Preliminary evaluation of the effects of photobiomodulation therapy and physical rehabilitation on early postoperative recovery of dogs undergoing hemilaminectomy for treatment of thoracolumbar intervertebral disk disease

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OBJECTIVE
To evaluate the effects of postoperative photobiomodulation therapy and physical rehabilitation on early recovery variables for dogs after hemilaminectomy for treatment of intervertebral disk disease.

ANIMALS
32 nonambulatory client-owned dogs.

PROCEDURES
Dogs received standard postoperative care with photobiomodulation therapy (n = 11), physical rehabilitation with sham photobiomodulation treatment (11), or sham photobiomodulation treatment only (10) after surgery. Neurologic status at admission, diagnostic and surgical variables, duration of postoperative IV analgesic administration, and recovery grades (over 10 days after surgery) were assessed. Time to reach recovery grades B (able to support weight with some help), C (initial limb movements present), and D (ambulatory [≥ 3 steps unassisted]) was compared among groups. Factors associated with ability to ambulate on day 10 or at last follow-up were assessed.

RESULTS
Time to reach recovery grades B, C, and D and duration of postoperative IV opioid administration did not differ among groups. Neurologic score at admission and surgeon experience were negatively associated with the dogs' ability to ambulate on day 10. The number of disk herniations identified by diagnostic imaging before surgery was negatively associated with ambulatory status at last follow-up. No other significant associations and no adverse treatment-related events were identified.

CONCLUSIONS AND CLINICAL RELEVANCE
This study found no difference in recovery-related variables among dogs that received photobiomodulation therapy, physical rehabilitation with sham photobiomodulation treatment, or sham photobiomodulation treatment only. Larger studies are needed to better evaluate effects of these postoperative treatments on dogs treated surgically for intervertebral disk disease. (*Am J Vet Res* 2017;78:195–206)

Intervertebral disk disease is a common cause of neurologic dysfunction in dogs. Hansen type I or extrusive IVDDs are mainly observed in chondrodystrophic breeds[1] and typically are associated with acute onset of clinical signs. Affected animals can have various clinical signs, including signs of pain referable to the vertebral column, ambulatory or nonambulatory paraparesis, paraplegia, urinary dysfunction, and loss of nociception.[2,3] Medical management can be considered for dogs with signs of mild pain or mild neurologic deficits,[4] but in more severe cases, surgical decompression is needed.[5] The most common surgical treatment for Hansen type I thoracolumbar IVDD is hemilaminectomy.

The goals of postoperative physical rehabilitation in patients with acute spinal cord disease are maintaining a normal range of motion of the joints, reducing the degree of muscle atrophy, and improving the degree and speed of neurologic recovery, compared with results for patients that do not receive postoperative physical rehabilitation.[6] Investigators of 2 studies[7,8] on cranial cruciate ligament rupture found that

ABBREVIATIONS

IVDD	Intervertebral disk disease
MFS	Modified Frankel score
SCI	Spinal cord injury

postoperative physical rehabilitation was associated with improved function of the affected limb after surgery, compared with that for dogs that underwent exercise restriction or a home-exercise (walking) program. In another study,[9] dogs with degenerative myelopathy remained ambulatory longer when a rehabilitation program was used, with dogs undergoing intensive rehabilitation having longer survival time than dogs that had moderate or no rehabilitation treatment. However, no association was found between physical rehabilitation and outcome in 1 retrospective study[10] of dogs with ischemic myelopathy. Although reduced pain has been mentioned as a goal of physical rehabilitation in patients with spinal cord diseases,[6] exercise during the early postoperative period has the potential to exacerbate pain. To the authors' knowledge, no study has evaluated the effects of physical rehabilitation on recovery or pain management variables in dogs following surgery for treatment of intervertebral disk herniation.

Photobiomodulation therapy, also described as low-level laser therapy,[11] has been the focus of many clinical studies in human medicine. In experimental wound healing studies, photobiomodulation has been reported to improve rates of healing (less time for wound closure), collagen formation, wound tensile strength, and flap survival.[12] It was also shown to resolve inflammation,[13] reduce the pain associated with chronic neuropathic lesions and chronic joint disorders,[12,14–17] and reduce acute soft tissue injury edema after second-degree ankle sprain,[18] compared with standard care (rest, ice compress application, and elevation). Positive outcomes (ie, reduction of pain, improved function, faster recovery, and circulating concentrations of markers for inflammation and muscle damage) have been associated with photobiomodulation therapy for diseases such as osteoarthritis, tendinopathies, wounds, muscle fatigue, and various neurologic dysfunctions[19,20] in human clinical trials. Results of a systematic review with meta-analysis of randomized controlled trials showed that photobiomodulation reduces pain immediately after treatment in human patients with acute neck pain and up to 22 weeks after completion of treatment in those with chronic neck pain.[16]

The mechanism of action of photobiomodulation therapy is not fully understood. It has been established that red and near-infrared wavelengths penetrate tissue easily and induce dissociation of nitric oxide from the oxygen-binding site of cytochrome c oxidase in the mitochondria.[19,21,22] This photodissociation would allow oxygen fixation and thereby enhance cellular respiration and metabolism. This type of treatment has been shown to reduce production of factors associated with oxidative stress in various cell types in vitro as well as in affected tissues of laboratory animals with experimentally induced ischemia-reperfusion injury or age-related retinal changes[21,23–26] and to protect against oxidative stress by activating scavenging superoxide anions.[27] In rats with blunt-impact muscle trauma, photobiomodulation therapy blocked reactive oxygen species release and activation of nuclear factor-κB, inhibited overexpression of inducible nitric oxide synthase, reduced the inflammatory response, and decreased collagen production in the traumatized muscle, compared with traumatized muscles from rats that did not undergo photobiomodulation therapy.[28]

Results of in vitro studies have shown that exposure to light enhances proliferation of Schwann cells,[29] affects nerve cell metabolism, and increases neuronal sprouting and migration.[30–32] Moreover, in vivo and in vitro studies have shown that exposure to light causes changes in inflammatory cell migration into the injured spinal cord[33–36] and modulates microglia polarization from a proinflammatory to anti-inflammatory phenotype.[37] After peripheral (sciatic) nerve injury, the transcutaneous application of laser light over the corresponding segment of the spinal cord improved measures of nerve function and neurologic recovery in rats, compared with values for (non–laser-light-treated) controls.[38,39]

To the author's knowledge, only 2 clinical trials on photobiomodulation therapy in dogs with naturally occurring SCI have been conducted. In one of those studies,[a] 17 dogs with acute onset of paraplegia secondary to IVDD were assigned to receive 1 laser application (635-nm wavelength, 4 X 5 mW, in pulsed mode) once daily for 4 days following hemilaminectomy or to receive no laser treatment. There was no association between recovery of ambulation 2 weeks after surgery and photobiomodulation therapy. In the other study,[40] postoperative photobiomodulation therapy (once daily for 5 days; 810-nm wavelength, 5 X 200 mW, in pulsed mode) was associated with a shorter time to regain ambulation in dogs following surgery for IVDD. The effect of postoperative photobiomodulation therapy on signs of pain or the need for analgesic treatment was not evaluated in these trials.

The purpose of the study reported here was to assess and compare the effects of immediate postoperative photobiomodulation therapy and physical rehabilitation in dogs undergoing hemilaminectomy for treatment of thoracolumbar IVDD. We hypothesized that dogs receiving either treatment would have a more rapid recovery, as assessed by a predetermined grading system over a 10-day postoperative period, compared with that of dogs receiving sham photobiomodulation treatment alone. We also hypothesized that dogs undergoing physical rehabilitation would require postoperative IV opioid analgesic administration for a longer duration than dogs receiving photobiomodulation therapy or sham treatments.

Materials and Methods

Dogs and study design

Dogs evaluated at the Veterinary Faculty of the University of Liège between January 20, 2013, and August 1, 2014, because of nonambulatory paraparesis or paraplegia were considered for inclusion in the study. A clinical examination, including a neurologic examination, was performed on each animal by a board-certified surgeon or resident. An MFS as described by Scott and McKee[3] was assigned to each patient on the basis of neurologic examination findings (1 = signs of pain with no neurologic deficit, 2 = ambulatory paraparesis, 3 = nonambulatory paraparesis, 4 = paraplegia with or without urine retention and overflow, and 5 = paraplegia with loss of bladder control and loss of deep pain perception). Dogs were considered ambulatory if they could stand and take 3 steps on a nonslip surface without falling in the absence of physical manipulation. A dog was considered paraplegic if no voluntary motor function was observed or elicited during the examination. Nociception was assessed by application of hard pressure to the digits with a hemostatic forceps; a conscious response such as vocalization or snapping was interpreted as a positive response.[41] Intervertebral disk herniation was diagnosed by a board-certified radiologist through use of CT with or without myelography and was subsequently confirmed during surgery for each patient.

Inclusion criteria were predefined as follows: clinical signs present for < 5 days; neurologic examination findings consistent with an MFS of 3, 4, or 5; a diagnosis of thoracolumbar intervertebral disk herniation; and owner agreement to treat the patient by decompressive surgery. Hemilaminectomy (with or without fenestration, depending on the surgeon's preference) was performed by the veterinary surgeon who performed the clinical examination. Any concurrent disease that could interfere with locomotion or postoperative recovery (eg, patellar luxation or severe osteoarthritis) or an unsuitable temperament was considered cause for exclusion from the study.

Owners were informed of the nature of the study and the results of previously published articles on the subject[40] prior to signing a consent form. The study protocol was reviewed and approved by the Institutional Animal Care and Use Ethics Committee of the University of Liège (reference No. 1413), where the study was carried out.

The study was conducted in accordance with CONSORT guidelines.[42] Each dog included in the study was randomly assigned, on the basis of the MFS determined in the initial evaluation at hospital admission, to 1 of 3 postoperative treatment groups in a 1:1:1 ratio (photobiomodulation therapy [photobiomodulation group], physical rehabilitation with sham photobiomodulation treatment [physical rehabilitation group], or sham photobiomodulation treatment [sham treatment–only group]). Block randomization was used to maintain similar sample sizes in the treatment groups with a block size of 3. A random-number table was used that had been generated by 1 investigator (Bennaim) with a computer-based random-number generator prior to the study.

Procedures

All dogs were hospitalized after surgery for 10 days or until considered ambulatory (able to rise and walk ≥ 3 steps without assistance). Each patient received standard nursing care; which included provision of soft, padded, dry bedding; turning and repositioning the patient ≤ every 4 hours; and provision of easily accessible water and food. Each patient had a urinary catheter placed, and standard catheter care was provided until voluntary motor function was present and voluntary bladder control was subsequently observed.

Postoperative analgesia for all dogs consisted of methadone hydrochloride (0.3 mg/kg, IV, q 4 h) and carprofen (2 mg/kg, IV, for the first administration, then PO, q 12 h, for 5 days). Methadone could be administered to the patient for the first time at the time of anesthetic induction or at the end of the surgery, depending on the anesthetic protocol. Carprofen was administered for the first time at the end of the surgery. The dose of methadone was decreased on the basis of subjective pain assessment performed twice daily by an anesthetist or a surgeon, and buprenorphine hydrochloride (15 µg/kg, IV, q 8 h) was administered to some patients once methadone was stopped. If a dog had been administered steroids following evaluation by the referring veterinarian prior to referral or was receiving steroids for another condition, carprofen was not provided.

Dogs in the photobiomodulation group underwent a photobiomodulation treatment protocol similar to one previously described.[40] An 810-nm wavelength, 1-W (5 X 200-mW) laser cluster probe[b] (peak power, 227 mW; duty cycle, 88%; beam area, 0.0364 cm^2; irradiance, 5.5 W/cm^2; energy, 12 J; fluence, 329.7 J/cm^2) was used. The laser light was applied transcutaneously over the affected segment of the spinal cord (site of the hemilaminectomy) and the 2 adjacent segments (1 cranial and 1 caudal). The laser probe was applied with pressure to each area for 1 minute in a pulsed mode (frequency, 2.5 Hz). Hair had been clipped on the surface where the laser was applied for purposes of surgical site antisepsis. The first treatment was performed by the surgeon under the supervision of one of the authors (Bennaim, AJ, MP, or MH) immediately after surgical wound closure. Subsequent treatments were performed by trained veterinary technicians once daily for 5 days.

Dogs in the physical rehabilitation and sham treatment–only groups received sham photobiomodulation treatments as follows. The laser probe had been modified by the company to allow for a sham treatment delivery and was applied in this mode according to the same schedule as described for true photobiomodulation therapy. When the probe was used in sham treatment mode, 4 guide light–emitting diodes (wavelength, 660 nm; power, 4 X 6 mW [approx 30 mW/cm^2]) were on as they were when the probe was used in treatment mode, and the body of the probe was heated to simulate the heat generated by the laser diodes during normal operation.

In addition to sham photobiomodulation treatment, patients in the physical rehabilitation group underwent a 3-phase physical rehabilitation protocol as described **(Appendix)**.[6] The protocol for phase A, which included cold pack application and range-of-motion exercises with or without elicitation of limb withdrawal by toe pinching, was initiated 2 days after surgery, except that cold pack application was only performed during the first 48 hours after surgery. Phase B was implemented once the animal was able to support some weight in a standing position (but still had no voluntary pelvic limb movement) and included continuation of the exercises in phase A with the addition of assisted standing exercise, hydrotherapy, and neuromuscular electrostimulation.[c] Phase C was started when voluntary pelvic limb movements were first observed and included range-of-motion exercises, hydrotherapy, neuromuscular electrostimulation, and assisted standing and weight shifting. In the event that phase B or C of the protocol began < 3 days after surgery, hydrotherapy was delayed until day 3 after surgery because it was not compatible with surgical wound management. Veterinary technicians trained in the rehabilitation tasks performed these duties.

Dogs included in the sham treatment–only group received only standard nursing care, pain management, and sham photobiomodulation treatments as described. No rehabilitation exercises were performed.

To maintain blinding, physical rehabilitation exercises as well as all true and sham photobiomodulation procedures after the initial postoperative treatment were performed by trained veterinary technicians in a closed room. Hair was clipped on all dogs at the site of application of the electrodes for neuromuscular electrostimulation. Owners and all evaluators (ie, surgeons and anesthetists) were blinded to treatment allocation.

Outcome measure assessment

Four grades used for recovery assessment were defined as follows: paraplegic and unable to support any weight (grade A), able to support weight with some help (grade B), initial voluntary pelvic limb movements present (movement of > 1 joint; grade C), and ambulatory (able to rise and walk ≥ 3 steps without assistance; grade D). During hospitalization, a clinical examination of each study dog, including a general and neurologic examination, was performed 2 times/d (once in the morning and once in the evening) by the surgeon responsible for the case. A recovery grade was assigned by the surgeon after each clinical examination for 10 days after the day of surgery or until a grade D was assigned. Primary endpoints were defined as the number of days required to reach recovery grades B, C, and D. Each 12-hour period was recorded as a half day, and each morning or evening assessment was adjusted to the nearest 12-hour time period from the time of surgery.

Age, sex, breed, weight, MFS on admission, number of days between the onset of clinical signs and surgery, whether the dog received steroids before admission, whether a myelography was performed, whether fenestration was performed, years of experience of the surgeon, intervertebral disk spaces involved, possible adverse events, and duration of postoperative opioid analgesic administration were recorded for all study dogs. If the patient had not achieved a recovery grade D before discharge from the hospital, the owners were contacted by one of the authors, from a few days to 3 months later, to assess the ambulatory status of the patient. Follow-up within the study period was performed until the patient was ambulatory or was lost to follow-up.

Statistical analysis

Descriptive statistics were reported. Normality of the data was assessed by means of a Shapiro-Wilk test; no variables were normally distributed, and a nonparametric Kruskal-Wallis test was used to compare continuous variables among groups. A Fisher exact test was used to compare categorical variables among groups and to evaluate the association between categorical variables and ambulation status on day 10 and at last follow-up. Logistic binomial regression analysis was used to identify continuous variables that were important predictors of ambulation status on day 10 and at last follow-up. Kaplan-Meier curves and log-rank analysis were used to compare time to recovery endpoints (recovery grades B, C, and D) among the 3 treatment groups. Dogs that had not achieved a given recovery grade by the predetermined time point of day 10 after surgery were censored from this analysis. Because of the preliminary nature of the study, a priori sample size calculation was not performed. Statistical analysis was accomplished with commercially available software[d]; values of $P < 0.05$ were considered significant.

Results

Dogs

Sixty-one dogs were screened for study enrollment **(Figure 1)**. Twenty-one dogs did not meet the inclusion criteria, and 5 owners declined to participate. One dog was excluded because of questionable nociception that made it impossible to assign a specific MFS. Thirty-four dogs were included in the study (11 each in the physical rehabilitation and sham treatment–only groups and 12 in the photobiomodulation group). Two dogs developed myelomalacia shortly after surgery and were euthanized (1 in the photobiomodulation group and 1 in the sham treatment–only group). Both dogs had been assigned an MFS of 5 on admission. Thirty-two dogs completed the study.

There were 8 males and 3 females in the photobiomodulation group (median age, 5.7 years [range, 1.5 to 10.5 years]; median weight, 9.8 kg [range, 5.9 to 16 kg]). The breeds represented in this group included Dachshund (n = 4), French Bulldog (3), Maltese (2), Shih Tzu (1), and Beagle (1). The physical rehabilitation group comprised 7 males and 4 females (median age, 4.9 years [range, 3.8 to 13.8 years]; median weight, 10.8 kg [range, 6.4 to 13.7 kg]); breeds included French Bulldog (n = 4), Dachshund (3), Jack Russell Terrier (2), Maltese (1), and mixed (1). The sham treatment–only group included 3 males and 7 females (median age, 5.8 years [range, 1.2 to 8.3 years]; median weight, 10.3 kg [range, 3.3 to 25 kg]), and the breeds represented were Dachshund (n = 4), French Bulldog (2), mixed (2), Yorkshire Terrier (1), and American Cocker Spaniel (1). Age ($P = 0.86$), sex ($P = 0.15$), and weight ($P = 0.97$) did not differ significantly among groups.

There were no significant differences among groups for the proportion of dogs with MFSs of 3, 4, or 5 on admission ($P = 0.62$; **Table 1**). The mean number of days between the onset of clinical signs and surgery ($P = 0.12$), number of dogs that were administered steroids before referral ($P = 1.0$), years of experience of the surgeons ($P = 0.62$), number of disk herniations identified by diagnostic imaging ($P = 0.25$), number of intervertebral disk spaces for which surgery was performed ($P = 0.06$), number of dogs for which fenestration was performed ($P = 1$), and duration of surgeries ($P = 0.12$), as well as the mean proportion of dogs with upper motor neuron lesion localization ($P = 0.06$), also did not differ among groups (data not shown).

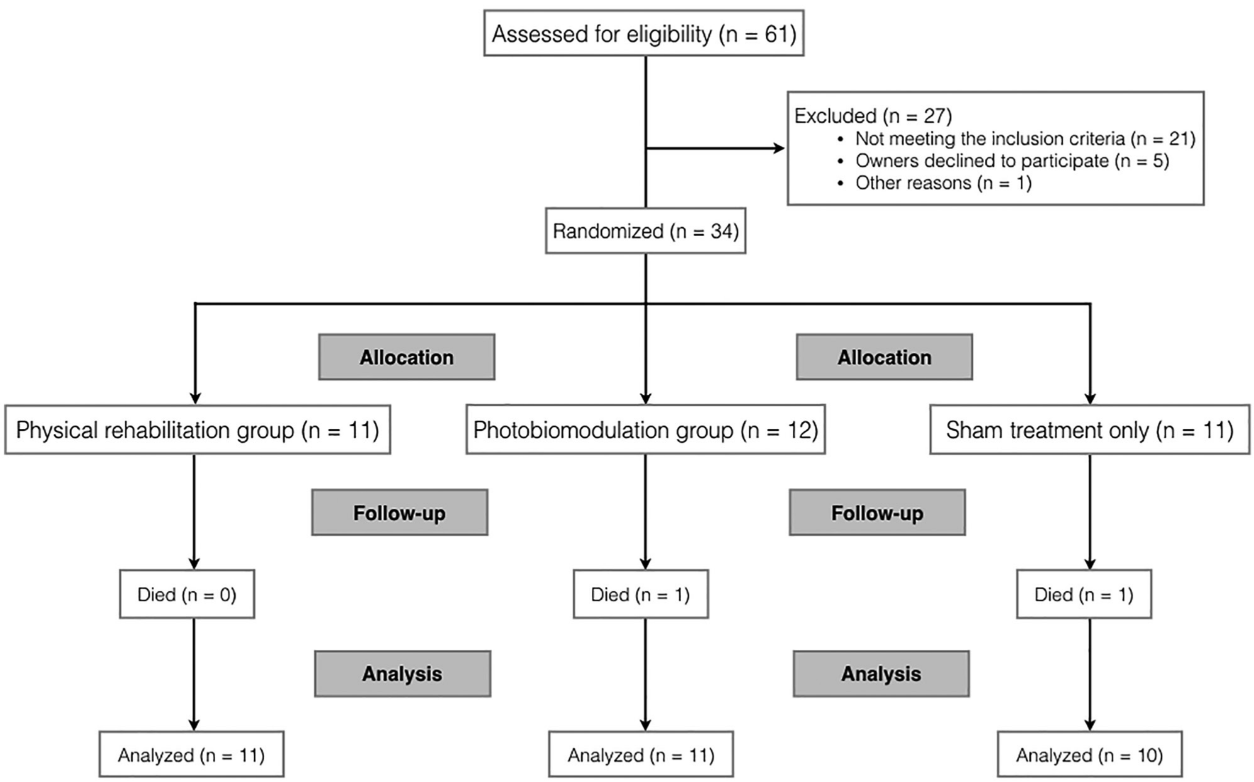
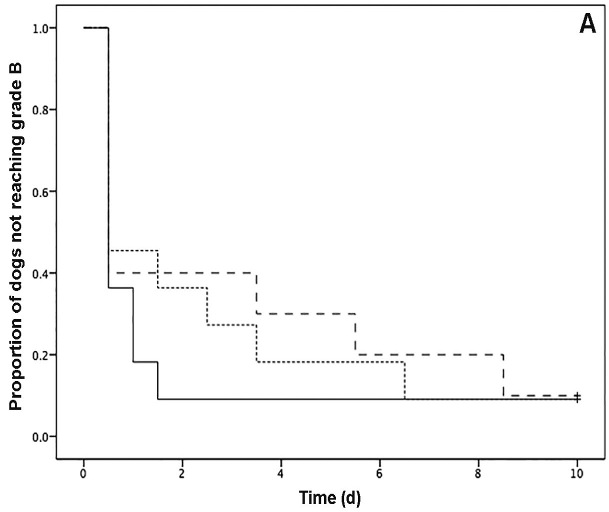


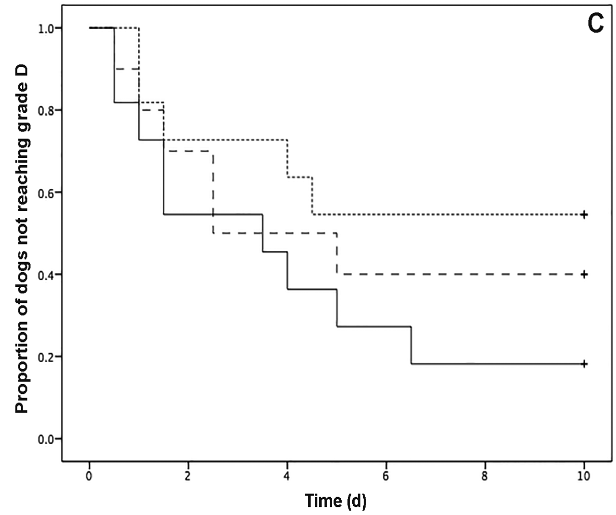
Figure 1—Flow diagram detailing numbers of dogs that were assessed for eligibility, were randomly allocated to treatment groups, and completed a preliminary study to assess the effects of photobiomodulation therapy and physical rehabilitation on early postoperative recovery following hemilaminectomy for treatment of thoracolumbar IVDD.

Table 1—Proportion of patients with initial MFSs of 3, 4, or 5 assigned to 3 treatment groups in a preliminary study to evaluate the effects of photobiomodulation therapy and physical rehabilitation on early postoperative recovery of dogs undergoing hemilaminectomy for treatment of thoracolumbar IVDD.

	Proportion of dogs			
MFS on admission	**Photobiomodulation group**	**Physical rehabilitation group**	**Sham treatment–only group**	***P* value**
3	4 /11	3/11	2/10	0.62
4	6 /11	6/11	6/10	
5	1 /11	2/11	2/10	

An MFS was assigned to each patient as described elsewhere (scale of 1 [signs of pain with no neurologic deficit] to 5 [paraplegia with loss of bladder control and loss of deep pain perception]).[3] Dogs were prospectively assigned to the 3 study groups in a 1:1:1 ratio on the basis of initial MFS (block randomization method). Dogs in the photobiomodulation group underwent 6 photobiomodulation treatments 24 hours apart, with the first treatment applied at the end of the surgery. Dogs in the physical rehabilitation group underwent a 3-phase physical rehabilitation protocol[6] and received sham photobiomodulation treatment. Dogs in the sham treatment–only group received sham photobiomodulation treatment without additional physical rehabilitation. All dogs received standard nursing care.





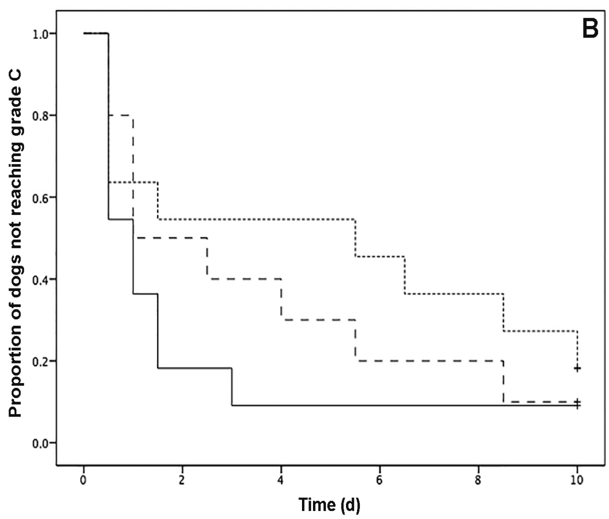


Figure 2—Kaplan-Meier curves depicting recovery to each of 3 grades for 32 dogs over a 10-day period after hemilaminectomy for treatment of thoracolumbar IVDD (designated as day 0), stratified according to postoperative treatment group (photobiomodulation [solid line; 11], physical rehabilitation [dotted line; n = 11], or sham treatment only [dashed line; 10]; A through C). Dogs were evaluated 2 times/d (once in the morning and once in the evening) and assigned recovery grades of A (paraplegic and unable to support any weight), B (able to support weight with help), C (initial voluntary pelvic limb movements present [movement of > 1 joint]), or D (able to rise and walk ≥ 3 steps without assistance). Each 12-hour period was recorded as a half day, and each morning or evening assessment was adjusted to the nearest 12-hour time period from the time of surgery. Evaluations for each patient were performed until grade D was assigned or until day 10. There was no significant (P = 0.686, P = 0.301, and P = 0.260, respectively) difference among groups for time to reach recovery grade B (panel A), C (panel B), or D (panel C). Vertical marks indicate censored dogs (ie, those not achieving the specified recovery grade by day 10).

Table 2—Median (range) time to reach postoperative recovery grades B (able to support weight with some help), C (initial voluntary pelvic limb movements present [movement of > 1 joint]), and D (able to rise and walk ≥ 3 steps without assistance) for the same dogs as in Table 1.

	Photobiomodulation group (n = 11)		Physical therapy group (n = 11)		Sham treatment–only group (n = 10)	
Postoperative recovery grade	**No. of dogs achieving grade**	**No. of days**	**No. of dogs achieving grade**	**No. of days**	**No. of dogs achieving grade**	**No. of days**
B	10	0.5 (0.5–1.5)	10	0.5 (0.5–6.5)	9	0.5 (0.5–8.5)
C	10	1.0 (0.5–3.0)	9	5.5 (0.5–8.5)	9	1.75 (0.5–8.5)
D	9	3.5 (0.5–6.5)	5	NA (1.0–4.5)	6	3.75 (0.5–5.0)

Dogs were evaluated 2 times/d (once in the morning and once in the evening) and assigned recovery grades from A (paraplegic and unable to support any weight) to D. Each 12-hour period was recorded as a half day, and each morning or evening assessment was adjusted to the nearest 12-hour time period from the time of surgery. Evaluations for each patient were performed until grade D was assigned or up to 10 days after surgery. Dogs that did not achieve the specified recovery grade within the observation period were included in the calculation of median values but excluded from the range.

NA = Not applicable (a median time was not calculated because less than half the dogs in this group had a recovery grade of D by postoperative day 10).

Recovery time

There was no significant difference among groups for the time to reach recovery grades B (P = 0.686), C (P = 0.301), or D (P = 0.260) during the 10 days following surgery **(Figure 2)**. The median number of days for dogs in each group to reach each recovery grade was summarized **(Table 2)**. In the photobiomodulation group, 1, 1, and 2 dogs did not reach recovery grades of B, C, and D, respectively; the numbers of dogs in the physical rehabilitation and sham treatment–only groups with these findings were 1, 2, and 6 and 1, 1, and 4, respectively. Because less than half (5/11) the dogs in the physical rehabilitation group achieved recovery grade D within the study period, a median time to reach this grade could not be reported for those dogs.

Duration of postoperative IV analgesic administration

Dogs from the photobiomodulation treatment, physical rehabilitation, and sham treatment–only groups received methadone IV at the highest dosage (0.3 mg/kg, IV, q 4 h) for a median duration of 0.5 days (range, 0 to 1.5 days), 0.75 days (range, 0.3 to 1.5 days), respectively, and 0.5 days (range, 0 to 1.5 days), which did not differ among groups ($P = 0.57$). The median total time that postoperative IV opioid analgesic administration was provided (1.5 days [range, 0.5 to 3.5 days], 2.25 days [range, 1.3 to 4.5 days], and 2.5 days [range, 0.5 to 3.5 days] for the photobiomodulation, physical rehabilitation, and sham treatment–only groups, respectively) did not differ among groups ($P = 0.45$).

Outcomes

Nine of 11 dogs in the photobiomodulation group, 5 of 11 dogs in the physical rehabilitation group, and 6 of 10 dogs in the sham treatment–only group had recovered ambulation by postoperative day 10; these proportions were not significantly ($P = 0.21$) different. The number of days between onset of clinical signs and surgery ($P = 0.50$), whether dogs received steroids before referral ($P = 0.67$) or underwent myelography ($P = 0.71$), the number of disk herniations identified on diagnostic imaging ($P = 0.56$), the number of intervertebral disk spaces on which the surgery was performed ($P = 0.86$), localization to upper versus lower motor neurons ($P = 1.0$), whether fenestration was performed ($P = 1.0$), and the duration of surgery ($P = 0.45$) were not associated with ability to ambulate by day 10. The MFS at admission ($P = 0.001$) and years of experience of the surgeon ($P = 0.002$) were negatively associated with ability to ambulate by day 10.

At last follow-up, 11 of 11 dogs in the photobiomodulation group, 9 of 11 dogs in the physical rehabilitation group, and 10 of 10 dogs in the sham treatment–only group had recovered ambulation ($P = 0.31$). One dog that was lost to follow-up was nonambulatory at the time of last follow-up, and another was nonambulatory at last follow-up 3 months after hospital discharge. The number of days between onset of clinical signs and surgery ($P = 0.82$), whether steroids were administered before referral ($P = 1.0$), MFS at admission ($P = 0.15$), whether the patient underwent myelography ($P = 1.0$) or fenestration ($P = 1.0$), the number of intervertebral disk spaces on which surgery was performed ($P = 0.15$), lesion localization to upper or lower motor neurons ($P = 0.29$), duration of surgery ($P = 0.29$), and years of experience of the surgeon ($P = 0.06$) were not associated with the dogs' ability to ambulate by last follow-up. However, the number of intervertebral disk herniations identified on diagnostic imaging was negatively associated with this variable ($P = 0.01$).

Adverse events

Of the 34 dogs initially allocated to the 3 treatment groups, 1 dog in the physical rehabilitation group and 1 in the sham treatment–only group were euthanized because of myelomalacia 3 days and 1 day after the surgery, respectively. The assigned study treatments had been administered to these dogs following surgery as described. Myelomalacia in these dogs was thought more likely attributable to the severity of the SCI (each of these dogs was assigned an MFS of 5 on admission) than to the postoperative treatment assignment. Gastrointestinal signs (eg, vomiting or diarrhea) were observed in 3 dogs of the photobiomodulation group, 3 dogs of the physical rehabilitation group, and 5 dogs of the sham treatment–only group during the 10-day period of observation. These signs were mild and self-limiting in all dogs and not thought likely to be due to the postoperative treatment assigned.

Discussion

Results of the study reported here did not reveal any difference in time to achieve grade B (able to support weight with some help), C (initial voluntary pelvic limb movements present [movement of > 1 joint]), or D (able to rise and walk ≥ 3 steps without assistance) recovery status among dogs that received photobiomodulation therapy (photobiomodulation group), physical rehabilitation with sham photobiomodulation treatment (physical rehabilitation group), or sham photobiomodulation treatment (sham treatment–only group) after hemilaminectomy for treatment of thoracolumbar IVDD and were monitored for 10 days after surgery. However, the small sample size prevented the findings from being conclusive. Nonambulatory dogs, regardless of the presence of voluntary motor function or nociception before the surgery, were included in this study. Although the presence of voluntary motor function before surgery is not a factor known to affect recovery time,[44] the presence of nociception before surgery is such a factor.[45] Therefore, the inclusion of dogs without nociception on admission (although these dogs were present in similar proportions within the study groups) might have influenced the ability to identify a difference in this variable among groups.

Results of a nonblinded, nonrandomized clinical study[40] suggested that postoperative photobiomodulation therapy was associated with a shorter time to recover the ability to ambulate in a population of dogs similar to those of the present study. Wavelength, power, irradiation time, beam area at the skin, pulse settings,[e] anatomic locations, and treatment intervals for photobiomodulation in that study[40] were similar to those in our study, although dogs in the photobiomodulation group in the present study received 6 applications, whereas those in the aforementioned study received 5. The optimal number of postoperative laser applications in dogs with IVDD is unknown, and the additional application could potentially have influenced our results. Additionally, our study protocol required recovery evaluation over 10 days, and in the other trial,[40] recovery was evaluated over a longer time. The choice of 10 days was made because we considered that outpatient evaluation (such as performed in the previous study[40] for some dogs) could be unreliable for assessment of the primary endpoint (ie, short-term postoperative recovery). The effect of postoperative photobiomodulation therapy might be more marked after the first 10 postoperative days, which could explain why the other study[40] found a difference in the time to regain ambulation between dogs that did and did not receive postoperative photobiomodulation but our study found no such difference. However, we not only assessed the time to ambulation, we also determined the time for dogs to reach earlier stages of recovery (ability to support weight and evidence of voluntary motor function). Other investigators found no effect of postoperative photobiomodulation therapy in dogs with IVDD[40]; however, although not clearly stated, the design appeared to be a nonblinded and nonrandomized study. Because most of the treatment variables in that study[40] were dissimilar to those used in the present study, comparison of the results was not possible.

The physical rehabilitation protocol used in the present study was based on published protocols for dogs with SCI.[6,46,47] To our knowledge, no data regarding the synergistic, additive, or negative effects of combining various rehabilitation modalities or the optimal timing and frequencies of different components in a combined intervention strategy have been reported. Differences in these variables could potentially result in different outcomes. It has been suggested that a rehabilitation program should be defined for each patient individually.[48] In the present study, the physical rehabilitation protocol was divided into 3 phases and administered on the basis of recovery status and was thus adapted on a daily basis. Investigations of rodents with experimentally induced SCI showed that locomotor recovery could be improved with exercise,[49–51] although this was not a consistent finding.[52] Physical rehabilitation was associated with increased motor function in cats several weeks after surgical severing of the spinal cord[53–55]; however, cats undergoing this experimental treatment had complete spinal cord disruption, and under those circumstances, rehabilitation can only have an effect on intersegmental tracts. In dogs with IVDD, physical rehabilitation can also affect ascending and descending spinal tract function. Intervertebral disk disease in dogs bears similarities to acute SCI in people.[56] A systematic review[57] found insufficient evidence to determine the superiority of locomotor training in human patients with incomplete SCI. Authors of a subsequent randomized, controlled trial[58] found that robotic-assisted gait training resulted in improvement in ambulatory function, compared with that for conventional physical rehabilitation, suggesting a benefit of some rehabilitation interventions. In the field of veterinary neurology, results of 1 study[9] showed that physical rehabilitation was associated with a longer time between diagnosis and euthanasia in dogs with degenerative myelopathy, although this may have been attributable, at least in part, to the owners' positive perceptions regarding the effects of treatment. Conversely, another study revealed no association between physical rehabilitation and outcome in dogs with ischemic myelopathy,[10] and controlled trials studying the effect of physical rehabilitation in dogs with this condition are lacking. A retrospective study[59] was performed to evaluate recovery times in dogs with Hansen type I IVDD undergoing thoracolumbar hemilaminectomy with fenestration and physical rehabilitation. In that study,[59] dogs that underwent more physical therapy sessions were more likely to have neurologic improvement than dogs that had fewer sessions. However, the description of the scoring system used to assess recovery was unclear, and the numeric quantification of recovery appeared subjective, making interpretation of the results difficult. Additionally, the study did not include a control group that did not receive physical rehabilitation. In our study, only the functional outcome was assessed. Physical activity was shown to improve quality of life in human patients with SCI,[60] and this may also be an important factor in the quality of life for dogs.

The MFS at admission in the present study was negatively associated with the ability to ambulate on postoperative day 10, but not at the last follow-up. Absence of nociception has been identified as a negative prognostic factor in larger studies[45,61] that included longer follow-up times than those in the present study. We believe that the lack of a significant effect for this variable at the last follow-up in our study was likely attributable to a type II statistical error resulting from the small number of dogs with an MFS of 5 on admission that completed the study (5/32). The surgeons' experience was negatively associated with the ability to ambulate by day 10, which is counterintuitive. However, in the hospital where the study was carried out, intervertebral disk surgeries are attributed in priority to residents in the beginning of their training. This unequal repartition of cases may have resulted in a type I statistical error.

The number of intervertebral disk herniations identified by diagnostic imaging was negatively associated with ability to ambulate at last follow-up. To our knowledge, this association has not been reported in other studies of dogs undergoing surgery for IVDD. In the dogs of this study, hemilaminectomy was performed at the level of the herniation considered likely to explain the acute onset of clinical signs on the basis of clinical assessment and imaging features. However, subclinical neurologic deficits resulting from mild spinal cord compressions distant from the surgery site may have become clinically apparent following surgical decompression at the site responsible for the acute onset of neurologic signs. Another explanation would be that further herniation of a disk other than that at the surgical site worsened during the recovery period.

The duration of postoperative IV opioid administration was not different between the 3 treatment groups in the present study. The IV opioid administration was modified at the clinician's discretion on the basis of subjective pain assessment. The use of a validated pain scale to modify analgesic treatments and subsequently evaluate differences in pain score would have allowed a more objective assessment of the effect of photobiomodulation therapy and physical rehabilitation on signs of postoperative pain. Although the frequency of gastrointestinal signs in this study is high, the episodes were mild and self-limiting and did not lead to any particular intervention other than the addition of histamine H_2-receptor antagonists and dietary changes. Possible causes for these gastrointestinal signs include recent anesthesia, NSAID administration, hospitalization-associated stress, or sudden dietary changes during hospitalization. Although the prevalence of gastrointestinal signs following hemilaminectomy for thoracolumbar IVDD has not been reported to the authors' knowledge, gastrointestinal ulcerations may be present in many cases.[62] Further investigation is needed to evaluate whether a higher prevalence of postoperative gastrointestinal signs is present in dogs that undergo hemilaminectomy for thoracolumbar IVDD, compared with the prevalence in those undergoing other surgeries.

The strengths of the present study were the prospective, randomized, blinded, controlled design and the ability to examine and manage all dogs throughout the 10-day postoperative observation period. The main limitations were the lack of a priori power analysis, which resulted in a small sample size, and the inclusion of dogs from subcategories known to have different recovery times. Although dogs without nociception were present in similar proportions in all groups, their presence increased the variance within the groups and therefore the likelihood of a type II statistical error. Considering that postoperative recovery time in dogs without nociception is longer than that of dogs that have nociception, it was first thought that the effect of the various postoperative treatment modalities would be more marked in such patients; furthermore, a previous investigation[40] of photobiomodulation therapy had suggested a large effect size regardless of the neurologic status at admission. The inclusion of dogs with an MFS of 5 did enable preliminary evaluation of the safety of postoperative treatments included in the study and their effects on the need for postoperative analgesia by increasing the overall sample size. Other limitations included the fact that several surgeons performed the surgeries and evaluations and that the period of observation was short.

In this small trial, we found no significant differences in outcome measures of dogs of the photobiomodulation therapy, physical rehabilitation, and sham treatment–only groups, and no adverse events that could be attributed to photobiomodulation or physical rehabilitation treatments were identified. However, larger studies of similar design with longer observation periods and adequate numbers of dogs of each preoperative MFS are needed to fully explore the possible effects of these treatment modalities on recovery time and outcome in dogs after surgical treatment of thoracolumbar IVDD.

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Footnotes

a. Williams CC, Barone G. Is low level laser therapy an effective adjunctive treatment to hemilaminectomy in dogs with acute onset paraplegia secondary to intervertebral disc disease? (abstr) *J Vet Intern Med* 2011;25:730–731.
b. DDv control unit and laser cluster probe, THOR Photomedicine Ltd, London, England.
c. Cefar Rehab X2, DJO Inc, Guildford, Surrey, England.
d. R, version 2.15.3, R Statistical Software, Foundation for Statistical Computing, Vienna, Austria.
e. Schubert T, University of Florida, Gainesville, Fla: Personal communication, 2015.

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Appendix appears on the next page

Appendix

Summary of a 3-phase postoperative rehabilitation protocol used for treatment of a subset of dogs (rehabilitation group) in a study to evaluate the effects of postoperative rehabilitation and photobiomodulation therapy in dogs following hemilaminectomy for IVDD.

Phase	Procedure	Description
A	Cold pack application	Examination gloves filled with water and 70% isopropyl alcohol (2:1, 270:130 mL [vol/vol]) and frozen at –18°C were applied to the incision site, with a thin layer of disposable tissues placed between the incision and the gloves, for 12 min 6 times/d.
	Range-of-motion exercises	Flexion and extension of each joint of each pelvic limb 15 times, followed by 15 rotational pedaling movements of each pelvic limb, 4 times/d.
	Toe-pinch exercises*	A digit was pinched to elicit withdrawal 5 times for each pelvic limb, 4 times/d.
B	Range-of-motion exercises	Same protocol as for phase A.
	Toe-pinch exercises*	Same protocol as for phase A.
	Assisted standing	The dog was placed in a harness and assisted to stand with partial weight bearing for 2–5 min 4 times/d.
	Hydrotherapy†	The dog was placed in a hydrotherapy pool filled to a depth of 70 cm (which did not allow the feet to contact the pool bottom) with static water at a temperature of approximately 30°C. A hydrotherapy harness was used to help support the dog; if deemed necessary, an attendant placed a hand at the caudoventral aspect of the thorax to minimize stress. The procedure was performed for 2–5 min‡ every other day.
	Neuromuscular electrostimulation	The patient was placed in lateral recumbency for electrostimulation of the quadriceps (first muscle group) and biceps femoris, semitendinous, and semimembranous muscles (second muscle group[43]; frequency, 30–60 Hz; pulse, 300 microseconds; waveform, symmetric biphase pulse; 12 s on and 25 s off). Amplitude was increased until muscle contraction was deemed adequate. The procedure was performed for 15 min (each muscle group of each pelvic limb) once daily.
C	Range-of-motion exercises	Same protocol as for phase A.
	Hydrotherapy†	Same protocol as for phase B.
	Neuromuscular electrostimulation	Same protocol as for phase B.
	Assisted standing and weight shifting	The dog was placed in a harness, assisted to stand with partial weight bearing, and manipulated to cause weight shifting onto each limb (or placed on an unstable pad for this purpose) for 2–5 min 4 times/d.
	Walking	The patient was walked at a slow pace, with a harness used for support when needed, for 4 min 4 times/d.

The physical rehabilitation protocol was based on procedures described in other sources.[6,46,47] Phase A was started 2 days after surgery, except that cold pack application was performed only during the first 48 hours after surgery. Phase B was implemented once the animal was able to support its own weight in a standing position (without pelvic limb movements), and phase C was started when deliberate movement of the pelvic limbs was observed.

*Performed for patients with upper motor neuron injury only. †When phase B or C was implemented < 3 days after surgery, hydrotherapy was postponed until the third day after surgery to allow for adherence to surgical wound care requirements. ‡Duration was determined on the basis of the attendant's subjective assessment of the dog's degree of fatigue.

(Adapted from Olby N, Halling KB, Glick TR. Rehabilitation for the neurologic patient. *Vet Clin North Am Small Anim Pract* 2005;35:1389–1409. Reprinted with permission.)