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A retrospective study of canine cervical disk herniation and the beneficial effects of rehabilitation therapy after ventral slot decompression

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Abstract: The objective of this study was to evaluate the clinical outcome of ventral slot decompression and rehabilitation therapy in dogs with cervical intervertebral disc herniation (IVDH). Surgical decompression was performed in dogs with IVDH using the ventral slot procedure. After surgery, physiotherapeutic rehabilitation consisted of a combination of electrotherapy, infrared therapy and mechanical massage; treadmill exercise was started when the animal could stand up. A total of 58 dogs were selected from the hospital and included in two groups: rehabilitated group (RG, n = 34) and non-rehabilitated group (NRG, n = 24). Dogs of each group were subdivided into five groups based on a pre-operative clinical grading system. Grade 1 designated spinal pain only, grade 2 designated ambulatory paraparesis, grade 3 designated non-ambulatory paraparesis, grade 4 designated paraplegia with deep-pain perception intact and grade 5 designated paraplegia without deep-pain perception. Post-operative changes of both groups were evaluated and compared, including time until unassisted standing and walking after surgery and the success rate. Overall, 79.41% (27/34) of dogs had a successful neurologic outcome in the RG group, which was significantly (P < 0.05) higher than the NRG group 62.50% (15/24). Interestingly, the success rate differed when the preoperative grading system was considered. The success rates of grades 1, 2, 3, 4 and 5 were 100% (9/9), 100% (7/7), 75% (3/4), 53.85% (7/13) and 100% (1/1), respectively, in the rehabilitated groups, whereas in the non-rehabilitated groups success rates were 100% (5/5), 83.33% (5/6), 60.00% (3/5), 28.57% (2/7) and 0% (0/1), respectively. The differences in success rates between the two groups according to grading were 0, 16.67, 15, 25.57 and 100%, respectively. The proposed rehabilitation therapy after surgical decompression of cervical IVDH can improve the success rate when the preoperative pathological condition is severe.

Keywords: neurologic outcome; neurologic grading; exercise; electrotherapy, infrared therapy

Intervertebral disk herniation (IVDH) is considered a very common cause of neck pain, back pain and neurologic dysfunction in dogs (Cherrone et al. 2004; Rossmeisl et al. 2013; Jeong et al. 2018). Cervical IVDH in dogs accounts for approximately 14–25% of intervertebral disk hernia-

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tion cases (Cherrone et al. 2004; Rossmeisl et al. 2013). Cervical IVDH can occur in all breeds, but small chondrodystrophic dog breeds are more susceptible than non-chondrodystrophic dog breeds (Cherrone et al. 2004; Rossetti et al. 2016). Moreover, the Dachshund breed is generally affected more than other chondrodystrophic dog breeds, as reported by several studies (Rossmeisl et al. 2005; Hillman et al. 2009; Bottcher et al. 2013; Rossmeisl et al. 2013). However, occurrence may differ by region, and we here sought to determine the most susceptible breed in Korea.

There are several methods for surgical treatment of cervical IVDH, including ventral slot decompression (VSD), VSD with fixation, modified slanted slot, cervical hemilaminectomy and dorsal laminectomy. Methods can be applied according to the cause, pathologic condition, position and surgeon preference. Several studies have reported that surgeries alleviate pain intensity and correct neurologic deficits. Overall functional success is achieved in 70–90% of cases (Shamir et al. 2008; Hillman et al. 2009; Rossmeisl et al. 2013), and the recurrence rate is 20–28% in dogs (Shamir et al. 2008). Furthermore, fewer than 60% of paraplegic dogs without pain perception have positive clinical outcomes, and many of these dogs suffer from lack of strength and quadrupedal coordination (Zidan et al. 2018). These circumstances indicate the need for a structured physiotherapy program designed to overcome these difficulties. In veterinary practice, there have been few reports about the effect of physiotherapy rehabilitation for patients with disc disease with contrasting findings (Bennaim et al. 2017; Hodgson et al. 2017; Zidan et al. 2018), such as no difference in recovery-related variables among dogs that received physiotherapy (Bennaim et al. 2017), improved neurologic function and reduced postoperative complications (Hodgson et al. 2017), and safety without improvement of rate or impact on recovery level (Zidan et al. 2018). These contrasting outcomes might be due to variation in physiotherapeutic content and techniques. There is a scarcity of well-defined, structured physiotherapy programs. The main objective of this retrospective study was to investigate the benefits of well-structured rehabilitation physiotherapy after surgery for cervical disc disease with respect to neurologic function for a five-year (2012–2017) period to increase understanding of cervical IVDH in our hospital.

MATERIAL AND METHODS

Case selection. The database of the neurology unit at the Royal Animal Medical Center was searched, and the clinical history of dogs with a diagnosis of cervical IVDH between 2012 and 2017 was recorded. Extracted information included breed, age, sex, body weight, clinical history, neurologic status, radiographs, CT scan, MRI findings, anatomic localisation of IVDH, surgical procedures and outcomes. Broadly, a total of 58 dogs were selected from the clinical history of the hospital and divided into two groups: rehabilitated group (RG, n = 34) and non-rehabilitated group (NRG, n = 24). Indeed, post-surgery recovery depends on the pathologic condition of the pre-surgery patient. So, it is not wise to put patients with different pathologic conditions in the same group. For this reason, dogs of each group were carefully subdivided into five groups using the historical records of the hospital. This subdivision was based on severity of neurologic dysfunction using a grading system described elsewhere (Rossmeisl et al. 2005; Rossmeisl et al. 2013). Briefly, the neurologic grading system was as follows, 0 – normal dog, 1 – only cervical spinal pain is present, 2 – ambulatory paraparesis with mild motor deficits, 3 – ambulatory paraparesis with moderate motor deficits, 4 – non-ambulatory tetraparesis or tetraplegia without respiratory compromise and 5 – tetraplegia without deep pain perception and with neurogenic hypoventilation. Rehabilitation therapy was only used when the owner agreed to pay, and these dogs served as the RG group. Dogs that had follow-up until death or for six months were included.

Diagnosis. Primary diagnosis was based on physical examination of clinical signs and symptoms. Clinical history and confirmatory diagnosis were assessed by complete diagnostic imaging reports including survey radiographs and CT scan or MRI. The diagnostic procedures are shown in Figure 1. Radiography was performed using a Titan 2000, (COMED Medical Systems CO. Ltd., Seoul, Republic of Korea) and was interpreted by an experienced (ten years) radiologist. Computed tomography (CT) imaging using an ECLOS 16-row detector CT scanner (Hitachi, Tokyo, Japan) and MRI were performed (GE healthcare, New York, USA) to exclude other pathologic abnormalities.

Surgery and evaluation of neurologic outcome. In preparation for surgery, dogs were admi-

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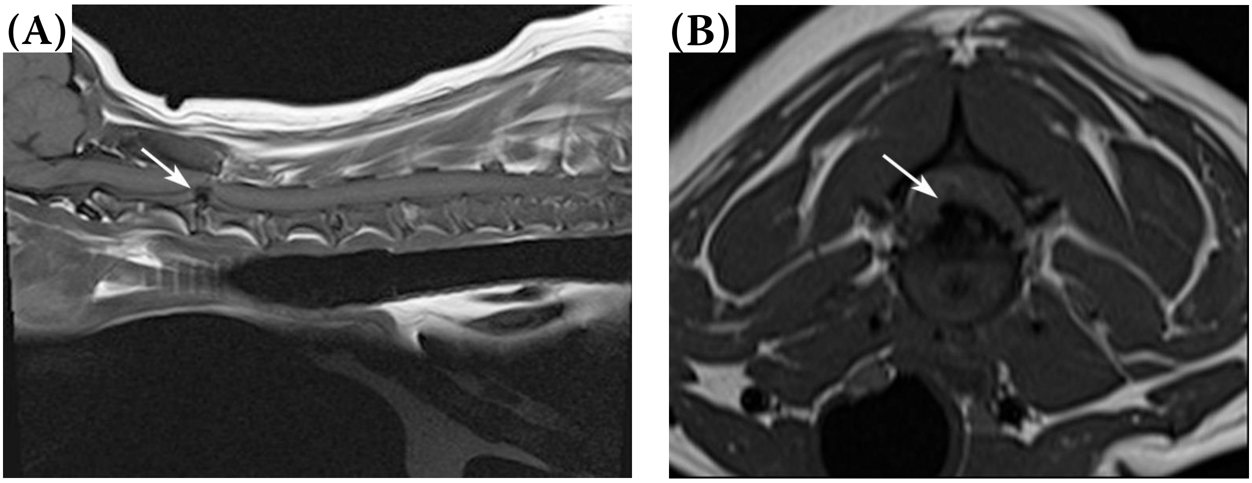

Figure 1. Preoperative MRI images of a dog with C2–C3 disc herniation causing left hemiparesis. (**A**) Left parasagittal and (**B**) transverse T2 W1 MRI images of a dog showing C2–C3 disc herniation (arrows)

nistered intravenous (*i.v.*) 0.9% normal saline (10 ml/kg/h), cephradine (30 mg/kg *i.v.*), bid), tramadol (2 mg/kg *i.v.*), tid) and steroid dexamethasone 1 mg/kg *i.m.* or methyl prednisolone sodium succinate (15–30 mg/kg *i.m.*). Prior to surgery, general anaesthesia was performed using slow *i.v.* propofol 6–8 mg/kg (Provive®1%, Myungmoon Pharm. Co., Ltd., Seoul, Republic of Korea) infusion and volatile anaesthetic sevoflurane inhalant (1–5%; Abbott Korea Ltd., Seoul, Republic of Korea). Inhaled oxygen and positive pressure were maintained, and an automated anaesthetic machine (PAIEON, J & TEC, Goyang-Si, Gyeonggi-do, Republic of Korea) monitored ECG and CO_2 partial pressure during surgery, as described previously (Seo et al. 2017; Choi et al. 2018a; Choi et al. 2018b). After shaving the entire back region, aseptic preparation, clipping, and draping were performed. The animal was positioned in ventral recumbency. A ventral slot approach was used following dissection of the subcutaneous tissue. The desired part of the vertebral joint was exposed, and the herniated part of the disk was corrected by modified ventral slot, as described elsewhere (Shamir et al. 2008; Rossmeisl et al. 2013).

Dogs were discharged from the hospital 7–14 days after surgery depending on the dog's condition. However, dogs in the rehabilitation groups were admitted to a physical therapy and rehabilitation department upon owner request. Animals were kept in the intensive care unit (ICU) for four days for regular observation, vital sign monitoring, adequate analgesia and fluid therapy. Atropine, enrofloxacine (10 mg/kg, *i.m.*, bid), cephradine (30 mg/kg, *i.v.* bid or tid), tramadol (2–3 mg/kg *i.v.* bid or tid) and cimetidine (10 mg/kg, *i.v.*, bid) were administered. In addition, steroid dexamethasone (1 mg/kg, *i.m.*) or methyl prednisolone sodium succinate (15–30 mg/kg, *i.m.*) was administered for two to three days after surgery, as required. A questionnaire was designed to glean information relating to the dog's behaviour after discharge, recovery of specific neurologic functions, recurrence of clinical signs and date and cause of death. Dogs were recorded standing and walking on a flat non-slip surface. The neurologic functions assessed were, regaining normal gait, ability to walk unassisted, urination and pain resolution. Moreover, the final clinical outcome at hospital discharge was assessed as described previously (Rossmeisl et al. 2013). Outcomes were defined as excellent when dogs were neurologically normal or fully ambulatory with subclinical neurologic deficits that had resolved by discharge; good when postoperative neurologic grade was sufficiently improved from preoperative condition to require no or minor therapy after discharge; fair when postoperative neurologic status was unchanged from preoperative condition; poor when major postoperative complications developed as a consequence of worsened neurologic grade at discharge compared to preoperative state or when other clinical disabilities developed that were not present at admission or with death. The success rate was calculated with the following equation: (Excellent + Good)/Total animals × 100.

Physical therapy and rehabilitation for dogs with IVDH. Three types of physical examination

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were performed prior to physical therapy: (a) assessing muscle power and tonicity with the MyotonPRO technique; (b) assessing superficial and deep pain by needle or finger; (c) assessing each dog's ability to stand by itself. Intensity and duration of physical therapy were determined based on the animal's condition to boost neuromuscular function.

1. Electrotherapy: The purpose of electrotherapy is restoration of muscular function. According to each animal's health status, initial electricity was fixed (10–20 mA) and gradually increased up to certain limits (30–45 mA) until there was visually sufficient shrinkage. Electrotherapy was performed twice a day for 30 min or once a day for 120 min using the PORTABLE TENS LT1061 (Shenzhen Dongdixin Technology Co., Ltd, Shen Zhen, China). After shaving, therapeutic patches were attached with sonogel (to increase absorption capacity) to the biceps brachialis and triceps brachialis.
2. Infrared treatment: infrared irradiation at 800 nm to 1200 nm is not harmful to tissues, and is even considered to protect against the effects of ultraviolet light because of anantioxidant effect (Gale et al. 2006). Infrared rays were applied (10–15 min twice a day) to the paralysed area to increase blood flow. The irradiated area was touched periodically to avoid burning.
3. Standing training: Dogs were passively trained to stand up. It was initially difficult for dogs to stand by themselves, and a passive standing posture was created using tools such as a sling and ball. The time spent standing alone was slowly increased in proportion to a patient's gradual recovery until 15–20 min were achieved.
4. Balance board training: When dogs were capable, self-standing or upright posture on a balance board was used to maintain height and posture reflexes to enhance nervous system recovery. This was trained for 15–20 min twice a day.
5. Deep tendon reflex (spinal reflex) stimulation: Aα nerve fibres are affected in lower motor neuron disease, which consequently reduces deep tendon reflexes and muscle tone. In contrast, Aγ nerve fibres are affected in upper motor neuron disease, which consequently increases deep tendon reflexes and muscle tone. Therefore, deep tendon reflex (spinal reflex) stimulation can stimulate Aα nerve fibres and Aγ nerve fibres by sustaining stimulation of the deep tendon reflexes, helping to restore nerves and muscles to improve disability. Deep tendon reflex stimulation was performed for 12–20 min each day.
6. Underwater treadmill: Aquatic exercise was performed when a patient was capable of standing and walking to some extent. The exercise was initially started with lower speed and gradually increased. Initially, water was filled up to the height of the hip joint and was then gradually reduced depending on performance.

Statistical analysis. Data were analysed using a Bonferroni post hoc test following one-way ANOVA of non-rehabilitated (NRG) versus rehabilitated (RG) groups using Prism 5.03 (Graph Pad Software Inc., San Diego, CA, USA). The results were expressed as mean ± S.E.M. or proportion and were considered statistically significant when $P < 0.05$. Percentages of data were analysed using a two-sample proportion test with Minitab software (version 16.1) to assess any significant difference between the two groups.

RESULTS

This study included 32.76% (19/58) Shih Tzu, 17.24% (10/58) mixed breed, 8.62% (5/58) Pomeranian, 8.62% (5/58) Pekingese, 8.62% (5/58) Yorkshire Terrier, 8.62% (5/58) Cocker Spaniel, 3.44% (2/58) Dachshund, 3.44% (2/58) Maltese, 3.44% (2/58) Beagle, 3.44% (2/58) Chihuahua, 3.44% (2/58) Silky Terrier, and 15.52% (9/58) other dog breeds. Age ranged from 1 to 14 years, and the average age was 8.10 ± 0.54 years. With respect to age, 17.24% (10/58) of dogs ≤ 4 years old, 46.55% (27/58) of dogs between 5–9 years, and 36.21% (21/58) of dogs were ≥ 10 years old. Moreover, 62.07% (36/58) of dogs were male (28/36 dogs were castrated males), and 37.93% (22/58) of dogs were female (16/22 were spayed). Dogs had a median body weight of 6.67 ± 0.75 kg (range, 2.5 to 16.5 kg). During the initial evaluation, 26.47% (15/58) of dogs had a history of at least one episode of clinical signs compatible with cervical IVDH that had been treated conservatively. The remaining 73.53% (43/58) of dogs had no known past history suggesting cervical IVDH. The median

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Table 1. Rehabilitated group: Post-operative clinical outcome of dogs with cervical intervertebral disk herniation based on pre-operative grading score

Preoperative grade	Surgical result	Case	Mean standing after surgery (days)	Mean walking after surgery (days)	Recovery percentage
1 (*n* = 9)	excellent	8	5	7	100%
	good	1	5	6	
2 (*n* = 7)	excellent	6	4	7	100%
	good	1	8	9	
3 (*n* = 4)	excellent	3	7	8	75%
	fair	1	unique postural response x		
4 (*n* = 13)	excellent	3	5	7	53.85%
	good	4	6	13	
	fair	2	7 days (body only), 14 days (body only), no walking		
	poor	4	died prior to standing or walking		
5 (*n* = 1)	excellent	1	7	14	100%

duration of neurologic deficit prior to referral was 4 ± 1 days (range, 3.2 hours to 34 days).

Preoperative neurologic grading systems

The preoperative neurologic status in 34/58 dogs of the RG was as follows: 9/34 (26.47%) grade 1, 7/34 (20.59%) grade 2, 4/34 (11.76%) grade 3, 3/34 (38.24%) grade 4 and 1/34 (2.94%) grade 5 with bilateral deep nociception loss in the pelvic limbs and positive deep nociception in the tail (Table 1). In the NRG group (24/58 dogs), 5/24 (20.83%) dogs were grade 1, 6/24 (25%) dogs were grade 2, 5/24 (20.83%) dogs were grade 3, 7/24 (29.17%) dogs were grade 4 and 1/24 (4.17%) dogs were grade 5 (Table 2).

Location of cervical IVDH

Of 58 dogs, the most frequent site of confirmed disk herniation was C3-C4 in 23/58 dogs (39.66%)

Table 2. Non-rehabilitated group: Post-operative clinical outcomes of dogs with cervical intervertebral disk herniation based on pre-operative grading score

Preoperative grade	Surgical result	Case	Mean standing after surgery (days)	Mean walking after surgery (days)	Recovery percentage
1 (*n* = 5)	excellent	3	5	8	100%
	good	2	6	8	
2 (*n* = 6)	excellent	3	5	7	83.33%
	good	2	8	10	
	fair	1	7 days (body only), no walking		
3 (*n* = 5)	good	3	8	10	60.00%
	fair	1	not improved		
	poor	1	died prior to standing or walking		
4 (*n* = 7)	good	2	8	14	28.57%
	fair	3	5 days (body only), 7 days (body only), 10 days (body only), no walking		
	poor	2	died prior to standing or walking		
5 (*n* = 1)	poor	1	died prior to standing or walking		0%

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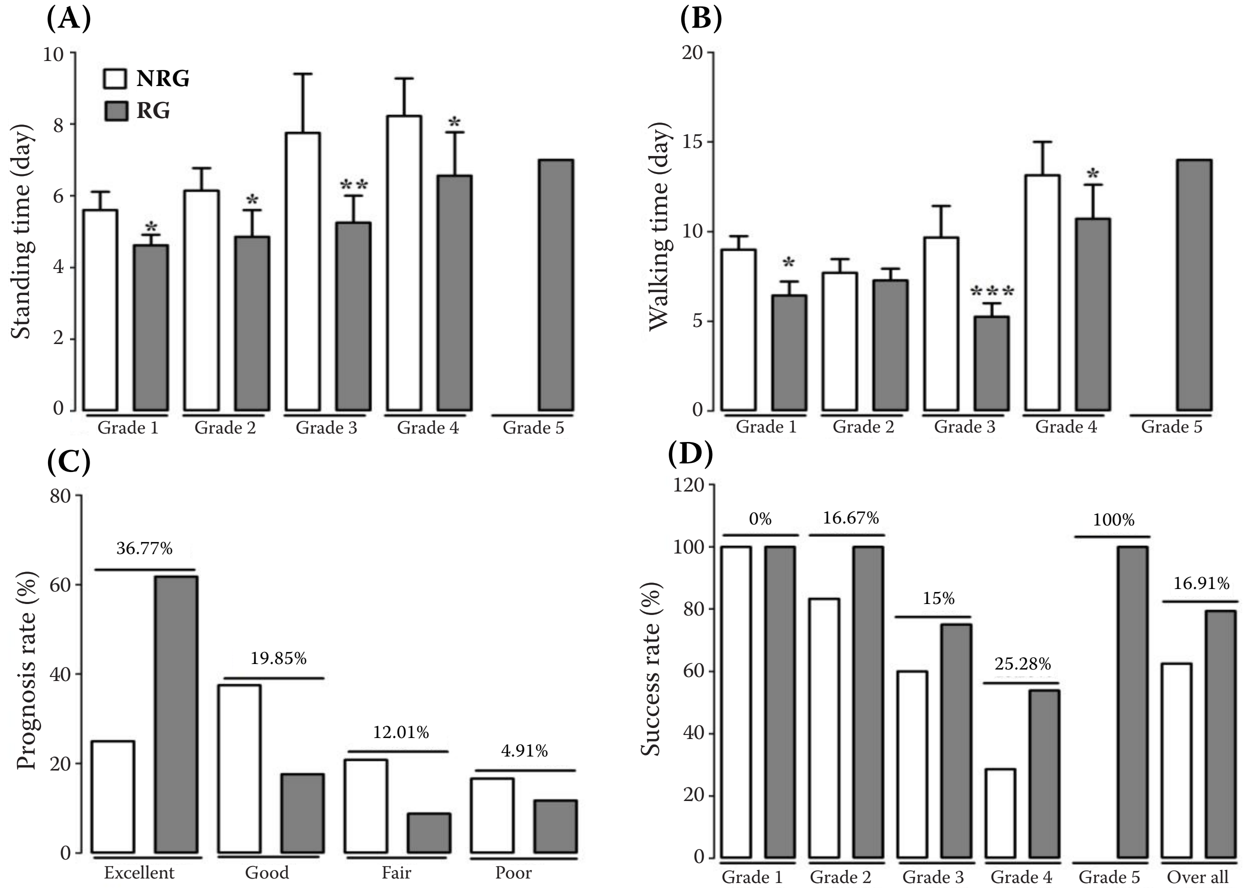

Figure 2. Comparison of standing time, walking time, prognosis and success rate between rehabilitation and no rehabilitation groups. The bars above columns in Figures (**C**) and (**D**) indicate differences between the two groups

Data were analysed using the Bonferroni post hoc test following one-way ANOVA of non-rehabilitated (NRG) versus rehabilitated (RG) groups (*: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$)
NRG = non-rehabilitated group; RG = rehabilitated group

followed by C2-C3 in 16/58 dogs (27.58%) and C5-C6 in 9/58 dogs (15.52%) C4-C5 was herniated in 8/58 dogs (13.79%) and C6-C7 was herniated in 2/58 dogs (3.45%). No C1-C2 cervical disk herniation was seen in the admitted dogs in our hospital.

Clinical outcome

Overall, 27 of 34 (79.41%) dogs were considered to have successful neurologic outcomes in the RG group while 21/34 (61.77%) dogs had excellent outcome, 6/34 (17.65%) dogs had good outcome, 3/34 (8.82%) dogs had fair outcome and 4/34 dogs (11.76%) had poor outcome (Table 1 and Figure 2). In the NR group, 15/24 dogs (62.5%) dogs had successful clinical outcomes, which was significantly lower ($P < 0.05$) than the RG group. In the NR group, 6/24 (25%) dogs had excellent outcome, 9/24 (37.50%) dogs had good outcome, 5/24 (20.83%) dogs had fair outcome and 4/24 dogs (16.67%) had poor outcome (Table 2 and Figure 2).

Interestingly, the success rate varied according to preclinical grading systems in both groups. The success rate of grade 1 in both NRG and RG groups was the same (100%), but standing and walking time of the RG was significantly shorter than that of the NRG ($P < 0.05$) (Figure 2). Along with significantly shorter standing and walking time, success rates increased from grade 2 to 4 in the RG group compared to the NRG group. Only one dog in each group with grade 5 cervical IVDH was admitted to our hospital within this period. In the RG group, the dog recovered successfully and started standing and walking at 7 and

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14 days, respectively, while the dog in the NRG group died (Figure 2).

DISCUSSION AND CONCLUSIONS

In this study, 79.41% (27/34) of dogs were considered to have successful neurologic outcomes in the RG group based on normal walking, which was better than the 62.50% (15/24) in the NRG. Interestingly, the success rate differed when the preoperative grading system was considered. The success rates of grades 1, 2, 3, 4 and 5 were 100%, 100%, 75%, 53.85% and 100%, respectively, in the RG, whereas the success rates of the NRG were 100%, 83.33%, 60.00%, 28.57% and 0%, respectively. Higher preoperative neurologic grade corresponded with lower recovery rate of dogs with cervical IVDH. Similar results were observed in the RG group in this study even after rehabilitation therapy. Differences in success rates between the two groups by grade were 0%, 16.67%, 15%, 25.57% and 100%, respectively. Better success rates were clearly observed in the RG group, especially when preoperative neurologic grade was higher (grades 2, 3, 4, and 5). This might be due to structured physiotherapeutic regimentation. Therefore, rehabilitation therapy should be applied when the preclinical neurologic condition is severe. While there was no difference in success between the two groups for dogs characterised as grade 1, the beneficial effects of rehabilitation therapy were reflected in the RG group by earlier unassisted standing and walking compared to the NRG group. One limitation is that only one dog was grade 5, and results should be carefully interpreted.

IVDH can press the spinal cord and may disrupt communications between the brain and body, leading to loss of control over otherwise intact neuromuscular systems. By targeting this neuromuscular mechanism, rehabilitation therapy was structured using electrical stimulation, infrared therapy and exercise. Electrical stimulation is a promising technique for modulating the level of excitability and reactivation of dormant spinal neuronal circuits and sensorimotor function after spinal cord injury (Alam et al. 2015). Electrical stimulation has been shown to improve neuromuscular function and to restore gait and bladder control in patients with injured spinal cords (Ho et al. 2014). Electrical stimulation can also reduce pain (Richardson et al. 2002; Ho et al. 2014). Infrared therapy enhances microcirculation, the inflammatory process, the immune system, neurohormonal regulation, reparative systems and spasmolytic action. It stimulates Ca^{2+}-dependent processes, increases DNA and RNA synthesis and increases ATP synthesis and accumulation (Moskvin 2017). Gale et al. (2006) reported that infrared therapy improves wound healing, relieves arthritic knee pain and chronic back pain and increases endorphin levels. Furthermore, infrared therapy has been shown to delay paralysis in patients with spinal metastasis (Funayama et al. 2012). Infrared therapy may have contributed to improved clinical neuromuscular function in this study. When animals could stand up, treadmill exercise was initiated. Treadmill exercise improves recovery of locomotor function through axonal regeneration and enhances BDNF (brain-derived neurotrophic factor) expression in rats injured with spinal cords, contributing to neuronal integrity (Jung et al. 2016). Therefore, surgery combined with active, structured rehabilitation therapy is beneficial.

The objectives of the surgical procedures are to relieve pain and neurologic dysfunction by surgical decompression of the spinal cord or nerve. Among surgical techniques, VSD remains popular. VSD is considered an effective modern surgical technique by many surgeons and neurologists for treatment of cervical IVDH due to its ability to facilitate direct access to extruded disc material, quick relief of clinical signs of pain and good functional recoveries in dogs (Rossmeisl et al. 2013). VSD also provides 98% neutral zone range of motion during flexion-extension at the treated vertebral motion unit (Koehler et al. 2005). Postoperative complications and adverse effects also depend on the experience of the primary surgeon (Rossmeisl et al. 2005; Rahman et al. 2017; Choi et al. 2018b). The lowest incidence of major complications (2.6%) was found with the most experienced surgeons, compared with 2 to > 3 times higher (5.3–8.2%) incidences of complications with less experienced surgeons (Rossmeisl et al. 2013). This factor was not considered in this study as all surgeries were performed by the same surgeon who was assisted by the other authors. Moreover, surgical management of cervical IVDH may result in clinical improvement.

This study included 32.76% Shih Tzu, 17.24% mixed breed, 8.62% Pomeranian and 8.62% Pekingese dogs. In contrast to our study, in previous reports

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the Dachshund was the most commonly affected breed for both cervical and thoracolumbar IVDH (Dhupa et al. 1999; Lemarie et al. 2000; Levine et al. 2006; Rossmeisl et al. 2013; Smolders et al. 2013). This might differ from region to region based on the popularity of breeds. Lim et al. (2010) of Seoul, Republic of Korea, also found that Dachshunds were not the most commonly affected. According to their study, the predominant breed was Pekingese (42.5%) followed by Maltese (20.0%), Cocker Spaniels (12.5%), Shih Tzu (7.5%) and Dachshund (5.0%). In this study, C3-C4 (39.66%) disc spaces were the most commonly involved, followed by C2-C3 (27.58%), C5-C6 (15.52%), C4-C5, (13.79%) and C6-C7 (3.45%). This finding is consistent with those of some previous reports (Schmied et al. 2011; Rossmeisl et al. 2013) but inconsistent with Lemarie et al. (2000), who reported that the C4-C5 intervertebral disc space was the most commonly affected location.

A preoperative grading system was assessed in this experiment to evaluate whether it can be used as a prognostic indicator for dogs with cervical IVDH. Interestingly, early recovery as indicated by time of standing and walking was lower with low-grade IVDH and longer with more severe grades of neurologic dysfunction before surgery in both groups. Success rate was inversely related to grading system in the RG group. Statistical comparisons among neurologic grades demonstrated that preoperative grade can be used as a prognostic indicator for neurologic outcome, and rehabilitation should be used in all patients after spinal surgery to increase success rates, especially when the preoperative pathologic condition is severe.

The above results suggest that physiotherapeutic rehabilitation following ventral slot decompression surgery may increase recovery rate and that recovery rate also depends on the preclinical pathologic condition. This study showed that the most commonly affected breed is Shih Tzu (32.76%) and the most commonly affected site is C3-C4 (39.66%).

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