Journal of Veterinary Science & Technology

Gonçalves, et al., J Veterinar Sci Technol 2016, 7:2
DOI: 10.4172/2157-7579.1000301

Research Article Open Access

Functional Neurorehabilitation in Dogs with Cervical Neurologic Lesion

Filipa Inês Rodrigues Gonçalves, Ângela Paula Neves Rocha Martins* and Maria Margarida Ferreira Alves

Department of Veterinary Sciences, University of Lusófona, de Humanidades e Tecnologias Campo Grande 376, 1749-024 Lisboa, Portugal

***Corresponding author:** Ângela Paula Neves Rocha Martins, Department of Veterinary Sciences, University of Lusófona, de Humanidades e Tecnologias Campo Grande 376, 1749-024 Lisboa, Portugal, Tel: 212181441; E-mail: vetarrabida.lda@gmail.com

Rec date: Feb 01, 2016; **Acc date: Mar** 02, 2016; **Pub date:** Mar 04, 2016

Copyright: © 2016 Gonçalves FIR, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Abstract

Neurologic lesions in dogs may have countless causes and can occur, for example, in cervical region. Two different motor systems can be affected and, either one, can seriously compromise the animal's autonomy. In both cases, functional neurorehabilitation has been included in these cases treatment plan.

In the present master dissertation, we aimed to evaluate how the success in the rehabilitation of these animals can be influenced by the dog's characteristics, the disease, the type of treatment and the time elapsed between the initial lesion and the start of the functional neurorehabilitation.

A clinical study was performed, with 22 dogs with diagnosed cervical neurologic lesion. Conservative or surgical treatment was performed and the dogs were subjected to a functional neurorehabilitation protocol, elaborated at the Centro de Reabilitação Animal da Arrábida, where the type of lesion, patient characteristics, deficits presented at the entrance and exit from the Center and time elapsed between the lesion and the entrance and the exit of the Center, were evaluated.

There were no significant differences between the affected motor systems and the deficits presented or recovery time. Still, the type of treatment was related with etiology, where, generally, congenital and traumatic cases have been submitted to conservative treatment, while surgical treatment was mostly performed in degenerative and multifactorial cases. In concerning to deficits at the entrance of the Center and the type of treatment, surgical management was mostly applied in non-ambulatory tetraparesic patients, while conservative management was mostly performed in tetraplegic dogs or with other neurologic deficits.

We conclude that functional neurorehabilitation had a primary role in this patient's recovery, allowing 72.8% returning to functionality and regain autonomy, avoiding a more radical outcome.

Keywords: Cervical neurologic lesion; Neuromodulation; Neuroplasticity; Functional neurorehabilitation; Locomotor training

Introduction

Return to functional independence is the goal of neurorehabilitation for patients with neurologic injury. To achieve so it's required to promote restoration of neurologic pathways, as well as apply an appropriate management, which can prevent and treat consequences secondary to the animals neurologic condition, like pain, decubitus ulcers and urinary management [1-3].

After a neurologic injury it's aimed that the patient regains balance, posture and locomotion capability. The rehabilitation plan must be intensive in order to achieve success [4,5]. This one is based on neuroanatomical key principles related to central nervous system (CNS) and its properties, like neuroplasticity and neuromodulation. Despite of human being pyramidal and domestic species extrapyramidal, both have in common those two CNS properties. After a medullar injury, even in complete cases, with neuroplasticity, neuromodulation and a suitable locomotion training it's possible to re-educate CNS to use alternative pathways to perform locomotion, maintain posture and balance, allowing patient to achieve autonomy [1,6-8].

Functional neurorehabilitation (FNR) goal is the plasticity of central pattern generators (CPG), which have some automaticity and capability to generate rhythmic movements, more properly inducing flexor and extensor muscles to contract and flex rhythmic and repetitively.

To do so, it isn't needed to be included supraspinal information, despite this one being necessary to conscious locomotion and coordination [6,9-12]. In general, memorization of the locomotor training implies a process of reprogramming and retraining the nervous system, by cyclic and repetitive afferent stimulation, enabling alternative pathways to readapt, allowing the patient to be capable of performing station and gait [4,5,13,14].

Furthermore, we should associate electromyostimulation of peripheral nerves to facilitate the arise of fictive locomotion due to excitability promoted in the medullary segments [6,15,16].

Based on the CNS properties above mentioned, we aimed to evaluate the neurologic evolution of dogs with cervical neurologic lesion that have been subjected to a base FNR protocol, proving its importance in recovering patients functionality and autonomy, despite patients characteristics, injury and chosen treatment.

Materials and Methods

In the present study were included 22 dogs that come to Centro de Reabilitação Animal da Arrábida (CRAA), a rehabilitation center, after being assessed by a veterinary neurologist with academic career, which used complementary imaging exams like radiography, myelography, computed tomography (CT) and magnetic resonance (MR) to make diagnosis.

After precise and systematic assessment, there was created a FNR therapeutic protocol which aimed to promote patients autonomy and management of pain, inflammation and decubital ulcers.

We included all dogs with cervical neurologic lesion, diagnosed by a veterinary neurologist with academic career, who used complementary diagnostic exams like radiography, myelography, CT and MR, regardless the breed, gender, age, disease, type of treatment and clinical signs.

All patients that weren't dogs, without properly diagnosed cervical neurologic lesion or without being referenced by a veterinary neurologist with academic career weren't included in the present study.

Presenting included patients

Patients included in the study were characterized for breed, age, gender, weight, etiology, disease, affected motor system and applied type of treatment. It was also considered time elapsed between injury and entrance in the Center and injury-surgery-entrance in the Center, and both internment period in the Center and deficits present at the entrance and exit of the Center.

FNR protocol from CRAA to dogs with cervical neurologic lesion

A general FNR protocol elaborated by CRAA was applied to all patients above mentioned. Considering each patient's individualities there were applied specific modalities and exercises, for example pain management, which aimed to improve patient's quality of life. The chosen protocol was related to the kind of presented clinical signs, so, upper motor neuron (UMN) or lower motor neuron (LMN).

FNR protocol to patients with UMN signs: All patients with UMN signs began the FNR protocol with passive therapeutic exercises associated with proprioception exercises, for example assisted standing associated to bicycle movements in a rough floor, like central stimulation pad from FITPAWS®, to achieve a bigger stimulation of reflex arc by promoting afferent pathways. These exercises were applied in all limbs, six times a day, each with 30 series and without exceeding ten minutes per session.

Locomotor training consisted in gait on the treadmill, gait on underwater treadmill and gait stimulation in different paving. On the treadmill PROFESSIONAL FIT FUR LIFE TREADMILL, voluntary movement (VM) was promoted with the technician doing bicycle movements in both thoracic and pelvic limbs. Avoiding cervical oscillations was primordial during the training, as so ensure a symmetrical movement, thus respecting the imaginary line from median plane. At an initial phase training was performed two times a day, during five minutes, with 1 to 1.5 km / h speed and without incline. Progressively duration and speed have been raised. Only in the last phase of training it was used 1% incline.

Stimulation of gait was made in different paving, like grass, gravel, pebbles and leca. Patients passed through the different paving four to ten times, depending on patients cardiorespiratory resistance, four times a day. Every patient presenting non-ambulatory tetraparesis was helped with chest harness and slings on this exercise.

Another component of the locomotor training, the underwater treadmill HIDRO PHYSIO™, was done once a day, tem to 60 minutes, with a speed from 1.5 to 5 km/h, depending, once again, on patients cardiorespiratory resistance and ambulatory state. It's known that water properties like buoyancy, viscosity and relative density are essential to promote VM [17,18].

As patients improved to its ambulation state there were implemented active-assisted or active therapeutic exercises, which included exercises of balance, coordination and swing. For example, squats on FITPAWS® fisioball are an active-assisted therapeutic exercise. However, this was only practiced after three or six weeks in patients with conservative or surgical management, respectively. The circuit with therapeutic exercises was done four times a day, without exceeding 15 minutes per session. It was composed by cavalettis rails, poles, trampoline, balance board and wobble board.

Since in this kind of injury patients' present spastic muscles [19], mainly in extensor muscles form thoracic limbs (TL) and pelvic limbs (PL), it was applied class IV laser therapy on this muscle groups. Because class IV laser is warm, it promotes vasodilatation e reduces pre-inflammatory substances, like interleukins and nitrous oxide, reducing inflammation; also allowing pain management, once it reduces muscle spasm [20,21]. We've used PainTrauma program from LITE CURE COMPANION THERAPY LASER® CTC, which takes in account patients weight, coat and skin color. During five consecutive days it was applied once a day followed by a session each 48 hours, for 15 days, and then a session each 72 hours, until absence of pain.

We've also used electromyostimulation with BTL 4000 PREMIUM e BTL 4000 SMART, to pain management and promote muscle contraction, with transcutaneous electrical nerve stimulation (TENS) and neuromuscular electric stimulation (NMES), respectively. In

TENS we've applied an electrode in C7-T1/T2 segments, on radial nerve exit, and another one on the motor point from extensor muscles, from TL. To PL, we've applied an electrode above L4-L6 segments, on femoral nerve exit, and other one on the motor point from extensor muscles. This was done both with patient in station or in recumbency, once a day, until absence of pain. With NMES we aimed to stimulate contraction's co-activation to avoid atrophy of muscles, although this one is progressive when UPM is affected. An electrode was applied above C6-C8 segments, on musculocutaneous nerve exit, and another one on the motor point from flexor muscles, from TL. In PL, one electrode was applied above L7-S1 segments, on sciatic nerve exit, and the other one on the motor point of flexor muscles. This modality was performed with patients in station, once a day for 15 days and, then, on alternate days until the patient gain ambulatory capacity and VM.

For cervical muscle spasm it was used magnet therapy with BTL 4000. Here the patient was in lateral recumbency to each side, for 30 minutes, once a day, until absence of pain. Then, a relaxing massage was applied as it follows: stroking-effleurage-wringing-up-kneadings-thumbs-friction-wringing-up-effleurage-stroking. Since we aimed to achieve muscle relaxation, in friction's massage, the movements were made from the center of the muscles to the extremities, to relax Golgi tendon organs, or from the extremities to the center of the muscles, to relax muscle spindles.

FNR protocol to patients with LMN signs: In concerning to patients with LMN signs, FNR protocol was similar to the described above for UMN. However, therapeutic exercises were incremented 25%. So, passive therapeutic exercises and proprioception exercises were performed nine times a day, each with 30 series. Active-assisted and active therapeutic exercises were performed six times a day. Stimulation of gait was performed between six to 13 times a days.

NMES was performed both in extensor and flexor muscles from TL

Particularities about FNR protocol: Some patients presented deficits both related to UMN and LMN injury. In these particular cases the applied FNR protocol was a mix from the two protocols above mentioned, based on each patient's particular needs.

Statistical analysis

Informatic program IBM® SPSS® Statistics 20.0 was used to do the result's statistical analysis. First, it was done a descriptive statistical analysis to characterize the sample: breed, age, weight, gender, etiology, disease, affected motor system, applied treatment, time elapsed injury-surgery, time elapsed surgery-entrance at the Center, time elapsed injury-entrance at the Center, out time and deficits presented at the entrance and exit of the Center. Then, it was made the inferential statistical analysis with Chi-Square test, since the majority of the variables were categorical. Here, results were considered statistically significant if $p \leq 0.05$, showing statistical dependence.

Results

Statistical analysis breed versus etiology

Analyzing the variables breed and etiology we obtained in congenital cases one Yorkshire Terrier and one Chihuahua. In degenerative cases there were two mixed breeds, two Pomeranian, one Greyhound, one Yorkshire Terrier, one Poodle, one Bernese Mountain Dog, one Dalmatian and one mixed Dalmatian. Cases with traumatic origin included one American Staffordshire Terrier, one Labrador Retriever, one Greyhound, one mixed breed, one mixed Pequinois, one mixed Chihuahua and one mixed Labrador with Golden Retriever. In the multifactorial cases there were two Dobermann e one mixed breed.

There was no statistical dependence, since p-value was 0.286.

Statistical analysis age versus etiology

Age groups are young dogs, less than two years, adult dogs, between three and seven years, and geriatric dogs, with more than eight years.

Analyzing the variables age and etiology we observed three traumatic cases and two congenital cases in young dogs. In adult dogs there was one traumatic case, two degenerative cases and three multifactorial cases. In geriatric dogs there were three traumatic cases and eight degenerative cases.

There was statistical significance, with p-value 0.02. We observed that in younger dogs it's more common cervical neurologic lesions of congenital origin, while in adult dogs there are multifactorial lesions and degenerative lesions start to show up. In geriatric dogs there is a major incidence of degenerative lesions. In concerning to traumatic lesions, they're appeared in all age groups (Figure 1).

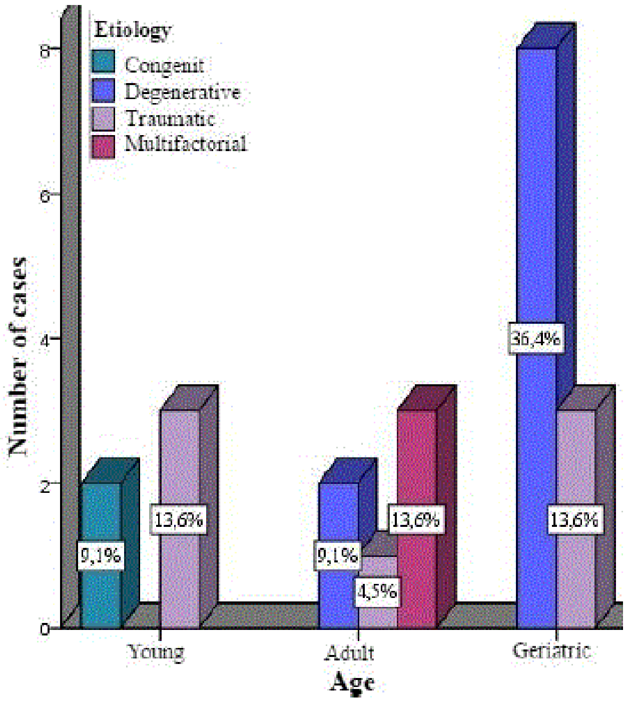

Figure 1: Relation between age and etiology variables.

Statistical analysis etiology versus treatment

Analyzing the variables etiology and treatment it was observed that conservative management was applied to two congenital cases, two degenerative cases and five traumatic cases. Surgic treatment was performed in eight degenerative cases, two traumatic cases and three multifactorial cases (Figure 2).

There was statistical dependence, with a p-value 0.024. So, in congenital cases it was mostly chosen conservative treatment, while surgic management was preferred in degenerative and multifactorial cases.

Statistical analysis affected motor system versus deficits presented at the entrance of the center

Analyzing the variables affected motor system and deficits presented at the entrance of the Center, we observed, in patients with UMN signs, five presented with tetraplegia, one with hemiplegia, five with non-ambulatory tetraparesis and one non-ambulatory paraparesic. Patients with LMN signs, one presented tetraplegia, two TL monoplegia and two non-ambulatory tetraparesis. Regarding patients with both UMN and LMN signs, one presented tetraplegia and four non-ambulatory tetraparesis.

There was no statistical dependence, since p-value was 0.236.

Citation: Gonçalves FIR, Martins APNR, Alves MMF (2016) Functional Neurorehabilitation in Dogs with Cervical Neurologic Lesion. J Veterinar Sci Technol 7: 301. doi:10.4172/2157-7579.1000301

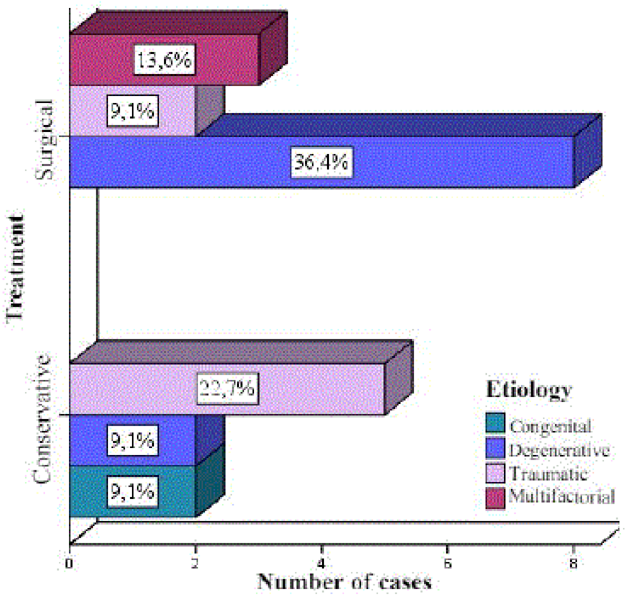

Figure 2: Relation between etiology and treatment.

Statistical analysis affected motor system versus deficits presented at the exit of the center

Analyzing the variables affected motor system and deficits presented at the exit of the Center we observed, in patients with UMN signs, four have leaved without deficits, with proprioceptive ataxia or have ended the FNR protocol due to other medical conditions. Patients with LMN signs, two have leaved without deficits or with proprioceptive ataxia and one was TL monoparesic. Regarding patients with both UMN and LMN signs, two leaved without deficits or with proprioceptive ataxia and one was non-ambulatory tetraparesic.

There was no statistical dependence, since p-value was 0.247.

Statistical analysis affected motor system versus time until exit of the center

Analyzing the variables affected motor system and time elapsed until the exit of the Center we observed that, in patients with UMN signs, one came out in less than 48 hours and another one until a week, four leaved until a month, five until two months and one after more than two months. Regarding patients with LMN signs, two leaved until one month or until two months and one after more than two months. Patients with both UMN and LMN signs, one leaved until a month and four until two months.

There was no statistical dependence, since p-value was 0.831.

Statistical analysis treatment versus deficits presented at the entrance of the center

Analyzing the variables treatment and deficits presented at the entrance of the Center showed that conservative management was applied in the two cases of TL monoplegia, four tetraplegia cases, one hemiplegia case, one non-ambulatory tetraparésia case and one non-ambulatory paraparesis case. In concerning to surgical treatment, it was performed in three tetraplegia cases and ten non-ambulatory tetraparesis (Figure 3).

There was statistical dependence, with p-value 0.025. Surgical treatment was mostly performed on non-ambulatory tetraparesic patients, while conservative treatment was mostly performed on tetraplegic cases and in the remaining neurologic deficits cases.

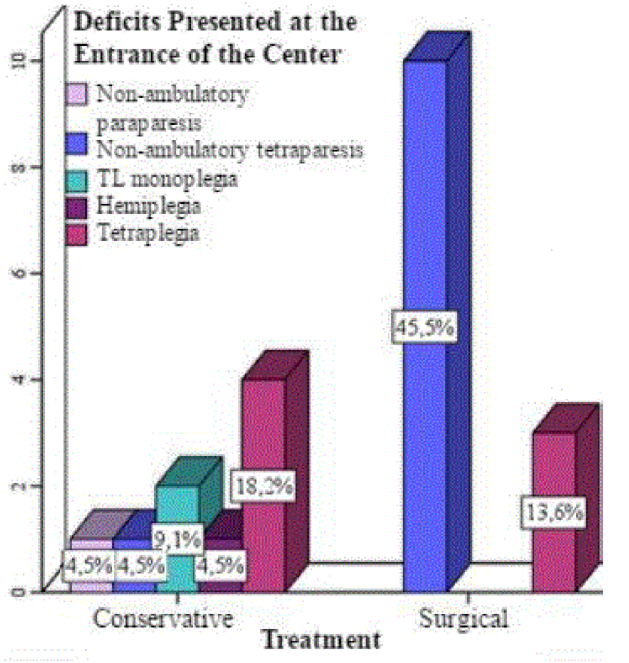

Figure 3: Relation between treatment and deficits presented at the entrance of the Center.

Statistical analysis time until exit of the center versus deficits presented at the entrance of the center

Analyzing the variables time elapsed until the exit of the Center and deficits presented at the entrance of the Center, was observed that one non-ambulatory paraparesic came out until one month as well as in the two cases of TL monoplegia. The hemiplegic patient leaved until two months. About non-ambulatory tetraparesic cases, three leaved until one month, seven until two months and one after more than two months. Regarding tetraplegic cases, one leaved in less than 48 hours, one until a week, antoher one until a month, three until two months and one after more than two months.

There was no statistical dependence, since p-value was 0.688.

Discussion

The sample obtained was quite diversified in concerning to breed variable. Apparently there was no dependence with the etiology variable. Note that in congenital atlantoaxial subluxation, there is known racial predisposition in miniature breeds [10,22-25]. In cervical spondylomyelopathy with medullar compression associated to soft tissue and intervertebral disk (IVD) degenerative changes, Dobermann is the most predisposed breed [22-24,26,27]. In concerning to degenerative or traumatic causes, currently, there isn't known any breed predisposition. Although in the present study there was no variable dependence, we've noticed that our two cases of congenital atlantoaxial luxation were from a Chihuahua and a Yorkshire Terrier. In the other hand, our three cases of cervical spondylomyelopathy were in two Dobermann and one mixed breed. Furthermore, our sample had 22.7% of congenital and multifactorial cases, respectively with two and three cases, and the other 77.3% were represented by degenerative or traumatic cases, with ten and seven cases, respectively. So, heterogeneous distribution and sample size may influence the final result.

In variable age was observed that 50% were geriatric patients, whilst 22.7% and 27.3% were young and adult patients, respectively. Note that half of the sample were geriatric patients, and they are considered a risk group. So, the longer the recumbency period the greater probability to develop medical events whom can severely compromise these patients quality of life or become really life threatening. This is why becoming them functional and autonomous again it's a priority. Note that mean rehabilitation time was two months. About age and etiology variables, our study was consistent with the literature, since congenital cases typically appear in young animals until two years [9,23-25,28]. Due to its progressive characteristic, degenerative lesions tend to appear in older animals [27,29], and may appear from five years [10,23,25]. In acute non-compressive nucleus pulposus extrusion the mean age is almost seven years [30]. Cervical spondylomyelopathy in large breed dogs is common between four and eight years [23]. There isn't currently known age predisposition to cervical fractures or brachial plexus avulsion.

In atlantoaxial luxation cases with minimal neurologic deficits, cervical pain, minimal articular misalignment and/or whom vertebrae still immature to support implants conservative management should be performed. Although satisfactory results, there aren't yet adequate information about the long-term results [10,23,31]. However, surgical management has associated high levels of mortality intra- and postoperative, about 20% [31] to 30% [23], and more recently, between 5 to 10% [22]. This is a result of the difficult access and ease of injuring both medullar and adjacent tissues, like respiratory tract. In concerning to degenerative cases, medullar compression secondary to IVD disease its dog's most common neurologic problem [24,29,32]. Notice that it represented 45.5% of our sample cases. Choosing between conservative or surgical management must take in account patient's history, presented neurologic deficits, associated risks and it includes also the clinical experience. Traumatic cases in cervical region occur mostly in atlantoaxial and cervicothoracic regions [24,33], and 70% of fractures are located in C1 or C2 [33]. Conservative management in these cases is performed in ambulatory patients, with minimal neurologic deficits and without evidence of medullar compression [24,33]. In the other hand, if there is deterioration of animal neurologic state, severe neurologic deficits or vertebral instability, the surgical management must be chosen. In type III hernia surgical treatment should be performed when there is medullar compression due to the fragments or when there are neurologic deficits that justify this treatment choice; otherwise, conservative management is preferred [24,30,34]. Of our three cases, two performed conservative management and one surgical management. In concerning to brachial plexus avulsion, mostly is treated conservatively [23,25], which was observed in our study, since our two cases were treated conservatively. In cervical spondylomyelopathy surgical management should be performed when exists severe and/or progressive neurologic deficits [24,26]. This kind of treatment was performed in all cases of our study. Statistical analysis revealed that it's possible to exist dependence between variables etiology and treatment. However, although this is according with literature, the small sample size doesn't allow us to make concrete inferences.

Nevertheless, it would be important to confirm this dependence, since it would allow elaborating a guideline scale for decision of the suitable treatment to apply in each situation, and thus eliminate associated subjectivity and empiricism.

Generally, LMN injuries are more difficult to rehabilitate than UMN injuries, and so, the first ones are associated to a worsen prognosis [10,32]. Moreover, neurologic injuries affecting both motor systems can be harder to diagnose, since LMN injury masks the presence of concomitant UMN injury, and so exclusive LMN injuries can be overdiagnosed [32].

There's consensus that and intensive and consistent rhythmic stimulus promotes CNS neuroplasticity, enabling readapt to station and gait through alternative pathways. However, this stimulus can be ineffective in LMN injuries due to nerve section or cell death processes [4,5,32,35]. So, it would be expectable to exist dependence between affected motor system and deficits presented at the entrance or exit of the Center variables, putting UMN injuries in a favorable position compared to exclusive or mixed LMN injuries. This incongruity it's probably a result of being applied a general FNR protocol to all patients, for the first time, regardless the affected motor system. Besides, with this FNR protocol, CPG of patients with LMN injury were being specifically stimulated. Also, sample size limitation could have contribute to this result. Same applies to statistical analysis results between affected motor system and time elapsed until exit of the Center variables and so to time elapsed until exit of the Center and deficits presented at the entrance of the Center. It should be noted that confirmation of this particular information would allow us to predict time necessary to achieve FNR and would be useful as a prognostic factor.

Despite sample's limitations, 36.4% of the patients leaved the Center without deficits or with proprioceptive ataxia, representing a clinical success of 72.8%. This proved FNR primary role in patient's recovery, regardless of the affected motor system. The mean time necessary to achieve clinical success, in FNR protocol regimen, was two months. We could suggest making a study with a control group to assess FNR real effectiveness. However, it would be ethically questionable.

Sample limitations related to size and distribution can be overcome with continued study.

This would bring us useful information related to patient's approach and appropriate follow-up, allowing save time, quicker start of treatment and FNR protocol.

The present study had pioneering nature in concerning to assessment of neurologic evolution in patients with cervical neurologic lesion, when subjected to a FNR protocol. It showed that even in severe neurologic deficits and in complex neurologic injuries, related to neurolocalization and, consequently, recovery, FNR played a central role in the return to function, proving its value as a necessary tool in the approach to this patients, as so it could prevent making premature irreversible decisions.

Conclusion

Neurologic injuries are a common reality in dogs. Cervical region can be affected once it's subject to several forces, such as rotation. Since this anatomic region includes two different motor systems, UMN and LMN, it's important to distinguish them and correctly localize the lesion in order to perform an adequate differential diagnostic list, a correct approach to the problem and a suitable treatment. FNR has an important role in these patients recovery regardless the applied management, conservative or surgical.

It's known and consensual that applying a FNR protocol with intensive and repetitive rhythmic movements has beneficial influence in CNS properties, neuroplasticity and neuromodulation, allowing it to readapt in injury cases. This, shows that FNR shouldn't be neglected, regardless the affected motor system, since the goal is to enable the patient to be autonomous again and, in many cases, it could be an alternative to euthanasia.

In the present innovating study in the assessment of neurologic evolution of dogs with cervical neurologic lesion, after performing a FNR protocol, most cases achieved clinical success, since patients leaved the Center without deficits or with proprioceptive ataxia, regardless the affected motor system. The results allow concluding that FNR had a primary role in functional recovery of these dogs, with a two month mean of internment, avoiding permanent and prolonged recumbency and consequent adverse effects.

References

1. Dragone L (2015) Rehabilitation of the Neurologic Front Limb. Presented on 4th VEPRA Conference International Conference on Physical Therapy and Rehabilitation of Animals, Gdansk, Poland.
2. Sims C, Waldron R, Marcellin-Little DJ (2015) Rehabilitation and Physical Therapy for the Neurologic Veterinary Patient. Vet Clin North Am Small Anim Pract 45: 123-143.
3. Thomas WB, Olby N, Sharon L (2014) Neurologic Conditions and Physical Rehabilitation of the Neurologic Patient. In Millis DL, Levine D, Canine Rehabilitation and Physical Therapy (2nd edn). Elsevier Saunders, Philadelphia.
4. Harkema SJ, Schmidt-Read M, Lorenz DJ, Edgerton R, Behrman AL (2012) Balance and Ambulation Improvements in Individuals with Chronic Incomplete Spinal Cord Injury Using Locomotor Training-Based Rehabilitation. Arch Phys Med Rehabil 93: 1508-1516.
5. Martins A (2015) Functional Neurorehabilitation -The Locomotor Quadrupedal Animal Training Adapted to the Bipedal Human. International Archives of Medicine 8: 1-11.
6. Martins A (2015) The Importance of Quadruped Animal Model in Functional Neurorehabilitation for Human Biped. International Archives of Medicine 8: 1-10.
7. Thompson AK, Wolpaw JR (2014) Operant conditioning of spinal reflexes: from basic science to clinical therapy. Front Integr Neurosci 8: 25.
8. Thompson AK, Wolpaw JR (2015) Targeted neuroplasticity for rehabilitation. Prog Brain Res 218: 157-172.
9. De Lahunta A, Glass E, Kent M (2015) Veterinary Neuroanatomy and Clinical Neurology (4th edn), Elsevier Saunders.
10. García-Alías G, Truong K, Shah PK, Roy RR, Edgerton VR (2015) Plasticity of Subcortical Pathways Promote Recovery of Skilled Hand Function in Rats After Corticospinal and Rubrospinal Tract Injuries. Experimental Neurology 266: 112-118.
11. Uemura EE (2015) Motor System. In Reece WO, Erickson HH, Goff JP, Uemura EE (Eds), Dukes Physiology of Domestic Animals (13th edn), Ithaca: Wiley Blackwell, pp: 68- 77.
12. Duysens J, Van de Crommert HW (1998) Neural control of locomotion; The central pattern generator from cats to humans. Gait Posture 7: 131-141.
13. Lavrov I, Musienko PE, Selionov VA, Zdunowski S, Roy RR, et al. (2015) Activation of spinal locomotor circuits in the decerebrated cat by spinal epidural and/or intraspinal electrical stimulation. Brain Res 1600: 84-92.
14. Shah PK, García-Alías G, Choe J, Gad P, Gerasimenko Y, et al. (2013) Use of quadrupedal step training to re-engage spinal interneuronal networks and improve locomotor function after spinal cord injury. Brain 136: 3362-3377.
15. Musienko P, Courtine G, Tibbs JE, Kilimnik V, Savochin A, et al. (2012) Somatosensory control of balance during locomotion in decerebrated cat. J Neurophysiol 107: 2072-2082.
16. Solopova IA, Selionov VA, Sylos-Labini F, Gurfinkel VS, Lacquaniti F, et al. (2015) Tapping into Rhythm Generation Circuitry in Humans during Simulated Weightlessness Conditions. Frontiers in Systems Neuroscience 9: 1-7.
17. Monk M (2007) Hydrotherapy. Animal Physiotherapy - Assessement, treatment and rehabilitation of animal, Blackwell Publishing.
18. Levine D, Millis DL, Flocker J, MacGuire L (2014) Aquatic therapy. Canine Rehabilitation and Physical therapy (2nd edn), Elsevier Saunders: Philadelphia.
19. Duffell LD, Brown GL, Mirbagheri MM (2015) Interventions to Reduce Spasticity and Improve Function in People With Chronic Incomplete Spinal Cord Injury: Distinctions Revealed by Different Analytical Methods. Neurorehabil Neural Repair 9: 566-576.
20. Cross CA (2014) Nose to tail application of red and therapeutic laser for the athletic (and non athletic) dog. Vet Folio.
21. Kirkby K (2014) Lasertherapy: 8th International Symposium on Veterinary Rehabilitation / Physical Therapy and Sports Medicine - American College of Veterinary Sports Medicine and Rehabilitation.
22. Dewey CW, Da Costa RC (2015) Practical Guide to Canine and Feline Neurology. (3rd edn), Wiley Blackwell.
23. Lorenz MD, Coates JR, Kent M (2011) Handbook of Veterinary Neurology. (5th edn) Elsevier Saunders: St Louis.
24. Olby NJ (2013) BSAVA Manual of Canine and Feline Neurology. (4th edn), British Small Animal Veterinary Association.
25. Tipold A, Bernardini M, Kornberg M (2010) Small Animal Neurology: An Illustrated Text. Schlütersche, Germany.
26. Fitzpatrick N, Fingeroth JM (2015) Advances in Intervertebral Disc Disease in Dogs and Cats. (1st edn), American College of Veterinary Surgeons Foundation (ACVS Foundation) & Wiley Blackwell.
27. Rytz U (2011) Small Animal Neurology: An Illustrated Text. Schlütersche: Germany.
28. Cerda-Gonzalez S, Dewey CW (2010) Congenital diseases of the craniocervical junction in the dog. Vet Clin North Am Small Anim Pract 40: 121-141.
29. Brisson BA (2010) Intervertebral disc disease in dogs. Vet Clin North Am Small Anim Pract 40: 829-858.
30. De Risio L, Thomas WB, Fingeroth JM (2015) Advances in Intervertebral Disc Disease in Dogs and Cats. ACVS Foundation, Wiley Blackwell: Iowa.
31. Olby NJ (2012) Spinal Trauma. In Platt SR & Garosi LS, Small Animal Neurological Emergencies, London pp: 383-397.
32. Granger N, Carwardine D (2014) Acute spinal cord injury: tetraplegia and paraplegia in small animals. Vet Clin North Am Small Anim Pract 44: 1131-1156.
33. Schmökel H (2012) Small Animal Neurology: An Illustrated Text. Schlütersche: Germany.
34. Coates JR (2012) Small Animal Neurological Emergencies (1st edn), Manson Publishing Ltd: London.
35. Gemmill T, McKee M (2012) Small Animal Neurological Emergencies (1st edn), Manson Publishing Ltd: London.