and repositioning frequency: scored as +1 if the cow was visited ≥ 3 times per day and repositioned at each visit; otherwise scored as 0.

¹A cumulative nursing care score ranging from 0 to 5 was assigned: nursing care was defined as "good" when the score was ≥ 3 versus "poor" when the score was ≤ 2 .

tank. The duration of this phase was approximately 30 min, and finished when the doors of the tank were closed. The filling phase lasted for approximately 5 min and involved filling the flotation tank by pumping approximately 2,400 L of previously heated water. Once the tank was filled and the cow was standing comfortably on 4 limbs, a water bowl and a feed bin were attached to the front of the tank. Cows that did not show any signs of struggling or distress while in the flotation tank, were standing on all 4 limbs, and were seen to be eating from the feeding bucket, were floated for 8 ± 2 h (flotation phase). Cows that were unable to stand, or were standing only on thoracic or pelvic limbs, or were not standing on all 4 limbs, and did not show any initiative to eat were removed immediately from the tank and euthanasia was recommended. The draining phase required approximately 15 min. Cows were allowed to remain standing in the flotation tank without water support for an additional 15 min to adapt to carrying their full weight. The gate was then opened and cows exited voluntarily or were gently encouraged to exit the tank.

The temperature of the water was measured with a thermometer (T-5622 Pool Thermometer, Taylor Precision Products Inc., Oak Brook, IL) at the beginning of the flotation phase and again immediately before the draining phase. The body temperature of a nonambulatory cow was measured before the flotation treatment using a rectal thermometer (Accuflex10, AMG Medical Inc., Montreal, QC, Canada), and again at the beginning of the floating phase and again before the water was drained.

HRV Variable Description

The HRV data were downloaded from the Polar HRM using Polar Performance software (Polar Electro Oy). Calculation of the HRV parameters was conducted using Kubios HRV 2.2 software (University of Eastern Finland, Kuopio, Finland; Niskanen et al., 2004). The HRV data were graphically and visually inspected for presence of the 5 types of anomalies as described by Marchant-Forde and colleagues (2004). Files that contained more than 5% anomalies or 3 consecutive anomalies were excluded from the analysis (von Borell et al., 2007). The frequency bands were set to 0.00 to 0.04 Hz for the very low frequency (VLF), 0.04 to 0.20 Hz for the low frequency (LF), and 0.20 to 0.58 Hz for the high frequency (HF), adjusted for the respiratory rate in cattle (von Borell et al., 2007; Stojkov et al., 2015).

Nine different periods were selected to analyze the HRV measures, with each segment lasting 5 consecu-

tive minutes (see Malik and Camm, 1995; Malik et al., 1996): baseline, filling, at 1, 2, 3, 4, 5, and 6 h into the flotation period, and draining. If the first selected 5-min period contained more than 5% anomalies or 3 consecutive anomalies, the next 5-min period in the same hour was selected. The HRV values from 1 to 6 h of flotation were averaged and used for the analysis. The final 5-min period was selected when the cow was standing in the tank without water support and was marked as draining.

Frequency domain measures including HF, LF, and LF-to-HF ratio were extracted and used in the analysis. Both LF and HF were expressed in normalized units (nu) where the absolute power of each component was expressed as a portion of the total power minus the VLF component [e.g., $LF / (\text{total power} - \text{VLF power})$]; LF (nu) and HF (nu); von Borell et al., 2007]. The total power incorporated the frequency range between 0 and 0.58 Hz. The HRV data during the first flotation therapy were collected from 18 cows. Due to anomalies, 1 cow was excluded, leaving 17 cows in the final data set that was used for the analysis; HRV data for the second therapy was obtained from 11 cows.

Outcome Evaluation and Additional Treatment Recommendations

The outcome of the immediate flotation treatment was considered a success if the cow walked out of the tank and resumed normal standing and lying behavior. Therapy was considered to fail if the cow was unable to stand on 4 feet when the tank was filled with water. Cows that were able to stand comfortably and showed initiative to eat during the flotation phase but became recumbent within the 12 h following flotation received a second flotation treatment (see Figure 1). The final outcome was based on the cow's ability to maintain normal standing and lying behavior within 7 consecutive days following the final flotation treatment.

After each flotation treatment and again after 12 h, the veterinarian assessed the cow's condition as having improved or deteriorated. In cases where the cow was observed to have improved but became nonambulatory either immediately following the flotation or within the next 12 h, an additional treatment was conducted. In cases where subsequent flotation treatments took place, the procedure described above was repeated. Additional treatments (third and occasionally fourth) were only recommended for cows that appeared to be in good condition, remained standing, and walked at least few steps out of the tank. All other cases were classified as not successful and we recommended that the farmer euthanize the cow.

Figure 1. Outcome of flotation treatments provided to nonambulatory cows ($n = 34$), including the number of cases that were reassessed and received additional flotation treatments.

Statistical Analysis

The manipulation required to place the cows into lateral recumbency resulted in numerous interruptions of the HRM and meant that the data during the manipulation period could not be used. The remaining 4 phases (baseline, filling, floating, and draining) were analyzed. Missing data from both the HRV and the behavioral outcomes resulted in 2 cows being dropped from the analyses, leaving 34 cows in the final data set. Univariate logistic regression was conducted using the LOGISTIC procedure in SAS (version 9.3, SAS Institute Inc., Cary, NC). The model was set to assess the effect of recumbency duration (h) on the outcome (recover or failed to recover) of the flotation treatment ($n = 34$). The Fisher Exact Test was used to assess the effect of

the nursing care (classified as good or poor) provided to the recumbent cows before the flotation treatment on the outcome of the treatment ($n = 34$). The frequency domain HRV parameters (HF, LF, and LF-to-HF ratio) and recumbency duration were tested for normality and presence of outliers using the UNIVARIATE procedure. The HRV data collected from 17 cows had missing values in various phases of the flotation therapy. Complete HRV data for all 4 phases of the treatment was only captured from 8 cows. Using a paired t -test we tested the following: (1) baseline versus filling the tank, (2) baseline versus floating in the water, and (3) baseline versus draining the tank. In addition, we tested the differences in the HRV measures between the first and second therapy. The HRV analysis of both data sets, $n = 17$ (with missing values in some phases) and $n = 8$

cows (complete values in all 4 phases) showed the same findings. We considered the latter as a subset of the larger data set and thus used the HRV data from 17 cows for the final analysis.

RESULTS

The water temperature at the beginning of the flotation treatment and at the end of the treatment averaged (mean $\pm$ SD) $31 \pm 3^\circ\text{C}$ and $27 \pm 3^\circ\text{C}$, respectively. The water was heated only at the beginning of the flotation therapy and maintained only from the cows' body temperature. The cows' body temperature at the beginning and at the end of the treatment was (mean $\pm$ SD) $38.6 \pm 0.4^\circ\text{C}$ and $38.5 \pm 0.3^\circ\text{C}$, respectively.

Distress responses to the flotation procedure were assessed by changes in the frequency domain HRV measures during the 4 phases of the flotation procedure (baseline, filling, floating, and draining). The greatest change of the sympathovagal balance was noted during the filling and draining phases (Table 3). During the filling phase, the HF component of the HRV declined on average by 45% to 2.8 ± 0.2 , compared with the baseline value ($P < 0.01$; Table 3). However, the HF component of the HRV returned to baseline levels within the first hour of flotation. During the draining phase, the HF component of the HRV once again declined to 3.1 ± 0.4 ($P < 0.01$; Table 3), similar to that observed during the filling phase. The LF and LF-to-HF ratio both increased during the filling and draining phase ($P < 0.01$ and $P < 0.05$, respectively; Table 3). The HRV measures in the first and second therapy indicated identical changes in the filling and draining phase during both treatments.

Of the 34 cows recommended for flotation, 17 cows recovered after receiving one or more flotation treatments (see Figure 1). Of the cows that recovered, 7 recovered after receiving only one flotation treatment, with the remaining cows needing 2 to 4 treatments (see Figure 1). In all but 3 cases, the animals walked into the tank for the subsequent (final) treatment. The cow that received 4 flotation treatments was placed on the mat and winched into the tank for the second and third

flotation treatments but walked into the flotation tank on the fourth treatment. Three cows that were recommended for flotation therapy were successful in their attempts to briefly stand before the treatment started. Given the high risk that these cows would return to the recumbent state, they were included in the study. However, the exclusion of these 3 cows did not change the results.

Of the 17 cows that failed, 9 were unable or unwilling to stand after the tank was filled with water. The condition of these cows was considered irreversible and euthanasia was recommended. An additional 8 cows were able to stand normally on all 4 limbs during the flotation phase and immediately following treatment but became recumbent again within 12 h. Of these 8 cows, 6 were recommended for euthanasia after the second treatment, and 2 cows received a third flotation treatment (see Figure 1). On average cows that failed to recover were subjected to 1.6 ± 0.7 flotation treatments (mean $\pm$ SD).

The duration of recumbency and the level of care provided before flotation affected recovery. Cows that were recumbent for just 12 h before treatment were more likely to recover (Figure 2) following flotation therapy [odds ratio (OR) = 4.37; 95% CI = 4.34–4.40]. The OR dropped to 2.7 and 1.7 when cows had been recumbent for 24 and 36 h, before flotation, respectively. Overall, the odds that the flotation treatment resulted in recovery of the nonambulatory cow declined with every additional hour that the animal was recumbent before treatment was initiated (OR = 0.96; 95% CI = 0.93–0.99, for 1-h increase; $P < 0.05$). Cows that had been recumbent for 48 h or more had low odds for recovery (OR = 1.02; 95% CI = 0.99–1.05).

Cows identified as having had good nursing care, based on survey questions and an on-site assessment by the veterinarian, were more likely to recover compared with cows that had received poor care ($P < 0.05$; Figure 3). During the study, 74% of the nonambulatory cows ($n = 25$) received good nursing care (mean score $\pm$ SD: 4.2 ± 0.7) and 26% ($n = 9$) were provided poor nursing care (mean score $\pm$ SD: 1.7 ± 0.5). Of those 25 cows that received good nursing care, 64% recovered after

Table 3. Arithmetic mean ($\pm$ SE) of high-frequency (HF) and low-frequency (LF) components of heart rate variability expressed in normalized units of total power (nu), and LF-to-HF ratio during the different phases of flotation treatment ($n = 17$)

Variable	Phases of the flotation therapy				<i>P</i> -value		
	Baseline	Filling	Floating	Draining	Baseline vs. filling	Baseline vs. floating	Baseline vs. draining
HF (nu)	5.1 ± 0.6	2.8 ± 0.2	4.9 ± 0.3	3.1 ± 0.4	0.006	0.814	0.002
LF (nu)	94.9 ± 0.6	97.2 ± 0.2	94.9 ± 0.3	96.8 ± 0.4	0.006	0.901	0.002
LF:HF ratio	21.8 ± 2.5	36.0 ± 2.7	22.3 ± 1.4	36.6 ± 6.5	0.016	0.470	0.047

undergoing, on average, 1.7 ± 0.9 (mean $\pm$ SD) flotation treatments. In contrast, 8 of the 9 cows provided poor nursing care failed to recover after receiving, on average, 1.7 ± 0.5 flotation treatments. In this study, 4 of the cows were reported to have been dragged by the neck and 1 cow was reportedly moved using hip clamps; all 5 were categorized as having received “poor” nursing care. Necropsy findings for the cow moved using hip clamps showed laceration of the abdominal musculature with hemorrhage, edema, and muscular necrosis.

DISCUSSION

This is the first study that provides evidence about the stress associated with flotation therapy in dairy cows using HRV measures. The frequency domain measures and the sympathovagal balance observed during the different phases of the flotation procedure suggest that certain phases were more stressful than others. The greatest changes occurred during the filling and draining phases. The reduction in vagal tone during these 2 phases, compared with the baseline, may be explained in part by the novelty of the rapid filling or draining of the tank. Changes in the HF component have been previously reported in cattle undergoing rectal palpation (Kovács et al., 2014), being introduced to novel milking systems (Hagen et al., 2005), and in calves subjected to external (ambient related stimuli) or internal (pathological stimulus) stress (Mohr et al., 2002). Similarly, horses subjected to novel exercises showed vagal tone reduction and a shift of the sympathovagal balance toward sympathetic domination (Rietmann et al., 2004).

Changes in the body posture and the effort involved to stand and remain standing during filling and drain-

Figure 3. The effect the quality of nursing care provided to the nonambulatory cows ($n = 34$) before flotation treatment on the likelihood of recovery. Nursing care was rated on a 5-item scale and classified as “good” for scores ≥ 3.0 (vs. “poor” for scores ≤ 2.0).

ing may also have contributed to the shift of the sympathovagal balance. As the tank filled, cows changed their body posture from lying to standing, which requires effort, thus affecting the sympathovagal balance; strenuous exercise in horses subjected to various types of exercises showed similar changes (Physick-Sheard et al., 2000). Similarly, during the draining phase, cows were required to exert increasing energy to remain standing, which likely contributed to the changes in sympathovagal balance. In summary, cows showed a physiological response to the filling and draining phases.

During each hour of the flotation phase, the frequency domain measures HF, LF, and LF-to-HF ratio remained relatively constant and similar to that observed during the baseline period. During periods of rest, there is a parasympathetic (vagal) dominance corresponding to an increase of the HF component of the HRV (Porges, 1995; von Borell et al., 2007). Exercise and stress amplify sympathetic activity, resulting in changes in the sympathovagal balance and an increase of LF component and LF-to-HF ratio, while the parasympathetic tone is reduced (Porges, 1995; von Borell et al., 2007). Horses that were subjected to exercise and stress have shown similar responses (Physick-Sheard et al., 2000; Rietmann et al., 2004). Changes in body posture (e.g., transitioning from lying to standing) have been shown to reduce the HF component in cattle (Frondeus et al., 2015).

To our knowledge, ours is the first study to assess the effects of duration or recumbency and nursing care on the outcome of flotation treatment. The results show that both nursing care and recumbency duration affect the outcome of nonambulatory cows subjected to flotation therapy. Duration of recumbency has been previously identified as prognostic for recovery of nonambulatory cows, with cows recumbent for ≤ 24 h being

Figure 2. The odds ratio (OR) for recovery of nonambulatory cows ($n = 34$) following treatment in the flotation tank, relative to the time that cows had been recorded as recumbent before treatment was initiated. Recumbency duration is presented in 12-h bins.

most likely to recover (Green et al., 2008). Duration of recumbency affects secondary compression damage, primarily in the large muscles of the pelvic limbs, which are usually nonfunctional or paretic in nonambulatory cows (Cox, 1988; Radostits et al., 2007). Unlike the front limbs, which are protected by the sternum that supports most of the weight during sternal recumbency, the pelvic limbs are always positioned under the cow's body and thus far more susceptible to compression damage (Cox, 1988). In one study, 50% of cows subjected to anesthetic-induced recumbency for durations of 6 to 12 h showed extensive compression damage to the muscles and nerves of the pelvic limbs (Cox, 1981). Necropsy findings revealed severe damage to the sciatic nerve; that is, discoloration and collagenous tissue proliferation and muscles of the pelvic limbs (i.e., described as pale, necrotic, and foul smelling; Cox, 1981). Based on these studies, it follows that compression damage is likely closely related to recumbency duration or the duration of the pressure insult. The results of our study provide additional evidence that extended durations of recumbency are negatively associated with recovery.

Previous studies recommending good nursing care for recumbent cows have included criteria such as (1) access to feed and water as it promotes health and biological functioning, (2) segregation to prevent additional injuries from other animals, and (3) relocation done in a humane manner to prevent additional injuries, pain, and suffering (e.g., using a wooden pallet or loader bucket; Cox, 1988; Stull et al., 2007). The quality of nursing care provided to the down cows in our study while recumbent had a profound effect on the outcome of the treatment. Relocation (1) of a nonambulatory cow to a comfortable segregated (2) sick pen, access to feed and water (3), regular repositioning (4) of the nonambulatory cow, and a dry, clean bedding (5) surface were the 5 criteria used to evaluate nursing care in this study. The use of poor practices for moving cows (e.g., dragging by the neck, hip clamps) may result in additional injuries such as tearing of abdominal muscles. During this study, 5 cows were moved in these ways. Only one of these cows was sent for autopsy; the serious injuries identified in the report may have been due to the way the cow was moved or could have been sustained before the cow became recumbent.

Regularly repositioning nonambulatory cows is thought to help avoid prolonged pressure points on the pelvic limbs and thus minimize secondary muscle and nerve damage (Cox, 1988; Stull et al., 2007). However, the one study to date that assessed repositioning found a negative association between repositioning and recovery (Green et al., 2008). This study should be viewed with some caution given that they included several cows that recovered within a few hours after treating

the primary cause (e.g., hypocalcemia); these animals did not benefit from repositioning (Green et al., 2008). Nursing care, particularly repositioning, provision of a supportive lying surface, and pain management are important components of human patient nursing care and are associated with reduced pressure damage (Arnold, 2003). Thus, in our study repositioning was considered as part of the good nursing care.

Previous work has concentrated on defining the success rate and identifying promising candidates for the therapy (Burton et al., 2009). Studies on horses and cattle have reported improvements from flotation therapy following skeletal injuries and limb surgery (Smith, 1981; Hutchins et al., 1987). Flotation therapy, referred to as hydro- or aquatherapy in human physiotherapy, promotes recovery in human patients with various conditions (reviewed by Becker, 2009). Improvements from hydrotherapy in human patients with musculoskeletal injuries have been related to increased cardiac output and redistribution of the blood flow toward the muscles. For example, an increase of 225% in muscle blood flow was reported in water-immersed patients compared with the control (dry land; reviewed by Becker, 2009). In geriatric patients, aquatic exercise decreased the risk of falling by improving balance and coordination (reviewed by Becker, 2009). In patients with fibromyalgia, a condition associated with pain and reduced quality of life, aquatic therapy has been reported to reduce pain and improve sleep quality, as well as physical and cognitive abilities (Munguía-Izquierdo and Legaz-Arrese, 2008). Aquatic therapy has also been reported as an effective tool to regain joint mobility in human athletes, described as a pain-free process with no risk for further injury (Prins and Cutner, 1999). Athletes that suffered ligament injuries recovered sooner and were able to return to athletic activities earlier if subjected to aquatic exercise compared with land-based exercises (Kim et al., 2010). Interestingly, both studies recommended that aquatic therapy begin in the early phase of the rehabilitation process. Collectively, these human studies show clear benefits of aqua therapy combined with exercise on recovery, suggesting that cows may also benefit if they could be induced to exercise while in the flotation tank.

There is little data to inform decisions regarding the number of times flotation therapy should be reapplied to a single patient. The nonambulatory cows in this study received 1 to 4 treatments before recovery or euthanasia but in other work cows have been re-treated as many as 13 times (Burton et al., 2009). The decision about whether additional therapy is warranted should depend upon the likelihood of recovery and the likelihood of suffering from both continued recumbency and the stress associated with repeated applications

of this procedure. When the likelihood of recovery is low and the welfare costs of continued treatment are high, treatment should be discontinued and the cow euthanized. In the current study, cows were evaluated after each treatment and were assigned to an additional session only if they met the pre-established criteria for improvement. We recommend the adoption of similar established criteria in practice, agreed upon in advance of treatment by the veterinarian and the producer, to avoid the potential for prolonged suffering in the hope that cows may recover after “one more treatment.”

In conclusion, 50% of the down cows deemed eligible for the study (e.g., were alert and able to maintain sternal recumbency) recovered following flotation therapy. The likelihood of recovery was higher when treatment was begun soon after cows became recumbent; chances of recovery were much higher if treatment was begun with 24 h, and recovery was unlikely if treatment began after more than 48 h. Recovery was also more likely if cows received good nursing care while recumbent, including the use of a segregated sick pen with provision of adequate bedding, access to feed and water, and regular repositioning. We strongly advise that all farms have an up-to-date standard operating procedure outlining best practices of how to care for nonambulatory cows that also places focus on minimizing suffering by clearly identifying humane endpoints.

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