Rehabilitation Plan

Uncomplicated (non-displaced) spiral fracture of the right tibia involving the proximal metaphysis and proximal to distal diaphysis and fissure on the right patella on a dog.

"Sounds so simple but maybe not"

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1. Anamnesis/Care

The dog is a Labrador retriever called ”Svante” and was a authentic rehab patient of mine. The owner has approved pictures of him and having his name in this paper. Svante was diagnosed with an Uncomplicated (non-displaced) spiral fracture of the right tibia involving the proximal metaphysis and proximal to distal diaphysis and fissure on the right patella when he was 9 weeks old, due to trauma playing with another heavier dog.

Fractures of the tibia are common in dogs and cats and occur most commonly as a result of substantial trauma (Beale B, McCally , 2020). Simple fractures include transverse, oblique, spiral, avulsion and incomplete fractures. Spiral fractures result from torsional forces creating a fracture line that winds up the long axis of the bone (Fossum 2013; DeCamp et al 2016). According to a survey study by Phillips, fractures of the radius and ulna, pelvis, femur and tibia were most common in dogs whereas fractures of femur, pelvis and mandible were more common in cats. The same author also found that 80% of the fractures occurred in animals under 3 years of age and 50% of the animals were under one year of age. Road accidents and fall and crush injuries were the main causes of fractures. Far from all fractures are surgically treated. Some animals are treated conservatively and others are euthanized (Phillips, 1979).

The spiral fracture was healed conservative without surgery in a cast in 3,5 half weeks’ time without any complications. During this time in cast the veterinary had revisits with x-rays every week for 4 weeks. During these 4 weeks Svante had to be on a strict cage rest with 5 minutes leash walks on stable ground. The cast was really big and heavy for a 9 weeks puppy and he had some pressure wounds on and between his toes and on his achilles tendon while having the cast. He could not sit nor walk normally with the cast. After the veterinary thought the fracture was stable enough the veterinary send a referral to me at Djur i Balans for help with stiff joints and muscle building.

Figure 1. Autentic X-rays of Svante.

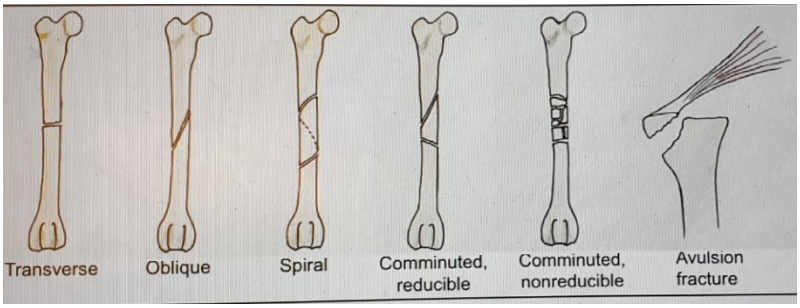

Figure 2. Classification of fractures based on fracture morphology. (By Yusi Fang, modified from Fossum, 2013 p. 1054 FIG 32-18)

Casts
Various different splints and cast can be used as indirect fixation method or to provide greater stability to surgically treated fractures. Generally, the cast or splint should cover at least one joint proximally and one joint distally to the injury site. Therefore, it is not suitable for injuries above the elbow or stifle joint. All cast and splints should have adequate padding underneath to prevent abrasions and pressure wounds. Protruding structures on the limb should be carefully protected. The cast or splint should be checked at least once in a week, and sooner if the animal expresses discomfort towards the device (DeCamp et al 2016).

Rehab appointment
I first saw him at rehab 4 weeks after the incident when the fissure of the patella was fully healed and the spiral fracture of tibiae almost healed (noted in journal in latest x-rays). He was then 13 weeks old.

Physical therapy first assessment /Status of Svante: Mentally depressed, for a puppy 13 weeks old really low of energy and positive motivation, not so motivated by treats or toys, he did not seem scared or anything but just non expressive. (also noticed by the owner).
He was not fully weightbearing on his right hindlimb in standing position, weight shifting his body to his left hindlimb and also putting more weight on his left front limb, noticed in his paws in standing. 1-2 degree lameness in motion assessment, with hip hiking in his right hindlimb, not so much movement in his spine during gate analyses, holding his head and tail in the same position during gate analyses. Palpation showed pain and stiffness in parts of thoracic and lumbar spine, stiffness in left front leg in shoulder joint and pain in joint stabilisator shoulder muscles. He had severe decreased passive joint range of motion (PROM) in his RH (Right Hindlimb): tarsal joint in flex-ext without pain, almost chronic stiffness, severe stiffness in knee joint, more in extension but also in flexion, and also stiffness in patella joint. Palpation of muscles showed pain in lumbar muscles, RH hip flexors, severe pain in patellar tendon, LH hip flexor and TFL. Stiffness in patellar tendon in RH, severe hypotension in his right calcaneus tendon due to cast compression to the tendon and not using the muscle, the tendon felt like spaghetti.

Rehabilitation Goal for Svante: In this case the aim is to restore function after the fracture has healed (Gross Saunders, 2007). Building up muscle mass and increasing range of motion are the major goals (Henderson et al., 2015).

1. **Pain Assessment & Relief**

The International Association for the Study of Pain (IASP) has defined pain in humans as "*An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" and also states that "The inability to communicate verbally does not negate the possibility that an individual is experiencing pain*" (Merskey H, Bogduk N.1994), which allows for the definition to be applied to animals (Mathew et al, 2014, National Research Council (US) / Committee on recognition and alleviation of pain in laboratory animals, 2009 / Sneddon 2014). Thus, pain is also somewhat subjective and may be absent from tissue damage (Nisel1999). It has been debated to what extent animals do experience pain (Bateson P 1991), but now it has been concluded that that dogs experience pain beyond any doubts and since the neuroanatomy and physiology in pain in humans and dogs are similar there are arguments for parallel pain experiences in dogs and humans (Sneddon 2014).

Assessment and evaluate pain in dogs

Assessing pain in animals can be complicated. The biggest challenge is that the animals cannot express their pain verbally to us, but there are also other factors that complicates the pain assessment of animals. One factor that contributes to the difficulties is that many different animal species tend to hide their pain, as it had increased their chances of survival in the wild. When the animal feel insecure, are threatened, are in foreign environments, the pain signs can be hidden. Different species of animals also shows pain in different ways, which requires good knowledge of the current animal species in order to recognize its signs of pain (Sharkey 2013). The same pain impact can be experienced differently by different individuals and express themselves in different ways. Previous experiences, emotional states such as fear and anxiety can have an impact and impact on the pain experience. It has been seen that all animals have about the same pain threshold, that is, the limit for when pain is experienced, but that animals have different pain tolerance which means how much pain can be endured. (Beck-Friis J 2001 / Hellebrekers L J 2000 / Sand O Sjaastad V Ø, Haug E 2004). Dogs inability to communicate their experience of pain in words makes it impossible for us to use self-reporting instruments to directly assess pain thus pain is a subjective unpleasant sensory and emotional experience in dogs (Mathews K,2014), as we normally asses pain in humans. Instead for dogs we can use instruments designed for completion by a proxy, e.g. the dog owner who also knows the dog best (Miklosi A,2015 / Fugazza C, 2014). Owner-reported pain instruments are based on canine behavioral changes affected by pain and the ability of the naive observers, i.e. the owners, to recognize the behavioral signs in their dogs (Wiseman-Orr,2004 / Brown,2007/ Hielm-Björkman 2009/ Reid, 2017/ Belshaw 2017 / Egger 2013). Visual movement and assessment assigning grades of lameness have been shown to have poor intra-and inter-rater reliability among owners (Burton NJ et al 2009) and veterinarians (Burton NJ et al 2009 / Quinn et al 2007). So, there is a challenge to have a good quality owner-reported instrument that actually prove adequate measurement properties.

Where in the body pain is originated from is also relevant to how pain is expressed and experienced. Pain can be divided into visceral, somatic and neuropathic pain, that will come from different parts of the body and expressed in different ways by the animals. This constitutes one further challenge in pain assessment, as a individual can express pain in different ways at different times. An additional factor affecting the pain assessment is that pain consists of two components: a nociceptive part, which is the nerve signals sent from the pain originates from, through the spinal cord to the brain, and a cognitive part, which is the brain interpretation of the signal and thus constitutes the pain experience itself. The nociceptive part and cognitive part can work separately from each other, and it is possible that pain signals are sent but not experienced, and the other way around that pain can be experienced without any actual pain involved, no pain signals being sent at all. In animal hospitals or in veterinary clinics its often behavioural changes that are most often the basis for pain assessment (Rutherford 2002). Finally, all pain is individual, and its not possible to assume that two individuals with the same type of injury have the same pain experience or express the pain in the same way. The pain is affected by the patient´s mental well-being, by social aspects, and also the presence of other stressors. The need for a tool to measure and evaluate the pain at the individual level is therefore great, so the pain relief can be tailored to the patient´s need (Robertson 2002; Sharkey 2013).

The body´s response to pain

There are many reasons why pain is negative for the body for tissue healing, and especially after an orthopaedic surgery or like in this case a fracture healing. It is among other things

negative for the healing process for several reasons. Pain, worry and fear trigger a stress responsive in the body (Flaherty D 2003). This activates the sympatic nervous system, which raises heart rate and blood pressure and high priority organs such as heart, brain and lungs get better blood supply. However, it leads to peripheral vasoconstriction (Sand O 2004), in addition breathing becomes faster but more superficially and it can lead to oxygen deficiency in the tissue. This gives a lower blood supply and thereby a lower oxygen saturation in the damage tissue which makes the tissue heal worse and also the deposit of collagen decreases and tissue heals worse (Lindholm C 2003). The healing process is also impaired by the effect on the energy balance. Pain gives sleep disturbances which affects the energy balance. At sleep, anabolism in the body then occurs when hormones such as somatotropin, testosterone and prolactin stimulate tissue repair. If the sleep is disturbed by for example pain, we get catabolism instead occurring in the body which releases hormones such as catecholamines and cortisol, which leads to tissue degradation (especially proteins in the muscle mass) to create energy. In addition, the energy balance is disturbed by the fact that the animal eats less which can lead to anorexia when in pain. It also has negative effect to the musculoskeletal system in the body because in pain the animal moves less if it´s in pain (Beck-Friis J 2001; Hellebrekers L 2000; Lindholm C 2003). In a British survey for nurses done in 2014, published in The Veterinary Record, 8% responded that they do not think that animals recovering gets faster after surgery if they get pain relief. 24% feel that some pain after surgery is good when the animal stays still (Coleman D 2007). This is a strong argument against pain relief, for example if an animal has a fractured bone people often think that the animal put to much weight on the bone and cause more damage if it does not feel that i hurts. The animal should not put too much weight in the beginning of the healing process in a fractured bone, but given pain relief, the healing process takes place faster and it´s good if the animal actually moves a little to give the fractured bone some pressure for normal healing (Beck-Friis J 2001; Rollin B E 2000).

Measurement methods for pain

There are various ways to determine if an animal has pain, such as measuring physiological and biochemical values. Example of these are blood tests on cortisol, adrenalin, norepinephrine and glucose or to control heart rate, respiratory rate and blood pressure. These tests are often expensive, and the results are not specific to pain or may take time to respond to. Therefore, the behaviour of the animal is usually used to determine if the patient is in pain (Flaherty D 2003). Many behaviours that can be interpreted as pain, for example whimpering can depends on other causes like stress or feeling lonely. A good way to find out if the patient actually is in pain is to give painkillers and see if the behaviour changes (Flecknell P 2000). A good thing to know is whether the patient has become sedated, the reaction to pain may change but the perception in the brain, thus the experience is still the same (McKelvey D 2003). Pain related to orthopedics is often evaluated by veterinarians with visual gait analyses. This analysis is only done visually and it´s a subjective form of assessment, which has been found to be poorly consistent with newer objective measurement methods such as gait analyse measurements plates (Waxman et al 2008). There are several types of aids for assessing pain severity. The most commonare different forms of scoring system to note pain. All these techniques mean that you have to rely on the animals behaviour for signs of pain. This becomes subjective in comparison with human care where a verbal communication is carried out with the patient. For a good pain assessment, it requires that it is the same person responsible for the pain care of the animal throughout the whole course of disease or the whole stay in a hospital (Flecknell P 2000).

A visual analog scale (VAS) is an accepted intensity scale used to determine the effect of treatment for human patients. The patient´s estimated degree of pain is indicated on a scale where zero corresponds to no pain at all, and hundred mm the worst pain possible. Pain around 70-80 mm and above that, as a rule, may be considered as severe pain. Below is an example of a visual analog pain scale (Nisell R 1999).

Numeric rating scale (NRS) is similar to VAS. Instead of making selection on a line, the observer selects a number between zero to ten (Beck-Friis J 2001; Flecknell P 2000; Hardie E M 2000).

Simple discriptive scale (SDS) consists of four to five expressions to describe pain intensity; no pain, mild pain, moderate pain and severe pain. (Beck-Friis J 2001; Flecknell P 2000; Hardie E M 2000).

Multifactorial pain scale (MFPS) is a series of numbers for example between zero to nine, where several different behaviours are measured separately and also physiological values can be included, such as heart rate and respiratory rate. The observer gives point for each value individually and does not know what the total sum will be (Beck-Friis J 2001; Flecknell P 2000; Hardie E M 2000).

Comparative studies have been conducted between VAS and NRS. In one study, lameness was graded, caused of "hovröta" in 45 different sheep's. Two observers rated according to NRS and VAS independently of each other. The study showed that VAS is more sensitive with the possibility of finer grading in easier cases. Also, the highest NRS value is not always matched by the highest value of VAS, therefore it is recommended to adhere to one and the same method continuity of pain measurement (Welsh E 1993).
There´s not much difference in accuracy between the VAS and the NRS scale. However, they have found that SDS is less sensitive than VAS and NRS. Comparisons between the three scales has demonstrated that VAS is probably the most appropriate for measuring pain in clinical settings (Flecknell P 2000; Welsh E 1993).

To evaluate pain and treatment effects for dogs with for example osteoarthritis, animal health professionals can use questionnaires specially designed to capture pain behaviour on dogs. People living with the dog contribute by answering questions. A well-established questionnaire is called Canine Brief Pain Inventory (CBPI). Questions in CBPI were translated into Swedish and has been evaluated whether the questions are useful in rehabilitation of dogs with osteoarthritis. The study showed that the translation was well completed and that all or part of the CBPI form can be used for better evaluation of pain-relieving treatment for Swedish dogs with osteoarthritis (Essner A et al 2017). Helsinki Cronic Pain Index is another owner-reported instrument that has been used in OA (Hielm-Björkman 2009), Liverpool osteoarthritis in dogs as well (Walton MB 2013), and the canine orthopaedic index (Brown DC 2014), designed to assess outcome in dogs with orthopaedic disease.

Pressue Algometer
Indications: Pain sensitivity/tolerance. Measures the mechanical nociceptive threshold (MNT) and is a semi-objective tool since it objectively measures pressure, but the threshold point is subjectively assessed by the examiner. In animals' algometry is mainly used to

quantify muscle tenderness, but in humans it is also used to measure overall pain threshold, wich is considered to decrease in patients with chronic pain.

Error Sources: The results are influenced by variation in speed of pressure applied and the threshold assessment/reading of the avoidance reaction. As with palpation, the level of mental awareness of the animal can influence the results, and there can be adaptation over time (Briley et al 2014, Coleman et al 2014, de Haus et al 2010). Also of course human error, variability in pain threshold at different anatomical sites, angle of device application, rate of pressure exerted through the algometer (Chesterton 2007).

Scientific Documentation: The method shows moderate to high intraexaminer reliability and low to moderate interexaminer reliability in dogs and horses (Bergh 2010, Coleman et al 2014, Haussler & Erb 2006; haussler et al 2007). In horses it correlates with palpation (de Haus et al 2010, Olsén et al 2013, Varcoe-Cocks et al 2006). A study by Briley et al (2014) reports that the pressure algometer device tested on normal dogs provided repeatable, reliable sensory threshold measurements. Evidence supports the substantial interrator reliability of digital algometry in human patients, as well as the ability of novice handlers to detect changes in pain threshold (Walton 2011).

Palpation

Indications: To detect and quantify the degree of pain, by provoking a pain reaction indication the location and severity of the pain. Can also be used to detect inflammation by assessing swelling and difference in temperature. Muscle tension (evaluate different muscle properties), soft tissue elasticity and mass, and the quality of joint end-feel.

Error Sources: Animal reacts differently to palpation based on its mental awareness, so if an animal is occupied with something like eating will not react as much to palpation as one that is fully concentrating on the examinator. Thus, it is important to examine the animal under the same circumstances. It is also known that the faster the pressure is applied to an animal, the stronger will the pain reaction be.

Scientific Documentation: palpation with the aim of assessing pain has higher intra-than interexaminer reliability. Hyytiäinen et al (2013) have shown a good correlation between the assesment of muscle atrophy in dogs by palpation and a preset selection of standard outcome measures susch as visual gait analysis and force platform measurement. Levine & Goulet (2014) demonstrated that when palpating the temperature of pads that mimicked skin temperature ranging from healthy to inflamed, clinicians were able to detect temperature differences of 1-5 degrees Celsius. Studies on horses reports a correlation between pain assessments by palpation and by pressure algometry (De Haus et al 2010, Olsen et al 2013, Varcoe-Cocks et al 2006).

3. Physical activity & Rehabilitation

A. **Ethological diagnosis =** Uncomplicated (non-displaced) spiral fissure/fracture of the right tibia involving the proximal metaphysis and proximal to distal diaphysis and fissure of the right patella.

Functional diagnosis = Restricted movement in tarsal joint, stifle joint, patellar joint, left front shoulder joint and lumbar spine; decreased flexion and extension of the right stifle joint, limited flexion and extension of the right tarsal joint**,** limited side bending of the spine and extension and rotation in the lumbar spine. Stiffness in muscles; iliopsoas, quadriceps and patellar tendon, quadratus lumborum, infraspinatus, supraspinatus, triceps. Loss of function in normal gait pattern in right hindlimb, mild lameness, lumbar pain.

Loss of function	**Symtom**	**Engaged tissue (reason for the symtom)**	**Evaluation method**
Right hind limb movement disorder	1. Restricted movement in flexion and extension in stifle joint. 2. Restricted movement in flexion and extension in tarsal joint. 3. Restricted movement in hipextension. 4. Muscle Atrophy 5. severe hypotension in right calcaneus tendon	1. Shortened muscle that counteracts flexion in stiflejoint, e.g quadriceps & sartorius caudal part (knee extender) Shortened muscle that counteracts extension in stifle joint; e.g. gastrocnemius (knee flexor) & hamstrings (knee flexor). 2.Shortened muscles that counteracts flexion in tarsaljoint e.g. m.gastrocnemius (tarsal extension) Shortened muscles that counteracts extension in tarsal joint e.g m. cranial tibial flexor. 3.Shortened muscle that counteracts extension in hipjoint e.g hipflexors (TFL, quadriceps femoris, iliopsoas. 4-5. Muscle atrophy in his right hind	1-3. Goniometer to measure joint movement restriction. (Liljebrink Y, Berg A 2010) 4-5. Tape Measure with dynamometer in hindlimbs. (Bergfors 2012). 4-5. Palpation of muscles. (Levine & Goulet 2014 / Hyytiäinen et al 2013)

		limb; in his gastrocnemius tendon, gastrocnemius muscle bulk, hamstrings, quadriceps and gluteal muscle.Non weightbearing for 3,5 weeks because of cast. Not really weightbearing now because of Pain? Shortened muscles as above.	
Pain	Pain when bending the stifle joint; extending the knee extension musculature. Pain in lumbar muscles when palpating. Pain in left font limb pectoral muscle when palpating. Pain in left front limb flexor mucles in his underarm. Pain in his muscles in his left limb, Dont want to fully weight bear his right hindlimb.	Knee extension musculature M.Quadricpes. Not equal weightbering and walking in his hindlimbs, wich give him lumbar pain in his muscles. Weightshifting his body more to his left frontlimb to avoid weight to his RH. Shifting his weight to his left hindlimb who involved tissues like left hindlimb gastrocnemius, hamstrings, quadriceps etcetera.	Palpation (Levine & Goulet 2014 / Hyytiäinen et al 2013) Pressure Algometer (Bergh et al 2016) Pain Protocols ((Firth & Haldane 1999 / Guillot et al 2011 / van Loon et al 2010)

B. Temporal Aspects of Healing - The fracture healing process

A fracture occurs when the force applied to the bone is greater than the strength of the bone leading to the disruption of the continuity of the bone or cartilage (Tobias and Johnston, 2012; DeCamp et al 2016). Bones heal by ”*restitutio ad integrum”* meaning restore to original condition. In other words, a properly healed bone after trauma is “as good as new”. Bone healing can be divided into primary (direct) and secondary (indirect) healing. The healing process is divided into 3 phases: the inflammatory phase, the reparative (proliferative) phase

and the remodelling phase. Indirect bone healing is when motion between fracture fragments is present which considering being the normal course of bone healing (Tobias and Johnston 2012). Primary bone healing also called direct healing is a fracture healing without the intermediate cartilage stage and callus. The orthopaedics often want to have direct bone healing when for example restoration of a articular fracture. This can only takes place under very stable conditions tolerating minimal fracture gap present with no strain allowed (Fossum 2013; DeCamp et al 2016). Bone healing has been studied for decades in large animals including dogs, sheep's, pigs and rabbits, but most studies that investigates the process of fracture healing were performed using rat and mouse models (Haffner-Luntzer M 2019). The healing of a fractured bone is a complexed physiological process that involves osteogenesis, angiogenesis, chondrogenesis and coordination of inflammation with the aim to ensure full regeneration. Many things can happen during the healing process that will delay the healing, and get complications, like disruptions of molecules signalling of growth factors and cytokines. (Fader L et al 2018). Fracture healing requires temporally and spatially coordinated interaction of numerous molecular mediators and cell types. Bone regeneration, in addition to biological factors is further influenced by the biomechanical environment at the fracture site (Haffner-Luntzer M 2019).

Acute phase of healing - The inflammatory phase
After a fracture immediately a blood clot is formed around the bone ends by blood vessels and incipient blood coagulation. Inflammatory mediators recruit to the injury site and in case of a open fracture pathogen-associated molecular cues also recruit to the site. The first cell type appearing hours after injury in the fracture haematoma is neutrophils that removes pathogens by phagocytosis, secrete various inflammatory mediators and chemokines and also remove cell debris. The pro-inflammatory factors recruits other immune cells like monocytes and lymphocytes. A crucial factor of fracture bone healing is recruiting of macrophages (Haffner-Luntzer M 2019). The haematoma is replaced by granulation tissue, tolerating high strain in the initially very instable fracture site. With these tissues in place, motion as well as strain will decrease. Another factor decreasing strain is the resorption of bone that widens the fracture gap. With less strain present, fibrous connective tissue and fibrocartilage replace the granulation tissue and provide further stabilization of the fracture (Fossum, 2013).

Intermediate phase of endochondral fracture healing –The reparative (proliferative) phase
The intermediate phase of bone healing is also called indirect bone healing (Haffner-Luntzer M 2019). During the reparative phase, mineralization of the fibrous cartilage into a callus can only occur when the fracture is stable enough. The revascularization carries osteogenic cells from the live bone tissue around and callus is formed both externally and internally. Haffner-Luntzer M 2019). Of both sides of the fracture gap, cartilage tissue grows and forms towards the fracture line to improve initially stability of the fracture gap. Chondrocytes during callus maturation becomes hypertrophic and mineralise there surrounding matrix called callus. To allow the recruitment of osteoprogenitor cells to empty lacunae some of the chondrocytes undergo aptosis. Other chondrocytes goes into osteoblasts to promote bone formation in the fracture callus (Haffner-Luntzer M 2019).

Last phase of fracture healing – Remodelling phase
During the final remodelling phase that may last for years, mineralized callus is continuously remodelled and increase in strength and stiffness resulting in bone that does not differ in structure or function from bone prior to the injury (Fossum 2013). When the injury site is in a

high degree of stability through bony bridging of the fractured cortices, haematopoietic progenitor cells of the monocytic lineage differentiate into osteoclasts, and start to resorbed the external fracture callus. The remodelling continues until the original bone structure and contour is restored (Haffner-Luntzer M 2019).

C. Treatment Methods

Factors that influence the choice of rehabilitation method depends on the condition and type of problems. Rehabilitation must be adapted to the individual´s as well as the owner´s conditions, the animal´s mentality and followed up with regular evaluations of progression (Marcellin-Little & Levine, 2015). This means that there is no template to follow, which is also shown when no evidence can be found for a specific program to be used for a particular type of damage. Based on this, an individual rehabilitation plan needs to be drawn up based on the individual´s own circumstances.

Therapeutic exercises that increase active joint mobility, muscle strength, endurance, speed and proprioception are generally the pillars of rehabilitation (Drum et al., 2015).

Physical treatment; Three phases of rehabilitation are included for recovery in dogs: the acute phase, subacute phase, and return-to-activity/play phase (Chmielewski 2003).

Acute phase: Set up goals with the owner and for the physical therapist. Example: Decrease pain, increase range of motion, retard muscle atrophy, normal gait pattern.
Common interventions; cryotherapy, laser therapy, NMES, joint mobilisation, soft tissue mobilisation, isometric exercise, range of motion exercises.

Subacute phase: Criteria to enter; full range of motion and effusion controlled. Goal: Increase muscle strength and endurance. *Common interventions*; isotonic (both open and close chain) and isokinetic exercises, NMES, proprioception exercises (balance), flexibility exercises, cardiovascular exercise Cardiovascular exercise (walking, hill work, underwater treadmill therapy)

Return to normal activity / play phase: *criteria to enter;* Can do all goals above.
Goal: Prepare patient for a return to normal activity. *Common interventions:* Depending of the dog owners' goal of the dog, i fits going to be an agility dog or a companion dog you need to train the dog for the sport that it's supposed to do.

Active or passive rehabilitation methods?
Passive rehabilitation has benefits such as helping the patient to move despite their own incapacity (Marcellin-Little & Levine, 2015). Active rehabilitation methods supports the patient to be more self-involved in exercise and weightbearing (Lawrence, 2006). Passive exercise training has not been shown to have any effect on muscle mass, muscle strength or fitness, therefore more important to start with active exercises as soon there is no contraindications for that (Prydie & Hewitt, 2015).

Passive range of motion and massage are passive methods and standing training is an example of active training. These three methods are example of easy to use exercises and could be suitable to use during the later stage of acute rehab phase and subacute phase, before the build-up phase begin (Prydie & Hewitt, 2015).

Range of Motion
True passive range of motion exercise is performed without muscle contraction and is facilitated by a therapist. Complete relaxation is rare in veterinary patients, so most range of motion exercises are active assisted. It is best to perform these activities in a quiet environment with the patient on a comfortable surface in lateral recumbency. It helps to relax the patient and relieve tension in the hind limb if massage therapy is performed before range of motion exercises. When performing range of motion exercises, it is best to involve only one joint at a time while keeping the other joints in a neutral position. The movements should start small and increase until the endpoint of the range of motion is reached and the patient appears to slightly resist. Applying steady pressure for 15 to 30 seconds at the end of flexion and extension of the stifle results in stretching. Fifteen to 20 repetitions performed two to four times a day is likely enough (Hardy 1998).

Physical Therapeutic Exercises
One of the most beneficial activities in a rehabilitation therapy program is therapeutic exercises (Taylor 1992, Simkin 1990, Millis & Levine 1997). Even short periods of standing provide an opportunity to build strength; aid in proprioceptive training; improve circulation, respiration, and elimination efforts; and enhance a patient's psychological well-being (Millis 2004). As therapeutic exercise training at the clinic the dog owner also gets home exercises according to witch rehab state the dog in is – acute, subacute och

Underwater Treadmill Therapy (UWTM)
Hydrotherapy is the term used when water is used as a therapeutic mode (Levine & Millis, 1997). Using a UWTM is a controlled exercise equipment to be achieved at an early rehabilitation phase. Movements are more controlled in comparison with swimming and it is not as easy to jump off an underwater treadmill as it is off a regular land treadmill (Davis et al., 2015; Marcellin-Little et al., 2015). It is also suggested that an underwater treadmill in some cases can be more appropriate for early rehabilitation than swimming as it places less strain on the spine and joints due to the level of control (Marcellin-Little et al., 2015) Underwater treadmill therapy is an excellent means of increasing strength and endurance during rehab. The benefits of UWTM include assisted weight-bearing, improved strength and endurance, cardiovascular fitness, range of motion, balance, and proprioception, as well as decreased joint effusion and peripheral edema. These benefits are due specifically to a combination of factors including buoyancy, hydrostatic pressure, viscosity, resistance, and surface tension (Hall 2004, Levine 2002,Driver 2004,Avellini 1982,Thein 1998, Dunning 2004). Buoyancy decreases the amount of weight placed on the affected limb and, therefore, decreases stress at the surgical site (Levine 2002). Hydrostatic pressure provides constant pressure to the affected limb submerged in water, which may aid venous and lymphatic drainage from an oedematous surgical site. Hydrostatic pressure has also been reported to decrease pain by providing a phasic stimulus to the sensory receptors to decrease pain perception (Richley 1997). The viscosity of water provides resistance which may help to strengthen muscles and promote cardiovascular fitness. Surface tension aids in strengthening as the joint undergoes increased motion and works to break through the water's surface (Millis 2004). Warm water in treadmills can help the dogs blood vessels do dilate and allows more blood to flow through the body (Brundell 2011) The warmth makes hydrotherapy a

form of heat therapy. Even this provides pain relief of some level (Flocker et al, 2014). For many dogs the warm pool provides relaxation (Levine & Millis, 1997). The decreased pressure on tissues during rehabilitation in underwater treadmill allows earlier weight bearing of weak limbs for instance after orthopaedic surgery and is in that sense a useful tool in rehabilitation (Connell & Monk, 2010). This applies to both walking on an underwater treadmill and swimming (Marcellin-Little et al., 2015). Standing assisted in water can be very comforting even for the non ambulatory patients (Marcellin-Little et al., 2015). Often the return of motor skills will first be noticed in water even though the animal would be non ambulatory on land (Drum, 2010). While unloading the weight bearing structures, the underwater treadmill also provides gentle straining which is beneficial for building muscle mass (Connell & Monk, 2010). Dogs also get a sensory experience when their feet are touching the floor of the treadmill. This can be utilised in the rehabilitation process (Brundell, 2011). Hydrotherapy can be used as a part of the rehabilitation process for trauma patients suffering from for example fractures. In these cases, the aim is to restore function after the fracture has healed (Gross Saunders, 2007). Building up muscle mass and increasing range of motion are the major goals (Henderson et al., 2015) suggests using a hot pack on the affected area before exercise to increase the extensibility of the muscle. It is worth remembering that the limb has probably been immobilized for several weeks before starting the physical therapy and exercising should therefore be started cautiously. Vigorous movements should be avoided until bone union can be seen on radiography. It is very individual when hydrotherapy can be started after a bone fracture. The type and location of the fracture impacts the healing rate greatly (Henderson et al., 2015). If the fracture has been repaired surgically, the same guidelines apply as in any case where postoperative hydrotherapy is used; the incision has to be healed and intravenous catheters taken out before starting the therapy. These include patients with external fixators as the fixator itself does not contraindicate the use of hydrotherapy (Davidson et al., 2005).

Medical Acupuncture

Most studies done on the effect of acupuncture are mainly performed on humans. Acupuncture is a multi-millennial treatment method that has its roots in traditional Chinese medicine. However, in Sweden healthcare for people, the treatment is based on science-wise physiological explanatory models and controlled studies. Pain conditions where there is good evidence of acupuncture in humans today are knee arthritis, back pain, neck-and shoulder pain, as well as headaches (Andersson, 1995). Acupuncture has been shown to provide analgesia, reduce chronic pain and improve outcomes when used in addition to, or in place of, opioids. (Bonnie D. Wright 2019). The effect of acupuncture in combination with analgesics was studied on 120 people with knee OA, and the result was that the combination of the two provided better pain relief than analgesics alone (Mavrommatis et al., 2012). In a study with dogs, nine dogs with elbow OA received as a result of elbow dysplasia acupuncture with electrical stimulation. None of the dogs showed a decreased lameness (Kapatkin, et al., 2006). Acupuncture is done by inserting acupuncture needles under the skin into muscles or soft parts in the body. Acupuncture inhibits pain by activating centers in the brain and spinal cord, which gives central pain relief. Endogenous opioids are released, and the pain fibers are blocked. The endorphin substance enkephalin improves bleeding and reduces muscle tone. In addition, other vasodilating substances such as calcitonin gene-related peptide (CGRP) are released. The improved blood flow stimulates healing and acts anti-inflammatory (Nisell R, Lundeberg T, 1999). Acupuncture has a good effect on nociceptive pain in muscles, tendons

and joints, as this pain is a reversible condition, while treatment with acupuncture in structural injuries that cause chronic pain results in poorer results. Studies show that 60-80% of human patients experience pain relief. However, the placebo effect is great on people (Werner M, Strang P, 2003; Nisell R, Lundeberg T, 1999).

TENS - Transcutaneous Eletrical Nerve Stimulation
Transcutaneous electrical nerve stimulation (TENS) is an external method for pain and hypotension relief (Vassak 2013, Liebano 2013, Arai 2012/2008). Several studies demonstrate that the possible mechanisms underlying TENS analgesia may be related to the endogenous opioid system (Sluka 1999, Kalra 2001). TENS is a clinical treatment that is non-invasive, inexpensive and safe to use with few side effect (Mauricio, 2017). TENS is based on the fact that skin-closed contacts nerves and / or muscles nerves are activated with a weak electrical current and thus stimulate the body´s own pain relief system due to the gate theory (Nisell R, Lundeberg T, 1998; Werner M, Stranf P, 2003).

Massage
Massage is defined as mobilization of soft tissue (Corti, 2014). For correct effect, the massage needs to have a specific purpose and the execution depends on the need that exists (Sutton & Witlock, 2014). The response received by the tissue during the treatment depends on how quickly the treatment is applied. Indication for massage are pain, muscle tension, decreased and adherent tissue (Hesbach, 2914; Sutton & Whitlock, 2014). The explanatory model for massage is that massage contributes to deactivation of limbic structures through the contact mind, modulation of activity in the sympathetic nervous system and reduced transport of nociceptive impulses, which are considered to have pain-relieving effect. Massage contributes to increased blood flow in the skin and reduced muscle tone, which is considered to lead to normalization of joint mobility (Coates, 2018; Sutton & Whitlock, 2014).

D. Assessment Methods (indications, error sources, scientific documentation)

Conclusions in Hyytiäinen et al 2013; ”Evaluation of atrophy, sitting position, quantitative measurement of static weight bearing, lying position, stifle flexion and extension, thrust from sitting and lying, and manual evaluation of static weight bearing ”*were the most valid and sensitive in detecting hind limb abnormality in our group of dogs, surgically treated for CCL and suffering from OA. We propose that these methods could be used when evaluating rehabilitation outcome of dogs with stifle problems”*(Hyytiäinen et al et al 2013).

Goniometer
Indications: Decreased joint range of movement.

Error Sources: Different people using the goniometer, moving dog.

Scientific documentation: Due to Jaegger et al Conclusions and Clinical Relevance in there study shows that Goniometry is a reliable and objective method for determining range of motion of joints in healthy Labrador Retrievers. Liljebrink Y and Bergh A showed in horses that ” 1) The intra-tester reliability was high to excellent (ICC 0.8-1) and the inter-tester reliability low to average (ICC 0.1-0.5); 2) significant differences in joint ROM were registered in carpus and hock when measuring in pairs compared to singly and 3) significant differences in joint ROM were registered measuring anaesthetised compared to standing

horses". And there conclusions where**"** as shown in human studies, goniometry is a promising tool in documenting passive flexion of fetlock, carpus and hock, if used by the same investigator. However, additional studies are needed for further validation".

Pressue Algometer

Indications: Pain sensitivity/tolerance. Measures the mechanical nociceptive threshold (MNT) and is a semi-objective tool since it objectively measures pressure, but the threshold point is subjectively assessed by the examiner. In animals' algometry is mainly used to quantify muscle tenderness, but in humans it is also used to measure overall pain threshold, wich is considered to decrease in patients with chronic pain.

Error Sources: The results are influenced by variation in speed of pressure applied and the threshold assessment/reading of the avoidance reaction. As with palpation, the level of mental awareness of the animal can influence the results, and there can be adaptation over time (Briley et al 2014, Coleman et al 2014, de Haus et al 2010).

Human error, variability in pain threshold at different anatomical sites, angle of device application, rate of pressure exerted through the algometer (Chesterton 2007).

Scientific Documentation: The method shows moderate to high intraexaminer reliability and low to moderate interexaminer reliability in dogs and horses (Bergh 2010, Coleman et al 2014, Haussler & Erb 2006; haussler et al 2007). In horses it correlates with palpation (de Haus et al 2010, Olsén et al 2013, Varcoe-Cocks et al 2006). A study by Briley et al (2014) reports that the pressure algometer device tested on normal dogs provided repeatable, reliable sensory threshold measurements. Evidence supports the substantial interrator reliability of digital algometry in human patients, as well as the ability of novice handlers to detect changes in pain threshold (Walton 2011).

Palpation

Indications: To detect and quantify the degree of pain, by provoking a pain reaction indication the location and severity of the pain. Can also be used to detect inflammation by assessing swelling and difference in temperature. Muscle tension (evaluate different muscle properties), soft tissue elasticity and mass, and the quality of joint end-feel.

Error Sources: Animal reacts differently to palpation based on its mental awareness, so if an animal is occupied with something like eating will not react as much to palpation as one that is fully concentrating on the examiner. Thus, it is important to examine the animal under the same circumstances. It is also known that the faster the pressure is applied to an animal, the stronger will the pain reaction be. (Bok – animal physiotherapy second ed.)

Scientific Documentation: palpation with the aim of assessing pain has higher intra-than interexaminer reliability. Hyytiäinen et al (2013) have shown a good correlation between the assessment of muscle atrophy in dogs by palpation and a present selection of standard outcome measures such as visual gait analysis and force platform measurement. Levine & Goulet (2014) demonstrated hat when palpating the temperature of pads that mimicked skin temperature ranging from healthy to inflamed, clinicians were able to detect temperature differences of 1-5 degrees Celsius. Studies on horses reports a correlation between pain

assessments by palpation and by pressure algometry (De Haus et al 2010, Olsen et al 2013, Varcoe-Cocks et al 2006).

Tape Measuring with dynamometer

Indications: Muscle mass measurements, inflammation, oedema, contralateral symmetry, joint circumference

Error Sources: Human error like force applied to the tape, positioning the body of the patient, differences in hair coat.

Scientific Documentation: Tape measure has shown to have very good intra-rater reliability and can therefore be a valuable tool for circumferential measurements (Bergfors 2012).

Pain Protocols

Indications: Different types of pain (acute/chronic), through measurement of behavioural traits by the physiotherapist or the owner. The pain protocols can be for example ethograms, pain faces, specific pain scales such as visual analogue scale, quality of life, activities of daily living questionnaires. Quality of life protocols are based on the individuals preferences and with animals that is the owner´s interpretation of what their animals prefer, i-e the situations that make the animal feel comfortable and uncomfortable (Budke et al 2008, Freeman et al 2012, Wiseman-Orr et al 20014).

Error Sources: The examinator bias is an important measurement error, for instant the physiotherapist´s/animal owner´s ability to understand and interpret the questions asked. If the protocol has been translated from its original language its important to translate it back to its original language to make sure that the intention of the protocol is the same.

Another bias of the clinician/owner is the interpretation of the animal´s behaviour. Further, there is an animal bias, i.e the animal´s level of motivation, how it participates in the text, and the influence that the examination setting has on its behaviour. It is also critical to analyse whether the altered behaviour is related to pain or if it can be explained by other non.pain.related factors.

Scientific Documentation: Depending on the specific protocol the validity ranges from low to high (Brown et al 2007,2013, Burton et al 2009, Hielm-Björkman et al 2011, Hudson et al 2004, Morton et al 2005, Walton et al 2013, Wiseman-Orr et al 2006. The repeatability is moderate (Bussieres et al 2008, Conzemius et al 1997, Shoening & Bradshaw 2006). The intraexaminer reliability is high (Firth & Haldane 1999, Guillot et al 2011, van Loon et al 2010) and the interexaminer reliability moderate (Hielm-Björkman et al 2011, Van Loon et al 2010). The numeric rating scale (NRS) and visual analogue scale (VAS) witch often used in human physiotherapy to measue pain) has in animals been shown to have week to moderate agreement and a intraexaminer variability that accounted for 35-36% of total variability, indicating that variability among veterinarians accounted for large differences in pain scores (Holten et al 1998, Hudson et al 2004, Quinn et al 2007. The NRS is recommended due to its lower variability.

Visual Lameness Examination /Gate analyses

Indications: Lameness. The subjective visual lameness examination is practical and inexpensive and enables assesment of movements other than just ordinary gait.
Error Sources: Examinator related. Not having a consistent surface at a consisted speed. Not being aware of compensatory movement that might mimic lameness.

Scientific Documentation: Lameness examination is a common method for assessing motion asymmetry, studies has shown a weak correlation between ratings by experienced clinicans and force – plate measurements wich apply for both dogs an horses, especially when assessing low-and moderate-grade lameness (Fuller et al 2006, Hewetson et al 2006, Keegan et al 1998,2010, Quinn et al2007, Waxman et al 2008). Despite demonstrating a weak correlation between visual evaluation of lameness in dogs compared to force platform measurements, Hyttiäinen et al 2013 reported good intraexaminer reliability.

Static weight bearing in hindlimbs with bathroom scales

Indications: The use of bathroom scales is the most cost-effective ´partly validated outcome measure of static weight bearing.

Error Sources: The positioning of the animal and the environment greatly influence the results. The magnitude of error due to inadequate positioning can differ between 15% and 30% of bodyweight.

Scientific Documentation: Hyttiäinen et al 2012 measured hindlimb weight bearing by force plate and bathroom scales, compared in dogs with OA. The sensitivity vas 39% and specificity 85% indicating that the method can be used in individual dogs but not for comparing different animals. Further, the agreement between the bathroom scale measurement and dynamic force platform was slight to moderate.

E. Recommended Plan

Treatment Protocol

Symtom	Tissue involved	Current status	Expected healing time	Overal Goal	Specifik Goal	Treatment	Evaluation
Non fully weightbearing right hindlimb.	1.Fractured tibiae 2.Muscle 3.Joints 4.spine	1.Almost healing completely 2.Atrohy, pain 3-4 stiffnes	6 weeks from actual fracture took place. So 2 weeks further. Veterinary expected full healing of	Return to normal function	1.Normal joint movement in stifle, tarsal joint and lumbar spine in 4 weeks. 2.Normal muscle strength in 8-12 weeks.	X-ray at the vet clinic Standing and walking with normal withbearing assisted help. Static balance training on	

			fracture 2 weeks from our fist meeting.			soft balancedisk Leashwalking in slow pase.

F. Advice on Returning Home

Nursing as a part of pain management

Since the main task of animal health professionals is to reduce the suffering of their patients, they must strive to reduce their pain and also give this to the pet owner when the dog comes home from an animal hospital. The important of good nursing is a big part of the pain treatment and cannot be emphasized enough. A patient who is scared or worried feels more pain. Unless the animals mental health is taken care of, painkillers do not have the same value.

Home environment

A simple but important measure is that the floor surfaces are not made of material that the dog can slip on. Lay out rugs for stability. Grass are often better surface to walk on outside because it does not put too much strain to the joints to the same extent than hard substrates (Jacson,2010; Marcellin-Little et al.,2014).

Home exercises

Rigidity can be aggravated in the morning and after the dog has been lying still for some time, the joints then benefit from warming up. This can be done with the help of thermotherapy followed by passive range of motion exercises (Jackson,2010; Marcellin-Little et al.,2014).

Activity/Exercise

Listening to the orthopaedic / veterinarian´s restrictions due to fracture healing how long walks and in what pace and when the owner can slowly progress. It should also be taken into account if more dogs are present in the household as a dog during rehab periods can be painfully affected and want to be alone from other dogs, or maybe even try to keep the same pace during walks as the healthy dogs and thus aggravate their pain (Millis & Levine, 1997).

Other

Other nursing measures are also to maintain the dog´s claws so that they are kept short as too long can cause injury, as well as review dog nutrition and eating habits as the dog will not move as much as before injury.

Discussion / Ethics & Law

According to the second section of the Animal Protection Act (SFS 1998:534), animals" must be treated well and protected against unnecessary suffering and disease". According to the fourth paragraph, they must" be kept and maintained in a good animal environment and in such a way that it promotes their health and allows them to behave naturally". It is therefore doubtful how high values of the pain scales can be accepted over a long period of time during for example rehabilitation of a dog, without being considered to violate Animal Protection

Act, as high value indicate that the dog is unable to behave naturally and also lives under constant pain.

There are many reasons as to why pain is negatively perceived. Apart from the actual suffering, prolonged pain can result in a weakened immune system and a deterioration of the wound healing process. There are many opinions about animal's pain. Recurring questions include whether animals can feel pain; how this pain is perceived; whether or not the pain relief is sufficient; and how to reduce pain. Nowadays it is well known that animals can sense pain in a similar way as humans, but the degree of pain might be difficult to judge. There are several different techniques and tools to help judge the degree of pain. Among others, scales that omit from animal behaviour. As the main purpose of veterinarians, animal nurses and physiotherapists are to decrease their patients' suffering, efforts must be made to decrease their pain. The basic concept for good care and pain management is 'Tender Loving Care', or TLC. Pain management (analgesic) is based either on blocking the nociceptors or on the body's own pain controlling system. Besides analgesic drugs we can use nonpharmacologic measures, such as acupuncture, transcutaneous electrical nerve stimulator (TENS), massage can relief pain by stimulating the body's own pain limiting mechanisms.

I find that one factor that may limit research in dog rehabilitation is control groups in study's done on animals, and it can be an ethical discussion. In an ethical discussion, what is acceptable to expose the animals to the gain of research? This meaning that rehabilitation methods may be evidence-based on the human side, but not on animals. More research is needed to know how these different rehabilitation methods can be used in an optimal way and what amount of training is appropriate. To be able to work evidence-based in practice we need more comparing studies with control groups. We also need more studies that compares methods against each other to evaluate whether combinations are more effective than others – and if so it would be ethical because no patient will be without rehabilitation methods as a control group will be.

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