The Veterinary Journal 210 (2016) 61–67

Contents lists available at ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

A simplified method of walking track analysis to assess short-term locomotor recovery after acute spinal cord injury caused by thoracolumbar intervertebral disc extrusion in dogs

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ARTICLE INFO

Article history:
Accepted 13 January 2016

Keywords:
Spinal cord injury
Intervertebral disc disease
Dog
Locomotor recovery
Outcome assessment

ABSTRACT

The purpose of this study was to evaluate a simplified method of walking track analysis to assess treatment outcome in canine spinal cord injury. Measurements of stride length (SL) and base of support (BS) were made using a 'finger painting' technique for footprint analysis in all limbs of 20 normal dogs and 27 dogs with 28 episodes of acute thoracolumbar spinal cord injury (SCI) caused by spontaneous intervertebral disc extrusion. Measurements were determined at three separate time points in normal dogs and on days 3, 10 and 30 following decompressive surgery in dogs with SCI. Values for SL, BS and coefficient of variance (COV) for each parameter were compared between groups at each time point.

Mean SL was significantly shorter in all four limbs of SCI-affected dogs at days 3, 10, and 30 compared to normal dogs. SL gradually increased toward normal in the 30 days following surgery. As measured by this technique, the COV-SL was significantly higher in SCI-affected dogs than normal dogs in both thoracic limbs (TL) and pelvic limbs (PL) only at day 3 after surgery. BS-TL was significantly wider in SCI-affected dogs at days 3, 10 and 30 following surgery compared to normal dogs. These findings support the use of footprint parameters to compare locomotor differences between normal and SCI-affected dogs, and to assess recovery from SCI. Additionally, our results underscore important changes in TL locomotion in thoracolumbar SCI-affected dogs.

Introduction

Intervertebral disc extrusion (IVDE) is the most common cause of acute spinal cord injury (SCI) in dogs, and chondrodystrophic breeds such as the Dachshund, Cocker spaniel, Basset hound, Beagle, Pekingese, Shih Tzu, Miniature poodle and Bichon Frise are commonly represented in the literature (Olby et al., 2003; Ito et al., 2005; Levine et al., 2011; Aikawa et al., 2012; Bergknut et al., 2012; Packer et al., 2013). The high incidence of spontaneous SCI in dogs makes them an important animal model for human SCI (Rice et al., 2009). Dogs offer a genetically similar, but environmentally heterogeneous study population, with comparable mechanisms of injury and resultant pathology to that in humans, which can bridge the gap between experimental rodent models and the human SCI population (Borgens et al., 1999; Laverty et al., 2004; Olby et al., 2004; Jeffery et al., 2006). Successful clinical trials in dogs with spontaneous SCI may lead to the development of interventional therapies that can help both dogs and humans.

Walking track analysis has been used previously to assess return of pelvic limb function following animal models of nerve injury and traumatic SCI (de Medinaceli et al., 1982; Kunkel-Bagden et al., 1993; Cheng et al., 1997; Klapdor et al., 1997; Hamers et al., 2001, 2006; Varejao et al., 2004; Gordon-Evans et al., 2009; Rangasamy, 2013). Measurements such as base of support (BS), stride length (SL), interlimb coordination, regularity of step patterns and paw position can provide valuable information regarding the animal's pattern of locomotion in both the thoracic limbs (TL) and pelvic limbs (PL) which may reflect the injury type, severity of injury, and specific spinal tracts affected by the lesion (Kunkel-Bagden et al., 1993; Klapdor et al., 1997; Hamers et al., 2001, 2006; Rangasamy, 2013). Dogs with spinal cord disease exhibit an uncoordinated gait that is quantifiably different using instrumented gait analysis from dogs with lameness due to orthopedic disease (Gordon-Evans et al., 2009). Coefficients of variance (COV) for SL, swing time and lateral paw positioning have previously been shown to differ in dogs with neurologic disease when compared to normal dogs (Hamilton et al., 2008; Gordon-Evans et al., 2009). Analysis of footprints recorded during walking track assessments may reveal gait deficits that can

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http://dx.doi.org/10.1016/j.tvjl.2016.01.013
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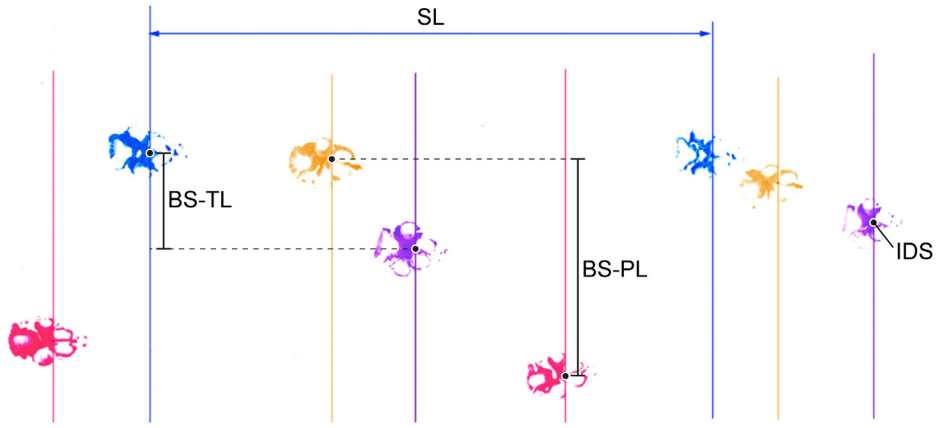

Fig. 1. Footprints were acquired using a simplified method of walking track analysis. Different colors of washable non-toxic paint were applied to each limb (blue, left thoracic limb; purple, right thoracic limb; pink, right pelvic limb; yellow, left pelvic limb). A reference point at the inter-digital space (IDS) was identified and marked as shown (black circle). Methods used to obtain stride length (SL), and base of support of the thoracic limbs (BS-TL) and pelvic limbs (BS-PL) are shown.

be objectively measured, and not readily detected through visual assessment only (McEwen and Springer, 2006).

Walking track analysis can be performed in a research setting using specialized equipment such as the Tekscan or Catwalk (Hamers et al., 2001, 2006; Gordon-Evans et al., 2009). However, this equipment is costly and not universally available, hindering its use in multi-center veterinary clinical trials for SCI.

The primary goal of this study was to evaluate a simplified 'finger painting' method of walking track analysis using inexpensive and universally available materials to compare footprint parameters between normal dogs and dogs with acute thoracolumbar SCI caused by IVDE. We also aimed to document the change in measurable footprint parameters in SCI-affected dogs over a 30-day recovery period, specifically SL and BS. We hypothesized that footprint analysis using this method would produce reliable measures of SL and BS such as those obtained via more expensive commercially available equipment; that SL and BS would differ between normal dogs and SCI-affected dogs; and that these parameters would improve toward normal during recovery after SCI.

Materials and methods

The study was conducted in accordance with the guidelines and approval of The Ohio State University Clinical Research Advisory Committee and the Institutional Animal Care and Use Committee (Approval No. 2012A00000149). Written owner consent was obtained prior to study enrollment for all dogs.

Normal and SCI-affected dogs

Normal, skeletally mature, behaviorally amenable small breed dogs (≤20 kg bodyweight) were recruited as controls from the pet population of The Ohio State University Veterinary Medical Center. Dogs were determined to be neurologically and orthopedically normal via clinical evaluation by two investigators (RBS – residency trained in neurology, and SAM, a board certified neurologist) and had no history of neurologic or orthopedic disease. Valgus and varus conformational limb variations typical for chondrodystrophic breeds were considered acceptable for enrollment to facilitate generalization of results across a realistic clinical population.

SCI-affected dogs from the same institution were prospectively and consecutively enrolled if they met the following criteria: (1) clinical localization of a T3-L3 myelopathy caused by acute IVDE determined by computed tomography with or without myelography, or magnetic resonance imaging; (2) intact nociception of both pelvic limbs and tail; (3) small-breed ≤20 kg; and (4) behaviorally amenable. All dogs underwent surgical decompression for their IVDE.

Footprint acquisition

Different colored non-toxic, washable paints were applied to each paw. Dogs were then walked with a leash at a natural, consistent pace by the same investigator (RBS) down 3 m of butcher paper. Five walking trials were collected during each testing session. Dogs that were reluctant to walk were encouraged with treats and verbal cues by a second investigator at the opposite end of the butcher paper. Notations on the butcher paper were made during testing to indicate if dogs stopped or deviated from the butcher paper path. Control dogs were tested on three different days, separated by at least 48 h. SCI-affected dogs were tested at days 3, 10 and 30 following decompressive surgery. Preliminary evaluation of this technique indicated that only dogs that were ambulatory without assistance could successfully perform the task sufficient for paw print acquisition.

Footprint analysis

The first and last steps per trial for each paw were excluded from analysis to account for the animal's adjustment to a unique walking surface. A single investigator (MSO) performed all measurements. Consistent with previous reports, a reference point for each paw print was located at the intersection of the intermetacarpophalangeal space and the P3-P4 inter-digital space (Kunkel-Bagden et al., 1993). For partial prints, a template indicating the inter-digital space was made using a complete print from the same testing session and overlaid using landmarks on the partial print to determine the inter-digital space. To correct for rotational variation of the paw, lines were drawn perpendicular to the edge of the walking track through each print at the inter-digital space as previously described (Kunkel-Bagden et al., 1993). The distance between these lines was measured for each step per paw, and designated as the SL. The distance between the inter-digital space on the right and left thoracic limbs was designated as the thoracic limb base of support (BS-TL). The same method was used to measure the pelvic limb base of support (BS-PL; Fig. 1).

Prints were excluded from analysis if the inter-digital space could not be identified either directly or by extrapolation, the dog stopped or slowed walking in the middle of a trial, or notations made during the test indicated an abrupt alteration in step cycle. When a print was excluded, the entire step cycle including that print was excluded from analysis. Mean SL, coefficient of variance (COV) of SL, mean BS, and COV BS were calculated for each limb per testing session for control and SCI-affected dogs using all measurable prints from that session.

Statistical analysis

Summary statistics including mean ± standard deviation, or median and range where appropriate, were calculated for clinical data on all dogs and for SL, BS, and COV for all testing sessions. Mean and COV of SL and BS were compared between normal dogs at session 1 and SCI-affected dogs at days 3, 10 and 30 using two sample *t* tests. Paired *t* tests were used to test for improvement in SL of each limb between days 10 and 30 for all SCI-affected dogs that had measurements obtained at both time points. A mixed effect model incorporating repeated measures was used to test the trends in SL and BS for each limb across three sessions for SCI-affected dogs that had measurements at all three time points. A mixed effect model was used to evaluate differences between normal dogs across three testing sessions. Analyses were conducted using commercially available software (SAS). A P value of <0.05 was considered statistically significant for all analyses.

Results

Normal dogs

Twenty normal dogs were recruited for the study. Ages ranged from 8 months to 6.5 years (median 3 years) and weight ranged from 3.7 to 17.2 kg (median 9.4 kg). There were eight spayed females and