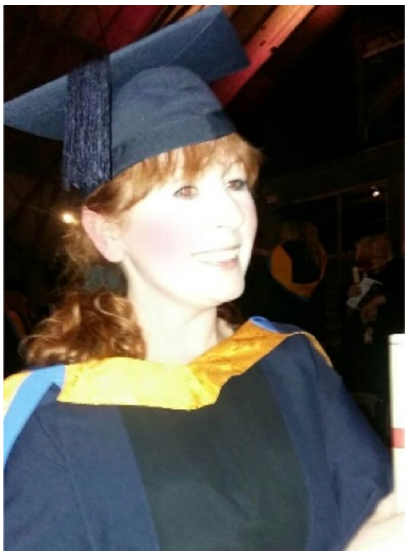
Canine cranial cruciate ligament damage and the use of hydrotherapy as a rehabilitation tool



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ABSTRACT: An examination of the pathophysiology of canine cranial cruciate ligament injury, for both acute and chronic presentations, describing the stages and modes of repair, and the use of hydrotherapy as a rehabilitation tool. Conclusions favour of the use of hydrotherapy as a beneficial, enjoyable and cost-effective rehabilitation tool, and as an excellent vehicle during the transition between the weak, post-operative and the fully rehabilitated state.

Introduction

What happens during the onset of canine cranial cruciate ligament (CCL) injury, and how effective is hydrotherapy as a rehabilitation technique? This article aims to describe the pathophysiology of CCL damage and examine the technique for use in both acute and chronic conditions, encompassing ethics, welfare and legislation, and finishing with a discussion and justification for the effectiveness of hydrotherapy during rehabilitation.

The mechanics of the stifle joint

CCL damage is the most common orthopaedic problem seen in veterinary practice (Hayashi, Kim, Lansdowne, Kapatkin, & Déjardin, 2009). The cruciate ligament comprises dense fibrous connective tissues, characterised by a precise organisation of sparse fibroblasts embedded in a highly organised, collagen-rich extracellular matrix (Dahlgren, 2007). The CCL is one of four ligaments supporting the stifle joint; it originates from the caudomedial aspect of the lateral femoral condyle and inserts at the cranial intercondyloid region of the tibia, which is positioned immediately caudal to the intermeniscal ligament, supporting the joint and contributing towards proprioception. It prohibits sliding or rotation of the tibia from the femoral head and hyperextension of the stifle joint. Medially and laterally within the stifle joint also lie two fibro-cartilagenous discs called menisci, serving as shock absorbers between the adjacent bone heads and providing additional stability to the stifle joint; these are commonly damaged during CCL disease (CCLD), particularly in large dogs (Troy & Bergh, 2015).

Pathophysiology of CCLD

Damage to the CCL can present at any point within a spectrum, ranging from minuscule tears deep within the ligament to a complete tear, transversely, through the whole structure, which for clinical purposes is graded into one of three levels of severity (**Table 1**), and may be identified using the cranial draw technique, whereby the veterinary surgeon places one thumb and forefinger on the femur

DOI: 10.1080/17415349.2017.1322476

Table 1. Grades of damage to the CCL tissues (Edge-Hughes & Nicholson, 2007)

Grade	Definition of damage
One	Minute tears to the inner fibres over time, with the synovial sheath intact
Two	Varying degrees of damage to the inner fibres as well as the synovial sheath over time
Three	Complete fibrous rupture, only successfully treated with surgical intervention as all the fibres, including nerve fibres, are broken. The animal may therefore display fewer signs of pain than one with a partial rupture, due to loss of pain sensation

and one on the tibia, pushing the tibia cranially and caudally while holding the femur still, seeking evidence of movement which will positively indicate CCL damage. Damage is frequently caused by a combination of insults including ligament degeneration through ageing, obesity, poor physical condition, conformation and breed (Duval, Budsberg, Flo, & Sammarco, 1999).

Acute and chronic presentations

Acute presentation has sudden onset, with partial to complete ligament rupture. Chronic CCLD is associated with greater prevalence of meniscal and osteochondral injuries (Dimond, Fadale, Hulstyn, Tung, & Greisberg, 1998); however, both presentations may have tears or misalignment to the menisci (**Table 2**). These are evaluated during treatment and damaged parts are removed; a damaged meniscus left in place will not permit full joint function to be regained (American College of Veterinary Surgeons, 2014).

After CCL rupture, the femur is left with nothing to prevent it sliding down the angled slope of the tibia – this is the action achieved during cranial draw. The slope is known as the "tibial plateau angle" (TPA). Morris and Lipowitz (2001) observed that, significantly, this TPA is greater than the average 25–30 degrees in dogs with CCL injury than in similar dogs with healthy stifles; therefore, the joint is continually under a higher level of stress during activity. A study of 81 Labrador retrievers by Reif and Probst (2003) found that this did not, however, present an increased likelihood of the animal experiencing CCLD.

Repair

The stages of repair

With both acute and chronic presentations, tissue repair occurs in three overlapping stages (**Table 3**), and each stage must be allowed to take place unimpeded in order for healing to occur properly (Bryant & Phillips, 2007). CCLs have a microstructure of collagen bundles of several types (predominantly Type I) plus a complex matrix of proteins and elastic systems and comprise approximately 66% water, thus displaying reduced metabolism and slow healing speed (Tjoumakaris, Donegan, & Sekiya, 2011).

The modes of repair

There are non-surgical (conservative) and surgical interventions for repair. Conservative treatment is normally the preserve of acute, partial-rupture conditions, or dogs weighing less than 15 kg (Comerford, 2007). The important elements of such repair are weight management, physiotherapy, modified exercise and anti-inflammatory analgesics, which minimise the need for long-term exercise restriction and medication (Comerford, 2007). In most instances early surgical repair such as extracapsular suture stabilisation (ESS), tibial plateau levelling osteotomy (TPLO) and tibial tuberosity advancement (TTA) are preferable to long-term conservative therapy. Surgical intervention cannot reverse the degeneration, but can minimise further deterioration (Hurley, Hammer, & Shott, 2007); it is required for acute an d chronic CCLD when there is complete rupture of the ligament, as there will be no communication to a mutual matrix on which new tissues can build. Whichever surgical technique is utilised, Jerram and Walker (2003) noted that approximately 85% of patients may exhibit clinical improvement; however, many will go on to demonstrate sporadic lameness or pain. Post-operative management is therefore integral in the treatment of CCL rupture, and Jerram and Walker's research reported significant benefits to limb function when post-operative physiotherapy was performed.

Rehabilitation

Immobilisation versus active or passive exercise

Older research suggests avoidance of post-operative weight-bearing and exercise, promoting immobilisation of the affected limb for around one month after surgery, allowing the ligament to rehabilitate in a non-traumatic environment (Dupuis & Harari, 1993). However, more recent thinking has found that limb function improves significantly faster where formalised post-operative physiotherapy occurs (Marsolais, Dvorak, & Conzemius, 2002) as it reduces detrimental biochemical and metabolic changes in articular cartilage (Keller, Aron, Rowland, Odend'hal, & Brown, 1994). Immobilisation results in muscle atrophy and a decline in motivation to re-use the limb (Michigan State University, 2014). Rehabilitation goals (**Table 4**) must reflect the stage of healing that the patient has achieved and avoid retarding or reversing the repair process, and a holistic nursing care plan could be implemented alongside the rehabilitation programme to record concerns and goals. Objective measures must be introduced in order to determine how effective the plan is, and may include such factors as lameness-scoring/gait analysis, range-of-motion (RoM) of the affected limb, measuring of muscle mass and general functional ability such as sitting squarely, using stairs or jumping into a vehicle (Monk, 2007).

The mechanisms of action of hydrotherapy

A 2008 blind study of 64 human patients with osteoarthritis of the knee by Silva et al. (2008) revealed that, although land- and water-based therapies both alleviated pain levels, hydrotherapy users experienced a "*superior*" level of analgesia over an 18-week intervention in comparison with land-based walking. Conversely, in the same year, Hall, Swinkels, Briddon, and McCabe (2008), in their study of human adults with neurologic or musculoskeletal disease, had concluded that there was no measurable difference in the analgesic effect of water-based therapy compared with land-based; however, they did acknowledge that a level of analgesic effect had been observed from the undertaking of hydrotherapy. More

Table 2. Acute and chronic CCL damage: signs and symptoms

Acute	Partial or complete rupture of the ligament fibres, associated with severe trauma to, or dislocation of, the stifle joint. Acute ruptures typically present with inflammation and effusion around the joint with the patient suddenly unable to bear weight, with no improvement after resting over a period of time. Secondary arthritic changes in acute CCLD are usually minimal. Any rupture of the CCL produces joint instability which, if left untreated, results in degeneration of the joint
Chronic	Partial or complete rupture is the end-stage process in a joint in which soft tissue has deteriorated over months or years before failing, and normally bilateral (Moore & Read, 1995). When forces exceed the ligament's elasticity parameters, or when repetitive loading creates damage which exceeds the speed that fibroblasts can repair (Dahlgren, 2007), the strength of the ligament is reduced, leaving it more receptive to damage. The femur and/or tibia heads may be thickened due to development of secondary arthritic changes occurring as the ligament deteriorates. This manifests as joint disease and lameness, and cranial draw may be achieved. The degeneration process releases inflammatory media, which degrade the cartilage and ligament yet further (Hay, Chu, Budsberg, Clayton, & Johnson, 1997). Osteoarthritis develops and eventually the CCL ruptures

Table 3. The stages of healing in soft tissue

Stage One	Days 1 and 2: Haemorrhagic phase	Neutrophils enter the area, causing swelling and inflammation
	Days 3 to 5: Substrate phase	Monocytes and macrophages break down and remove (ingest) necrotic material
Stage Two	Days 5 to 21 or more: Regeneration phase	Formation of new desmocytes, by fibroblasts
Stage Three	From week 6 to 1 year or more: Remodelling (maturation) phase	Collagen is laid down throughout the structure and reorganises to form scar tissue

dated research on human patients also supported hydrotherapy's effectiveness for pain reduction (Hall, Bisson, & O'Hare, 1990) and joint mobility, as well as balance and strength (Kelly, Roskin, Kirkendall, & Speer, 2000).

The Monk, Preston, and McGowan (2006) study of canine post-tibial plateau-levelling osteotomy patients made a comparison of RoM exercises, stifle flexion and muscle mass between land- and water-based physiotherapy. The researchers noted that after six weeks the underwater treadmill subjects demonstrated no discernible difference between affected and non-affected limbs for thigh circumference, stifle flexion or extensive RoM, whereas the land-based walking therapies highlighted a decrease in muscle mass as well as increased stifle stiffness.

Hydrotherapy and patient physiology

With a well-managed set of prescribed exercises, the water properties of hydrotherapy may well be positive contributors in addressing analgesia, neural health, body conditioning, musculoskeletal strengthening and fun activity. The seven symbiotic properties of water utilised during a customised hydrotherapy exercise programme are relative density, specific gravity, buoyancy, hydrostatic pressure, viscosity, surface tension and refraction, described more fully in **Table 5**.

Small or short-necked dogs may experience a strain on their vertebrae if they are required to lift their head above the water during treadmill hydrotherapy, so it is important to use the correct water level when employing this apparatus. The water level must be adapted to suit the patient's size and conformation, and the speed of the treadmill must be carefully measured to reflect the patient's physical strengths (Prankel, 2008). Care must also be taken to ensure that long-haired patients do not become entangled in the moving parts of the equipment.

The majority of the dog's sweat glands are located around the foot pads; therefore, during hydrotherapy, sweat is not able to evaporate from the skin's surface, and the patient must rely on panting to cool. The optimum temperature for the water during hydrotherapy is 30°C, preventing the body from cooling on immersion, yet suppressing overheating during exercising. The warm temperature also delivers thermography, heating superficial joints and improving circulation to the soft tissues (Prankel, 2008).

The relevance, suitability and benefits of hydrotherapy

Patients suffering from CCLD redistribute movement effort into their uninjured limbs, which are then subject to greater forces. This can result in elective restriction of activity, joint stiffness, weight gain and further pain (Rivière, 2007). A "typical" CCL patient has a one-in-three chance of subsequently suffering CCL injury in the contralateral leg (Haransen, 2003) within eight months of the first (Griffon, 2009); this may be due to the weight transferral onto the other limbs described above, although an early scintigraphy study by Brandt et al. (1997) found no significant link, describing early surgical treatment and hydrotherapy for the protection of the contralateral stifle.

Not all patients are suited to undertaking hydrotherapy and contraindications include:

- open, infected or draining wounds; unhealed incisions or suturing
- active gastrointestinal and contagious diseases
- pyrexia
- systemic compromise (for example, severe kidney/liver/heart disease)
- severe peripheral vascular disease
- uncontrolled epilepsy
- vestibular syndrome
- water phobia, causing extreme panic reactions. (Monk, 2007; National Association of Registered Canine Hydrotherapists, 2009b; Tomlinson, 2012)

Rehabilitation is designed to complement the phases of ligament repair and associated tensile strength of the tissues (Dahlgren, 2007). A hydrotherapy

Table 4. Goals during rehabilitation (Edge-Hughes & Nicholson, 2007)

Goals
Pain reduction
Promotion of healing
Maintenance of muscle mass, promotion of muscular development and joint stability
Maintenance of joint flexibility
Retraining of proprioception, balance and coordination
Facilitation of early return to function
Prevention of degenerative joint disease
Rebuilding of cardiovascular endurance

programme may be introduced soon after suture removal with sessions often running in conjunction with other physiotherapy modalities such as cryotherapy and massage, lasting between 8 and 12 weeks, with regular reviews monitoring the patient's progression, development of muscle mass and joint function, and level of activity. Further study into hydrotherapy may well prove that greater emphasis should be placed on prompt post-operative hydrotherapy rehabilitation, with Hinman, Heywood, and Day (2007) observing that "some movements which are impossible to make on the ground can be made in water".

Owner interaction, welfare and ethics

As noted above, consideration should be given to patients frightened by water as, with no definitive proof that animals are able to think beyond the present (Mendl & Paul, 2008), there lies an ethical concern that such patients may experience a stressful environment from which they perceive no escape. Pre-operative hydrotherapy can familiarise the patient with the water and apparatus, assisting with the confidence of these dogs, so reducing their anxiety when they are required to engage post-operatively. Where surgical intervention can often be perceived by owners as beyond their control (Prankel, 2008), during hydrotherapy they can be positioned in front or slightly to one side of the treadmill, or within the pool, encouraging their pet and so actively and rewardingly contributing to its recovery.

Given that a considerable proportion of dogs are genetically predisposed to CCLD through conformation (1.58%, in a study of 11,579 dogs over five years (Nečas, Zatloukal, Kecová, & Dvořák, 2000)), consideration could be given to preventing inherited transmission from parent to offspring. Legislation banning the breeding of genetically predisposed lines may be controversial but would ensure that further offspring are not born with inherited dysfunctional predispositions. With both obesity and excessive exercise regimens causing further injuries, owners may also benefit from education regarding the importance of maintaining a lean weight for their pet as well as providing sufficient, moderated levels of exercise.

In 2009, the RSPCA commissioned a report describing various initiatives aimed at eliminating inherited disease, observing that, when selecting a stud dog, breeders placed twice as much importance on the aesthetics of the dog than on advice from geneticists (Rooney & Sargan, 2009). This illustrates the struggle in educating people to recognise the importance of welfare over financial reward in, for example, the breeding sector. As there is no legislation (only recommendations) regarding breeding from genetically deformed animals, the practice is likely to continue, to the detriment of the health and welfare of the dogs.

Owner education by veterinary surgeons (VSs) and nurses might benefit from adopting a more holistic approach, with a focus on the Animal Welfare Act's Five Freedoms (2006), perhaps extending to the range of diseases including and beyond CCLD which can be attributed to a poor diet and obesity.

Legislation

It is not a legal requirement to hold a hydrotherapy qualification to deliver the therapy. Ideally, the decision for hydrotherapy for rehabilitation would be made by a VS, referred to a trained hydrotherapist, and the programme managed with ongoing two-way communication between the two bodies, employing a suitable rehabilitation model, although this, too, is not currently required by law. In order for a hydrotherapist to operate within legal parameters, adherence to additional acts and regulations should be considered for the health, safety, welfare and conduct of all involved. The list is not exhaustive and includes:

- The Veterinary Surgeons Act (1966)
- The Veterinary Surgery (Exemptions) Order (1962)
- The Animal Welfare Act (2006)
- The Dangerous Dogs Act (1999)
- The Data Protection Act (1998)
- The Health and Safety at Work Act (1974)
- The Control of Substances Hazardous to Health Regulations (2002)
- The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (2013)

Discussion

It would not be a full understanding of the dog's physiology to examine the rehabilitation of the CCL in isolation from the rest of the joint, as it is an intrinsic component of the stifle, alongside the musculature, bones and menisci. Acute and chronic presentations require very similar rehabilitation techniques and the findings

Table 5. Properties of water and explanations of action

Element	Description
Relative density	Relative density (RD) is the relationship between the patient's mass and volume to that of an equal body of water
Specific gravity	The RD is defined by specific gravity (SG); that of water is 1. Fat lowers SG and dense bone increases it; therefore, a stationary, lean animal (SG of less than 1) will sink faster than an obese animal with an SG greater than 1
Buoyancy	"The upward thrust exerted on a body that is partly or totally submerged in a fluid at rest, which is equal to the weight of water it has displaced" (Edlich et al., 1987). Providing "lift", with the patient appearing lighter, due to the buoyancy's effect. The leaner patient would, without buoyancy aids, sink
Hydrostatic pressure (HP)	The sum pressure exerted on the patient's body in water. The HP increases the greater the depth of submersion of the patient. HP is beneficial for effusion and oedema, as the pressure reduces the pooling of fluid in lower body parts. HP is thought to provide stimuli to sensory receptors in the skin, decreasing pain perception (Prankel, 2008), and facilitating a less-painful exercise experience for the patient
Viscosity	Viscosity provides resistance to movement due to the friction between the water molecules during movement, encouraging muscle strengthening. It supports the patient, reducing twisting and falling injuries (Prankel, 2008). It reduces as water temperature increases and so eases movement of weaker muscles when the water is at a higher temperature
Surface tension	Water molecules adhere together more on the surface, creating surface tension, so working the patient's limbs harder as they break the surface
Refraction	Light refracting as it passes from media of one density to another, distorting the view of the limb. This can affect the patient's proprioception and cause them to misjudge foot placement (Monk, 2007)

Table 6. The benefits of hydrotherapeutic treatment (National Association of Registered Canine Hydrotherapists, 2014)

Gross benefit	Clinical benefit
Pain relief and improved function	Decreased pain perception
	Relaxation of muscle tension and/or muscle spasm
	Reduction of oedema – either because of hydrostatic pressure or with increased limb movement in water
	Decreased inflammation
	Feeling of well-being due to release of endorphins
Non or partial-weight-bearing exercise	Non- or partial weight-bearing environment in hydrotherapy pool
	Earlier return to normal function
	Support for weakened joints
Improved muscle mass and function	Increased active range of motion
	Improved muscle patterning and recruitment
	Increased muscle bulk, strength and tone
	Prevention or reduction of muscle atrophy
Proprioception and gait retraining	Increased sensory perception – from action of water and hands on with hydrotherapists
	Animal can be supported in standing by the buoyancy of water and the hydrotherapist – helping to gain confidence and enough time to make corrections without falling
Other	Reduction of frustration for dogs on cage rest
	Improved quality of life for dogs with reduced mobility
	Prevention of secondary complications such as atrophy and contracture
	Improved cardiovascular fitness
	Reduction in obesity as part of a weight-control plan

are that, irrespective of the mechanics of damage and initial interventions, repair is always achieved through the three stages of healing described in **Table 3**.

When, despite preventative action being delivered, CCLD occurs, it is clear that targeting posture regulation and limb strengthening with hydrotherapy, ideally under the diagnosis, prescription and direction of a VS and used in conjunction with carefully managed exercise, bears weight as a measurable, low-impact, easy-to-deliver rehabilitation tool for acute and chronic CCLD. With patients for whom it is appropriate, hydrotherapy for CCL damage repair appears to be beneficial on many levels (**Table 6**), illustrating the holistic nature of this particular technique. Immersion in water provides external stimulation which obliges the patient to mobilise the whole body in order to maintain stability. The water offers buoyancy, resistance and muscle stimulation, while the heat relaxes tissues and provides an evidenced level of analgesia. It seems reasonable to state that post-operative rehabilitation therapies may be the most important component in successful clinical recovery, although the final composition and organisation of the tissues will not result in a full return to the previous level of performance.

Set within a framework of carefully managed rehabilitation techniques, hydrotherapy appears to be able to offer

a big part in weight control, muscle mass and overall body condition at a preventative level, as well as being a valuable tool for regaining body condition and activity levels post-operatively. Reviewing available evidence, there are few data suggesting that one single surgical intervention can offer a return to normal function, or the prevention of osteoarthritis. Likewise, complementary and alternative therapies cannot repair the ligament but, after surgical intervention, they can rebuild the patient as a whole, reinstating balance, mobility, proprioception and muscle mass and offering an evidenced contribution towards the analgesic experience. The blend of surgery and hydrotherapy seems to be a forceful one, offering the patient an achievable pathway to recovery.

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Multiple Choice Questions

1. How many ligaments support the canine stifle joint?

(a) 1
(b) 2
(c) 3
(d) 4

2. What grade of damage to the CCL would be indicated by varying degrees of damage to the inner fibres as well as the synovial sheath over time?

(a) Grade one
(b) Grade two
(c) Grade three
(d) Grade four

3. Which of the following is not a surgical technique for cranial cruciate ligament injury?

(a) ESS
(b) TPLO
(c) TTA
(d) SOP

4. At which stage of soft tissue healing is collagen laid down throughout the structure and reorganises to form scar tissue?

(a) Stage one
(b) Stage two
(c) Stage three
(d) Stage four

5. Which of the following is NOT a contraindication for hydrotherapy?

(a) Water phobia
(b) Infected wounds
(c) Recent surgery
(d) Pyrexia

6. A "typical" CCL patient has a one-in-three chance of subsequently suffering CCL injury in the contralateral leg within eight months of the first.

(a) True
(b) False

7. The relationship between the patient's mass and volume to that of an equal body of water is:

(a) Relative density
(b) Specific gravity
(c) Buoyancy
(d) Hydrostatic pressure

8. It is a legal requirement to hold a hydrotherapy qualification to deliver the therapy

(a) True
(b) False

For the answers to the MCQs, please go to: http://www.bvna.org.uk/publications/veterinary-nursing-journal