Case Report

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The Use of Physical Rehabilitation to Improve Outcome Following Traumatic Brain Injury in a Dog — A Case Report

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Abbreviations

ICU	**Intensive care unit**
MGCS	**Modified Glasgow Coma Scale**
OU	**Both eyes**
PROM	**Passive range of motion**
TBI	**Traumatic brain injury**
UWTM	**Underwater treadmill**

Abstract

Traumatic brain injury (TBI) in the canine patient is a common sequela to head trauma accidents such as vehicular trauma or high-rise falls. A 3-year-old, intact female mixed breed dog presented to Purdue University College of Veterinary Medicine following a suspected hawk attack. At presentation, this non-ambulatory, tetraparetic, mentally inappropriate, and stuporous patient was diagnosed with suspected TBI secondary to trauma. Physical rehabilitation was initiated and continued during the hospitalization period and afterwards on an outpatient basis. Rehabilitation focused on a combination of mental stimulation, proprioceptive and balance work, and sensory stimulation. Therapies and exercises used consisted of massage, stretching, passive range of motion (PROM), assisted standing, weight shifting, underwater treadmill (UWTM), and the use of textured surfaces, music, and positive encouragement. The patient's coordination, balance, and mentation greatly improved. At a follow-up visit 4 months post-injury, she could ambulate with no assistance and had minimal neurological deficits. Physical rehabilitation after TBI in humans is considered to be standard of care. In this veterinary patient, rehabilitation contributed to healing, return of function, and good quality of life.

Introduction

Traumatic brain injury (TBI) commonly occurs in small animals from blunt force head trauma such as vehicular accidents, missile injuries, bites, or falls (1). The term TBI is defined by evidence of neurological dysfunction following impairment to the structural or physiological function of the brain with resultant altered levels of mentation, gait abnormalities, and/or cranial nerve deficits (1, 2). Initial evaluations, patient prognoses, and serial monitoring are evaluated using the Modified Glasgow Coma Scale (MGCS) as an objective measurement tool, with scores from 3 to 8 indicating a grave prognosis, 9 to 14 a guarded prognosis, and 15 to 18 a good prognosis (3). Clinical treatment is supportive and involves maintaining the appropriate systemic blood pressure and intracranial pressure, providing adequate fluid therapy, maintaining appropriate oxygenation and ventilation, controlling hypothermia, and providing supportive care in the form of any needed anticonvulsant therapy and pain management (4). Given that head trauma patients are generally unstable on presentation, CT imaging is the modality of choice to provide rapid results and the level of resolution necessary to identify hemorrhage, edema, and fractures (5). Physical rehabilitation following TBI in humans is considered standard of care and allows patients to regain independent ambulation and life skills post-injury (6). Physical rehabilitation following TBI in veterinary patients as a mainstay of treatment is not documented; most therapies executed in practice are based on experimental investigations, personal experience, or are extrapolated from human literature. To the authors' knowledge, the use of physical rehabilitation as an adjunctive treatment following TBI in a canine patient has not been described. The goals of rehabilitation in this case were to utilize a combination of out-of-water and in-water therapies to restore diminished muscle function or movement, improve proprioception, and encourage cardiovascular fitness. Environmental enrichment was used to encourage the dog's mental

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well-being and independence. The aim of this case report is to describe the use of physical rehabilitation as an adjunctive treatment for TBI to assist in the return to normal daily independent function.

Case Report

A 3-year-old, 1.76 kg intact female mixed breed dog presented with TBI following a suspected hawk attack. On presentation, the patient was non-ambulatory, tetraparetic, stuporous, and mentally inappropriate. She displayed a left head turn, lateral strabismus OS, ventrolateral strabismus OD, and absent menace reflex with non-responsive, miotic pupils in both eyes (OU). She had severely diminished-to-absent oculocephalic reflexes OU, a decreased gag reflex, and decreased nasal sensation bilaterally. Conscious proprioception was absent in all limbs, albeit with normal reflexes. Cutaneous trunci responses were absent bilaterally, superficial pain was intact, and the patient tolerated gentle spinal palpation. Neurolocalization identified multifocal CNS lesions characterized as diffuse brain involvement and possible C8 to T1 spinal cord signs due to the absence of cutaneous trunci reflexes bilaterally. The MGCS measured 9 at the time of presentation, indicating a guarded prognosis (3). Additional physical examination findings included a laceration dorsal to the left orbit. Results of a whole blood critical care analysis (a) panel indicated the presence of metabolic acidosis with a pH of 7.291 (reference range 7.35 to 7.45) and hyperlactatemia of 2.8 mmol/L (reference range 0.5 to 2.0 mmol/L), both most likely secondary to shock and decreased perfusion. Initial stabilization included oxygen cage use to provide a level of 40% (compared to normal air which is 21% oxygen), intravenous fluids based on rehydration needs, and opioid pain medication consisting of fentanyl (3 mcg/kg/hr). Following stabilization with these initial therapies, the patient showed no clinical improvement in neurological status. She was presumed to have increased intracranial pressure and corresponding Cushing's reflex (defined as hypertension in the face of bradycardia) after a drop in heart rate and rise in blood pressure was suddenly noted on an hourly assessment of vital signs. The dog was administered mannitol (0.5 g/kg, IV) and hypertonic saline (4 ml/kg, IV) to decrease intracranial pressure. Following this diuretic therapy, a whole body, non-contrast CT scan was performed to evaluate for evidence of traumatic injuries. Sedation for imaging included a fentanyl bolus (3 mcg/kg), then a fentanyl drip (3 mcg/kg/hr). The CT results revealed a single left frontal and parietal bone fracture with concurrent mild displacement of the fractured fragment. Focal hypoattenuation of the brain parenchyma adjacent to the fracture margins was observed, with associated mass effect (mild ventral displacement of the left lateral ventricle) **(Figures 1A, 1B)**.

Figure 1A

Whole body, non-contrast, CT at 1.25mm slice thickness in a detail algorithm with patient in sternal recumbency. Standard orientation with left side of screen denoting right side of patient. Image represents a transverse plane through the level of the rostral fracture fragment. White arrows denote the margins of the sharply marginated fracture present at the left side of the frontal bone dorsally that extends caudomedially to the parietal bone and terminates on the midline just rostral to the level of the temporomandibular joints. There is mild overriding of the fragment as seen on this image.

Figure 1B

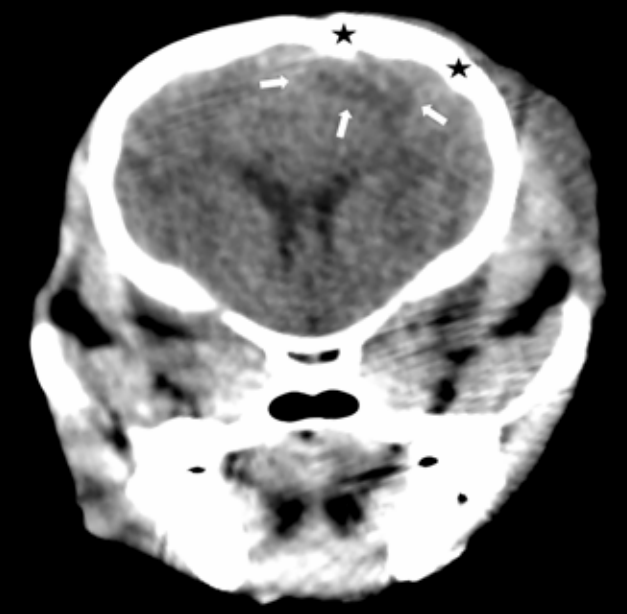

Image represents a transverse plane through the level of the mid-fracture fragment. White arrows outline a subtle, hypoattenuated region in the brain adjacent to the fracture margin. The left lateral ventricle is very mildly displaced ventrally. These changes may be consistent with focal hemorrhage, edema, or contusions. Alternatively, some of the subtle change in attenuation can be attributed to beam hardening from the adjacent displaced bone. Fracture fragments on this slice are denoted by the black stars.

Additional findings included fluid accumulation in the left nasal cavity, a proximal fracture of the right fifth rib, and possible focal pulmonary contusions or hematoma of the right cranial lung. No abnormalities were identified in the cervical vertebral column. All images were retrieved in DICOM® (digital imaging and communications in medicine) format and reviewed by the veterinary radiology resident (Dr. Buckley) and American College of Veterinary Radiology board-certified radiologist (Dr. Murakami) using open-source image analysis software (b, c). Following imaging, the patient was hospitalized and treated with Plasmalyte IV fluids (d) (60 ml/kg/day, IV) with added potassium chloride (0.05 mEq/kg/hr), fentanyl (3 ug/kg/hr, IV), meloxicam (0.1 mg/kg/day, IV), and metoclopramide (1 mg/kg/day, IV).

On day 2 of hospitalization, a generalized seizure was observed; midazolam (0.3 mg/kg, IV) was immediately administered with successful seizure cessation. Levetiracetam was given at a loading dose (60 mg/kg, IV) followed by 30 mg/kg PO every 8 hours thereafter. Supportive care included recumbency rotations, passive range of motion (PROM) exercises, exercises to all limbs, and eye lubrication every 4 hours. A nasogastric tube was placed for supplemental enteral feedings on the second day of hospitalization. On the third day of hospitalization, the patient demonstrated improvement in mentation, and her MGCS improved to 14, a score consistent with a guarded prognosis (3). Her mentation had improved from stuporous to dull, and a cranial nerve examination demonstrated improvement. The pupillary light and oculocephalic reflexes were both intact OU, menace responses were still absent OU, ventral strabismus was noted OS, her left head turn and decreased nasal sensation bilaterally were unchanged, and the pupils were midrange at rest. She held her jaw clenched, so a gag reflex could not be tested. Limb reflexes remained normal in all 4 limbs, and cutaneous trunci sensation was now intact bilaterally. She was non-ambulatory and tetraparetic, but when supported was able to take functional steps with the pelvic limbs. She was substantially weaker in the thoracic limbs. Conscious proprioception remained absent. The patient had stabilized medically and PROM exercises continued, with more intensive physical rehabilitation initiated for the remaining hospitalization period. By day 5 of hospitalization, the MGCS was 16 with a good prognosis, and the patient was deemed neurologically stable for discharge with continued anticonvulsant and NSAID therapy. A cranial nerve examination showed a persistent head turn to the left, ventral strabismus OS, absent menace OU, and decreased nasal sensation bilaterally. Intermittent spontaneous horizontal nystagmus with a fast phase to the right was newly identified. The patient remained non-ambulatory and tetraparetic but with movement present in all 4 limbs when left in lateral recumbency and encouraged to try to move to a sternal position. Conscious proprioceptive paw placement was absent in the thoracic limbs but only slightly reduced in the pelvic limbs.

Approximately 1 week later, the dog was returned to the hospital for outpatient treatment. Initially, rehabilitation was performed twice weekly for 2 weeks, then once weekly for 2 weeks, then every 2 to 3 weeks thereafter for a total of 9 sessions over a 9-week period. Written instructions and demonstrations for at-home exercises **(Table 1)** were provided to the owner for use between the in-hospital sessions.

Table1: Recommended physical rehabilitation exercises to be performed by the owners at home

At-home rehabilitation prescribed	Warm pack, massage*	PROM, stretching	Stretching*	Land work
Following discharge from initial intensive care unit visit	1. Dorsal cervical muscles 2. Shoulder muscles R 3. Hip muscles R	All joints of the thoracic and pelvic limbs	1. Cervical spine 2. Thoracolumbar spine 3. Shoulders 4. Hips	1. Assisted standing over physiopeanut 2 to 3 minutes per session 3 times daily with limbs touching textured mat
One week after starting out-patient rehabilitation package	1. Dorsal cervical muscles 2. Shoulder muscles R 3. Hip muscles R	All joints of the thoracic and pelvic limbs	1. Cervical spine 2. Thoracolumbar spine 3. Shoulders 4. Hips	1. Assisted standing over physiopeanut 2 to 3 minutes per session 3 times daily with limbs touching textured mat 2. Cookie stretches — going from lateral to sternal recumbency 2 to 3 times daily for 10 to 15 repetitions 3. Chew on toys to encourage jaw movement and normal canine activities 4. Sensory stimulation of feet with cotton swab, fingers, or brush

***R = right and L = left. PROM = passive range of motion**

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Hospital exercise program

During intensive care unit hospitalization

The patient received rehabilitation in the intensive care unit (ICU) consisting of exercises focused on preventing muscle contracture, encouraging muscle contraction, lessening the rapidity of atrophy, and encouraging mental stimulation. Neurologically-affected patients are often recumbent and have limited mobility, so early physical rehabilitation intervention is also key to limiting such secondary complications as bed sores, atelectasis, or aspiration pneumonia. In this instance, the use of warm packs over cervical and quadriceps muscles, appendicular muscle massage via simple stroking and petrissage, PROM of all joints in each limb, and slow stretches of the cervical spine and limbs were all instituted to prevent contractions of musculature. Ten to 20 repetitions of PROM of phalangeal, metacarpal, carpal, elbow, shoulder, metatarsal, tarsal, stifle, and hip joints were performed 3 times daily as tolerated by the patient. Thoracolumbar stretching in extension was performed with the use of the therapist's own body supporting the patient's back against the therapist's chest in order to stretch the patient's spine, or with the use of a large physiopeanut, positioning the patient with her ventrum laid across the peanut and stretching her spine while in extension. A smaller physiopeanut and a textured mat placed under the patient's feet were both utilized for assisted standing and weight-shifting exercises that were performed 1 to 2 times per day for 2 to 3 minutes per session. During the rehabilitation sessions, the therapist used vocal stimulation to encourage the patient mentally. The dog's name was called several times in an uplifting tone throughout the sessions. Additionally, she was taken outdoors to smell, feel, and be stimulated by nature during therapy sessions.

During outpatient visits

Outpatient rehabilitation **(Table 2)** began 5 days after discharge from the ICU and 10 days after presenting for TBI. The neurological examination at this time demonstrated a quiet

Table 2: In-hospital exercise performed during outpatient physical rehabilitation sessions.

Session #	MGCS*	Warm pack, massage	PROM, stretching	Assisted standing	UWTM: water level: mid femur	Swimming	Land work
1	17	1. Cervical muscles 2. Pelvic limb muscles	1. Pelvic limbs 2. Thoracolumbar spine	Physiopeanut with limbs on textured surface	Duration: 2.5 min then 1 min Speed level: 0.5 miles per hour	-	
2	NP	1. Cervical muscles 2. Pelvic limb muscles	1. Pelvic limbs 2. Thoracolumbar spine	Physiopeanut with limbs on textured surface	-	-	
3	17	1. Cervical muscles 2. Pelvic limb muscles	1. Pelvic limbs 2. Thoracolumbar spine	Physiopeanut with limbs on textured surface	Duration: 2.5 min then 2 min Speed level: 0.3 miles per hour	-	
4	NP	1. Cervical muscles 2. Pelvic limb muscles	1. Pelvic limbs 2. Thoracolumbar spine	Physiopeanut with limbs on textured surface	Duration: 2 min / 2 min Speed level: 0.3 miles per hour	2 sets 30 sec on/30 seconds off	1. Weight shifting: 3 sets 1 min
5	NP	-	1. Pelvic limbs 2. Thoracolumbar spine	-	Duration: 2 min Speed level: 0.4 miles per hour	5 min	1. Cavalletti rails, ground level: 1 set of 5
6 (first recording of being ambulatory)	17	-	1. Pelvic limbs 2. Thoracolumbar spine	-	-	3 sets of 2 min	1. Land walking on textured surface: 5 min 2. Wobble board 3 sets of 1 min
7	17	1. Quadriceps 2. Epaxial muscles	1. Pelvic limbs	-	-	-	1. Wobble board 3 sets of 1 min
8	NP	1. Cervical muscles 2. Quadriceps	1. Quadriceps muscles	-	-	-	1. Wobble board 3 sets of 1 min Weight shifting: standing on textured, elevated surface x 4 paws 5 sets 30 sec 2. Lifting each paw intermittently while maintaining stance
9	17	-	-	-	-	2 sets of 3 min	1. Weight shifting: standing on textured, elevated surface 5 sets of 30 sec 2. Wobble board 3 sets x 30 sec

***NP = not performed** **MCGS = Modified Glasgow Coma Scale** **PROM = passive range of motion** **UWTM = underwater treadmill**

but appropriate mentation and a non-ambulatory tetraparesis with motor movement observed in all limbs and thoracic limbs remaining weaker with respect to pelvic limb motor. She had decreased proprioception in the pelvic limbs and absent proprioception in the thoracic limbs. Exercise therapy stimulates transmission of nerve signals, reinforces proprioceptive and motor pathways, and aids in the restoration of muscle function for standing, walking, and other activities that require minimal or no conscious effort in the healthy patient. She continued to demonstrate ventral strabismus and absent menace reflex OS, decreased to absent menace OD, midrange pupils with normal pupillary light and oculocephalic reflexes OU, and no obvious pathologic nystagmus. Reduced nasal sensation was noted on the left side only. The initial weeks of outpatient rehabilitation remained focused on preventing muscle contracture via warm packing, massage, and passive stretching of cervical and pelvic limb musculature. The patient had a significant left head tilt and left head turn as sequelae of intracranial injury. She was recumbent, with pelvic limbs held in flexion, exhibited significant thoracolumbar spine kyphosis, and was unable to right herself. During therapy, the head and neck were stretched and held in an appropriate upright, forward-facing position after first warming up the cervical muscles. The thoracolumbar spine was also stretched both by supporting her dorsum against the therapist's bodies and by stretching her over a large physiopeanut following muscle warming.

For assisted standing therapies, an appropriately-sized physiopeanut or therapist hand-support was utilized **(Figure 2)**. During all standing exercises, feet were placed on a textured mat for sensory stimulation. To encourage normal canine walking movements and coordination and for a change in mental stimulation, water therapy was incorporated early in outpatient rehabilitation sessions. The water level in the underwater treadmill (UWTM) (e) was maintained at mid-femur to provide support while encouraging gait training. When she began to be more mentally alert and able to demonstrate appropriate affect and behavior at the fourth visit, swimming was used to encourage muscle strengthening and cognitive stimulation.

The dog remained non-ambulatory and tetraparetic until her sixth visit, 4 weeks after the initial presentation, when she was documented as being able to walk, with vestibular ataxia and listing and leaning to both the left and right sides. Unassisted coordination exercises were incorporated into her regimen through the use of weight-shifting on a wobble board or physio-half-spheres **(Figure 3)** and cavalletti rails at floor level. Sensory stimulation was also a focus during

Figure 2

Assisted standing with therapist hand-support

all exercise sessions. Music with an upbeat rhythm and frequent, repetitive, positive voice commands of encouragement were used for patient auditory and cognitive stimulation.

Throughout all visits, the patient's MGCS remained at 17, consistent with a good long-term prognosis (3). At the final physical rehabilitation session, 10 weeks after initial presentation for TBI, the dog was ambulatory, with mild vestibular ataxia. Mentation was normal and she had an absent menace OS and inconsistent but present menace OD. She showed positional ventral strabismus OS and a positional vertical-to-rotary nystagmus OU. Gag and nasal sensations, bilaterally, were normal. Conscious proprioception was normal in all 4 limbs, as were reflexes. The owner reported dramatic improvement at home, with the dog able to ambulate without assistance and behave normally. At a recheck examination 16 weeks post-presentation, the patient's neurological status remained relatively static other than mild improvements in her ataxia. Given that no further seizures

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Figure 3

Unassisted standing on textured surfaces (physio-half-spheres)

had been noted since the original ICU discharge, she was tapered off levetiracetam over 1 week with instructions to notify the neurology service if seizures recurred. Otherwise, given her remarkable improvement no further appointments were required .

Discussion

The identification of TBI and immediate intervention are pertinent to patient outcomes and considered standard of care in humans (10). Predicting the outcome in people is multifactorial and depends on age, cause of injury, MGCS motor score, serial neurologic examinations, and advanced imaging characteristics including identification of subarachnoid hemorrhage. However, prognostic indicators in veterinary species are limited, with the MGCS being used to correlate survival probabilities in the first 48 hours (1). Instituting a physical rehabilitation plan may prevent or minimize motor deficits and sensory deprivation while nervous tissue heals and in some cases function is restored (7–9). Furthermore, evidence in humans demonstrates a more rapid and improved recovery with rehabilitation, particularly with comprehensive multimodal therapy (10). When neuroplasticity, the ability for neural tissue to adapt and change in response to injury, becomes distorted by trauma, early integration of multimodal rehabilitation shows a positive correlation with improvements in function and sensation (8, 10, 11). A physical rehabilitation plan can be designed specifically for the TBI patient, focusing on minimizing pain, improving muscle strength, reestablishing normal neural pathways, and ultimately returning the patient to an independent life (12-14). Tailoring rehabilitation exercises to the specific life requirements and abilities of each patient is ideal. Adjustments are made in the types, intensities, frequency, and duration of exercises and equipment used to transition the patient from hospitalized to at-home. This style is representative of models used in human TBI patients in which targets include the musculoskeletal, neuromuscular, cardiovascular, and pulmonary systems (15). As the patient regains muscle strength and voluntary muscle control, the level of difficulty is adjusted. The gradual increase to faster or more strenuous exercises is associated with not only improvement of cardiovascular health but also proprioceptive, motor, and motivational benefits (16).

Consideration of treatment options and ease of administration help to assure compliance and successful outcomes. In the case of this canine TBI patient, frequent neurologic assessments using objective measures such as the basic neurologic examination and the MGCS were utilized to serially monitor progress, guide therapeutic goals, and make treatment adjustments (3). Although higher MGCS scores point to a more favorable prognosis, limited data exists correlating survival with a specific numerical score. Therefore, MGCS was extrapolated as an objective measure to assess neurologic progression rather than as a survival indicator (1, 3).

Modalities introduced early in the course of treatment included appendicular muscle massage and PROM. Massage improves circulation and lymphatic drainage and can be used to decrease edema and pain while providing stimulation that encourages nerve regeneration (13, 17, 18). Massage also promotes neuroplasticity and is beneficial in improving motor performance and deficits (19). Movement of muscles and joints during PROM prevents connective tissue and muscle contracture, promotes synovial fluid replenishment, improves local circulation, and provides stimulation of sensory and proprioceptive pathways (13, 18, 20) **(Video 1)**. Range of motion exercise is performed when the patient is relaxed and does not require maximal flexion or extension in order to be effective. Stretching prevents muscle and joint contracture, moving tissues beyond the normal passive range by increasing flexibility, decreasing muscle stiffness, and lengthening contracted muscles (21). From this single case report one is unable to draw conclusions

regarding any potential difference in outcome had physical rehabilitation not been employed. However, the use of massage and PROM allowed the dog to maintain range of motion in the joints and muscle elasticity. When she was neurologically able to move her limbs and conscious enough to walk, she could do so without impairment from joint and muscle contracture.

Assisted standing was also utilized as an adjuvant to lessen muscle atrophy, establish muscle tone, and promote normal posture (13, 18, 22). Cookie stretches **(Video 2)** and lateral -to-sternal-to-standing exercises provided active muscle contraction and work on balance, coordination, lateral stretching, and muscle control through shifts in the patient's center of gravity (22). Assisted standing exercises, in particular, focused on strengthening postural muscles while reinforcing proprioceptive and motor pathways to aid in muscle memory restoration for standing or walking normally, without conscious effort (13, 18). The muscles most vulnerable to disuse atrophy include postural muscles and extensor muscles (12). Rapid decreases in strength of these muscles are observed in the first week of recumbency. In this case, a physiopeanut used for assisted standing helped improve balance, neuromuscular coordination, and proprioceptive training as well as serving as an assistive device for the therapists (12, 13, 18, 22). Assisted standing exercises allowed the patient to practice standing in an upright, normal posture and, presumably, resulted in less rapid disuse muscle atrophy.

Once the patient was mobile, cavalletti rails and a wobble board were used to further improve balance, coordination, and proprioception (22). The sensory portion of the nervous system was stimulated by the use of massage and textured mats on which weight-bearing exercises were performed. Alterations in ground texture challenge functional proprioceptive abilities and facilitate sensory feedback from plantar surfaces (23). The use of textured surfaces and uneven flooring allowed for stimulation of the patient's proprioceptive system at the level of the joints and also within the spinal cord and brain. Encouraging movement stimulated the motor system, while the use of texture and encouraging sounds and music during therapy stimulated the sensory nervous system.

Aquatic therapy, through use of an UWTM and swimming, helped improve strength (12, 13, 18). The UWTM allows for a low-impact training environment needed in early recovery periods. The natural buoyancy of water supports the paretic patient while the moving treadmill belt stimulates the sensory and proprioceptive systems (24, 25). In the UWTM, the patient can relearn proper gait patterns, improve active joint range of motion, practice independence, and build stamina through adjusted water height (20, 26). The resistance supplied by the water can increase strength and reinforce proper foot placement and proprioceptive positioning by slowing movements (13, 18). Swimming allows for improved muscle strengthening, active joint range of motion, and mental stimulation (25). The controlled movement of gait patterning with swimming is much less than with the UWTM, however, and should be reserved for later in the rehabilitation program for strength training and endurance. The use of warm water promotes blood circulation, lymphatic drainage, nerve conduction, and muscle relaxation (13, 18, 25). The water allows for a different sensory stimulus to the nervous system with respect to proprioception, feeling, smell, and sound. Coordinated movement is necessary for walking but also swimming. The support provided with swimming and water walking also encourage patient independence.

Mental stimulation and environmental enrichment are important aspects of TBI rehabilitation in humans (27). As a result, these forms of stimulation were included during each of our patient's rehabilitation sessions through positive reinforcement and musicokinetic therapy. Enrichment consisted of additions to the animal's environment to promote motor, tactile, and visual stimulation (28, 29). Examples include use of toys, treats, daily outdoor therapy, and human touch during rehabilitation sessions. Outdoor therapy can foster positive effects on cognitive functions, providing olfactory, visual, and tactile stimulation (30). Secondly, the human-animal bond is a well-established connection between veterinarians, clients and animal patients (13). Positive interactions such as touch and massage, words of encouragement, and praise strengthen the veterinarian-patient bond. A goal for this patient was to increase independence and self-reliance in an effort to improve her mental health following injury. Music was also a part of the rehabilitation. Music has been demonstrated in several studies of TBI to promote awareness, stimulate auditory, somatosensory, and vestibular pathways, and activate emotional functions within the brain (31, 32). In addition, other studies suggest musical intervention facilitates early responsiveness during the acute stages of TBI in humans (33).

This case utilized the multimodal sensory approach in humans that has demonstrated facilitation of arousal in minimally conscious individuals where the risks are minimal (30). The patient's mentation was obtunded at the beginning of physical rehabilitation and for 3 days after initial presentation; she would open her eyes and blink when stimulated. By 2 weeks post-presentation she was deemed mentally appropriate, with at-home improvements reported in tail wagging, response to the owner, and attempts to move

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independently. At the final physical rehabilitation session, she was bright, responsive, and had been able to chase birds and play in the owner's yard as part of her environmental enrichment outpatient exercises.

Physical rehabilitation following TBI is considered a standard of care in humans. However, in veterinary medicine, TBI is not typically a reason for referral to a physical rehabilitation specialist. Rehabilitation contributed to this patient's effective healing following stabilization of her brain injury. Using the MGCS to track recovery from a TBI proved to be useful in identifying improvements in patient condition using a standardized objective measure to guide rehabilitation therapies and healing. To the authors' knowledge, there are no published reports regarding the use of physical rehabilitation as an adjunctive therapy in dogs suffering from TBI. Further research to compare rehabilitation techniques and protocols in veterinary patients with TBI is needed, particularly standardized case series comparing the recovery times to ambulation in patients who have and have not received rehabilitation following TBI. This case provides a foundation for more research in order to develop effective treatment techniques. Regardless, following immediate medical stabilization, physical rehabilitation can be initiated as adjunctive therapy for dogs suffering neurological deficits from TBI.

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Humane ethics approval was not needed for this case report.

Endnotes

a. Stat Profile Prime Plus® VET Critical Care Analyzer, Nova MicroSensor CardTM Technology, Nova Biomedical, Waltham MA 02454

b. 64-slice multidetector CT, GE LightSpeed VCT, GE Healthcare, Milwaukee WI

c. Osirix MD Bernex, Switzerland, v.12.0.1. Image acquisition parameters: helical scan mode, 120 kVP, 300mA, Window Center 40, Window Width 350Plasmalyte, Baxter International, Deerfield, IL

d. Underwater Treadmill, Hudson Aquatics, Aquapaws, Angola IN

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