Biotemas, 29 (2): 1-6, junho de 2016
ISSNe 2175-7925

http://dx.doi.org/10.5007/2175-7925.2016v29n2p1
Review

Development of locomotion after spinal cord injury in small animals – Literature review

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Submetido em 26/10/2015
Aceito para publicação em 05/04/2016

Resumo

Desenvolvimento da locomoção após injúria medular em pequenos animais – Revisão da literatura. A injúria da medula espinhal ocorre comumente em cães e gatos e resulta em déficits neurológicos graves, podendo causar incapacidade sensitiva e motora permanente. Em pacientes com prognóstico reservado a ruim, faz-se uso dos recursos e tratamentos complementares na tentativa de desenvolver deambulação involuntária e incoordenada, que se aproxima à marcha normal, chamada comumente de andar medular ou caminhar reflexo. Sob condições experimentais, é relatado na literatura o retorno de um caminhar rítmico após completa transecção da medula espinhal. Em medicina veterinária, o papel do desenvolvimento da marcha reflexa é de extrema importância em relação à qualidade de vida dos pacientes afetados, sua independência e tranquilidade dos proprietários. O presente trabalho objetiva revisão de literatura a respeito do desenvolvimento do andar medular após injúria medular em pequenos animais.

Palavras-chave: Cão; Gato; Medula espinhal; Plasticidade neural; Reabilitação

Abstract

Spinal cord injuries are common in cats and dogs and result in severe neurological deficit, which can lead to permanent loss of sensory and motor capacity. In patients with fair to poor prognoses, complementary treatments have been used to develop an involuntary and uncoordinated ambulation that resembles normal gait, commonly known as spinal locomotion or reflexive stepping. Under experimental conditions, the recovery of a rhythmic gait has been reported following complete spinal cord transection. In veterinary medicine, the development of reflex stepping is of extreme importance to the quality of life and independence of the patients, as well as the satisfaction and tranquility of the owners. The present study is a literature review about the development of locomotion after spinal cord injury in small animals.

Key words: Cat; Dog; Neuronal Plasticity; Rehabilitation; Spinal Cord

In cats and dogs, the occurrence of spinal cord injury is common (ARIAS et al., 2007). Spinal cord injury consists of damage to the neural elements of the spinal canal, resulting in severe long-term neurological deficit (ABREU et al., 2011). It can lead to permanent loss of sensor and motor capacity and treatment remains a challenge (VILLANOVA et al., 2014).

In veterinary medicine, compression of the spinal cord or vertebrae are the most common findings in clinical cases of spinal cord injury (FENNER, 2003). Intervertebral disc disease (IVDD) is the neurological disease with the highest reported incidence in dogs (LeCOUTEUR; GRANDY, 2005; LORENZ et al., 2011; FOSSUM, 2014) and the therapeutic protocols available vary from conservative treatments to decompression surgeries (COATES, 2000).

Dogs with thoracolumbar IVDD can be treated clinically or surgically, depending on the degree of neurological dysfunction (FESTUGATTO et al., 2008). Surgery is often performed in cases of relapse, progression of clinical signs, non-ambulatory paresis, paraplegia with deep nociception (deep pain reflexes) or paraplegia with nociception absent for no longer than 48 hours. If deep pain reflexes are absent for longer than 48 hours, the chances of post-operative functional motor recovery are reduced and the use of new therapies is thus encouraged (SHARP; WHEELER, 2005).

A fair prognosis for ambulatory recovery of some patients is directly related to the severity of the lesion and the implementation of adequate treatment (OLBY et al., 2008). In patients with fair to poor prognoses, complimentary treatments are used to achieve an involuntary and uncoordinated stepping that resembles voluntary stepping, also known as spinal locomotion or reflexive stepping (OLBY et al., 2008; JAGGY; COUTEUR, 2010; LORENZ et al., 2011). Animals with neurological deficit and impaired motor function require intensive and special care; therefore, the development of locomotion, even if abnormal, is extremely important. Furthermore, data obtained from animal experiments and successful treatments in veterinary medicine can aid in the development of effective therapeutic protocols (DIETZ, 2009).

Studies have demonstrated that small quantities of undamaged axons can restore the walking ability of spinal patients; functional/normal gait can be re-established if only 10% of the axons are undamaged (GUZEN et al., 2009). The return to a rhythmic gait after complete spinal cord transection under experimental conditions has been reported by several authors for cats, dogs, rabbits, guinea pigs, ferrets and rats (RANSON; HINSEY, 1930; SHURRAGER; DYKMAN, 1951; HART, 1971; GRILLNER, 1973; FORSSBERG et al., 1974; MILLER, VAN DER MECH, 1976; EIDELBERG et al., 1977; GRILLNER; ROSSIGNOL, 1978).

It has been suggested that reflexive stepping is associated with central pattern generators (CPGs) (EIDELBERG et al., 1980) and thus connected to networks of lumbosacral neurons, which retain an intrinsic capacity to oscillate and generate coordinated rhythmic motor outputs. These networks can be found in all vertebrate and invertebrate animals; however, the anatomical architecture of locomotor CPGs remains poorly understood (GRILLNER, 2006; KIEHN, 2006).

It is thus believed that directly accessing and activating spinal cord CPGs could facilitate the development of reflexive stepping and locomotor recovery after severe spinal cord injury (COURTINE et al., 2009). Several strategies have been tested to activate the locomotor circuits in mammals following spinal cord injury, including pharmacological treatments (CHAU et al., 1998; LANDRY et al., 2006), epidural electric stimulation (ICHIYAMA et al., 2005; 2008; GERASIMENKO et al., 2007) or intraspinal electric stimulation (BARTHÉLEMY et al., 2007; GUEVREMONT et al., 2006) and motor training (CHAU et al., 1998; De LEON et al., 1999; TILLAKARATNE et al., 2002; ICHIYAMA et al., 2008; KUBASAK et al., 2008).

Courtine et al. (2009) reported that after complete spinal cord transection in adult rats, a combination of serotonergic agonists and epidural electric stimulation was able to transform non-functional spinal circuits into highly functional ones. It has been suggested that these interventions could recruit specific populations of spinal circuits, refine their control via sensory input and functionally remodel these locomotor pathways when combined with training, leading to improvements in the development of spinal locomotion.

Neuroplasticity is the ability of the central nervous system to self-adjust to environmental stress and restore its functions following pathological processes (BERLUCCHI; BUCHTEL, 2009). Neural restoration and plasticity constitute the main objectives of modern neuro-rehabilitation and should thus be prioritized over improvements of isolated clinical signs, such as muscle tone or hyperreflexia (HUBLI; DIETZ, 2013).

The plasticity of neural circuits is directly related to the task performed during training, its frequency and intensity, as demonstrated by a study where cats acquired complete locomotor function, with weight bearing, following months of daily training (LOVELY et al., 1986; BARBEAU, ROSSIGNOL, 1987). De Leon et al. (1998) reported that cats trained to remain in quadruped position were able to bear weight for up to 1 hour, even though locomotor function and reflexive stepping on the treadmill were still debilitated. These findings suggest that the neural circuits learn the sensor-motor task that is specifically trained (TILLAKARATNE et al., 2002).

According to Krityakiarana (2010), neurogenesis and oligodendrogenesis in the intact spinal cord of rats are positively influenced by voluntary exercises, thus emphasizing the benefits of these exercises as a co-treatment in cases of spinal injuries. However, neural plasticity can also have negative and pathological effects when newly formed abnormal and defective circuits lead to inappropriate movement patterns and pain, as is the case of phantom limb pain (TILLAKARATNE et al., 2002; HOU et al., 2008; COURTINE et al., 2009). Therefore, research about patients with spinal cord injury should focus on the improvements of reflexive stepping and other motor functions through the adequate growth and regeneration of damaged axons (FOUAD; PEARSON, 2004).

The caudal neural circuits of a spinal cord injury can be activated by adequate afferent stimuli and constitute an important recovery base after injury (ROSSIGNOL et al., 2006). The results of applied neuro-rehabilitation therapy depend directly on the type, repetition and quality of functional motor training. Repetitive activation of the sensor-motor networks through training can reinforce the circuits and synapsis being used in the execution of the movement being practiced (CAI et al., 2006; EDGERTON et al., 2008).

Similarly, muscles and soft tissues reorganize and readapt in cases of injury and alterations to the central nervous system, according to their pattern of use (CARR; SHEPHERD, 2008). Training plays an important role in enhancing the recovery process in spinal injuries because stimulation of the spine leads to the development of new neural connections in the remaining tissue and consequent development of spinal locomotion and other motor functions. It is important to note that in order to achieve effective neuro-rehabilitation, an understanding of the neural mechanisms involved, the conditions for normal and pathological movements and the interaction between central and afferent feedback is essential (HUBLI; DIETZ, 2013).

Improvements on stepping and other motor functions, which promote the growth and regeneration of damaged axons, have become the focus of research studies in animals with spinal cord injuries (FOUAD; PEARSON, 2004). The stepping stimulus is considered an important tool in the development of spinal locomotion, as observed in several studies that used treadmills as the main stimulus for stepping (BARBEAU; ROSSIGNOL, 1987; KAY-LYONS, 2002; GUERTIN, 2013). Allied to the stimulus, total or partial weight bearing has proven to be very important for the development of reflexive stepping (WERNIG; MULLER, 1992; BARBEAU et al., 1999; McCAIN et al., 2008). Underwater treadmills can also be used to improve weight bearing and stepping, as underwater exercise increases joint flexibility and movement amplitude, strengthens the musculature and stimulates coordination and posture (MIKAIL; PEDRO, 2006).

During the initial phase of neurological rehabilitation following severe spinal cord injury, the precarious motor coordination, the paresis of the pelvic limbs and the compromised equilibrium limit the ambulatory ability of the animal. Therefore, treatment can begin with the physiotherapist or trainer manually making the movements for the patient (HUBLI; DIETZ, 2013). In the absence of load-related input, the contraction of the quadriceps muscles is stimulated when the animal is in quadruped position with both hind limbs on the floor, even if supported. The hind limbs should be suspended enough to avoid the toes touching the surface and subsequently lowered, simulating a weight bearing stance (OLBY et al., 2008).

Electromyography studies have shown that load-related exercises, with hind limb weight bearing over different surfaces, stimulate extensor muscle receptors during locomotion (RANSON; HINSEY, 1930).

In the absence of a treadmill, stepping should be encouraged with assisted walks using a commercial, customized or wheeled support to aid the movement of the pelvic limbs. It was demonstrated that locomotor training on a treadmill, associated with partial weight support, is an efficient method to generate and improve the cinematic characteristics of the gait in individuals that have suffered a stroke (McCAIN et al., 2008).

The current literature review highlights the main concepts about spinal locomotion and addresses how stepping can be improved with physiotherapy and training. Reflexive stepping is of extreme importance to the quality of life, independence and satisfaction of the patients and to the tranquility of the owners.

The essential components of a motor training program designed for routine use in human or animal patients with severe spinal cord injury have yet to be defined. Thus, further research is of outmost importance to overcome the lack of information on effective therapeutic protocols that could lead to early development of spinal locomotion.

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