13.6 Fracture healing

Laurie Edge-Hughes

Successful healing of a fracture is not only determined by complete bony union on radiographs, but also by the functional use of the limb thereafter. Physiotherapy following veterinary management of a fracture can be beneficial to fracture healing and is just as important as the corrective procedure itself in determining long-term outcome (Olmstead 1995; Nwadike & Hesbach 2004). Comprehension of healing stages and times is required for the implementation of an appropriate rehabilitation plan.

13.6.1 Stages of fracture healing (Magee 1986)

- *Stage1:* Haematoma formation.
- *Stage 2:* Traumatic inflammation (vasodilation, local swelling and loosening of attachment of periosteum to bone).
- *Stage 3:* Demolition (macrophages remove red blood cells, debris and fibrin. Detached bone fragments necrose and are attacked by macrophages and osteoclasts).
- *Stage 4:* Granulation (tissue formation, capillary loops form).
- *Stage 5:* Formation of woven bone and cartilage (woven bone is made of collagen ground substance called osteoid which is known as callus formation. Cartilage eventually dies and calcifies.)
- *Stage 6:* Lamellar bone formation: woven bone or cartilage is invaded by capillaries, and osteoblasts create osteoid.
- *Stage 7:* Remodelling: osteoclastic removal and osteoblastic formation occur simultaneously until bone is close to its pre-fracture state. Callus is slowly removed and becomes lamellar bone. The internal callus hollows and forms the marrow cavity.

13.6.2 Expected bone healing times (Olmstead 1995; Nwadike & Hesback 2004)

Time to clinical union for a fracture may be dependent upon age along with fracture type, severity and site. In canine patients younger than 3 months, bone-healing takes roughly 2 – 4 weeks, for animals 3 - 6 months of age, healing is 4 weeks to 3 months. When animals are between 6 and 12 months, healing can take 5 weeks to 5 months and if the dog is more than 1 year of age, then one might expect 7 weeks or up to 1 year for healing. There are known factors in human medicine that can contribute to delayed healing times such as insufficient frame stability, smoking (in the case of the canine patient, perhaps owner smoking could retard healing), poor weight bearing (perhaps due to pain), poor vascularization, diabetes, and poor nutrition (Gebauer 2002; Gebauer & Correll 2005; Steim & Lerner 2005).

13.6.3 Physiotherapy management of fractures

Physiotherapy management of fractures is very similar to post-operative joint surgery rehabilitation. Treatments can begin when the area is accessible (i.e. when a bandage or cast is off) or immediately if an internal fixation has been used. See post-operative joint surgery rehabilitation to determine goals for different stages of healing.

Additional physiotherapeutic interventions and electromodalities (see Chapter 10) have been recommended specifically for fracture management and may warrant consideration:

Ultrasound (U/S): Low intensity, pulsed U/S (0.03 – 0.05 W/cm^2 with either a 1.0MHz or 1.5MHz or 3.3MHz sound head used for 10 – 20 minutes per session daily, beginning day one post-operative fracture repair) has been shown to stimulate endochondral ossification due to stimulation of bone cell differentiation and calcified matrix production by intracellular calcium signalling and incorporation in chondrocytes (Gebauer 2002; Parvizi, Parpura, Greenleaf et al.

2002; Korstjens Nolte, Burger et al. 2004). U/S has been proven to be useful in increasing the stiffness of bone and speeding healing in diabetic rats (Gebauer 2002), and may be effective by stimulation of angioneogenesis (Childs 2003; Steim & Lerner 2005). Additionally, U/S has been shown to be effective on delayed unions / non-unions in children and did not have any effect on the growth plates (Gebauer & Correll 2005).

LASER: The use of LASER has been reported to increase bone stiffness by forming a smaller, stronger callus, which was more osseus in nature compared to controls in rats (Luger, Rochkind, Wollman et al. 1998). This study used a 632.8 nm, 35 mW laser for 30 minutes daily delivering 892 J/cm^2 superficially for fourteen (14) consecutive days.

Pulsed Electromagnetic Field (PEMF): Pulsed electromagnetic field has been reported to stimulate osteoblasts and chondroblasts (Childs 2003), however there are contradictory findings over the effectiveness of PEMF in bone healing in the literature. For this reason, particular attention should be payed to the parameters utilised in the studies that found this technique to be efficacious. Utilising a dog model, one study found that by using a PEMF setting of 1.5 Hz for 1 hour a day at four weeks post-op and lasting for eight weeks significantly increased stiffness and promoted greater new bone formation (Inoue 2002). This study also found an increase in mineral apposition rate and reduced porosity in the cortex adjacent to an osteotomy site. Delayed and non-unions have shown to improve with electrical and PEMF versus placebo and is comparable to bone grafting (Aaron, Ciombor, & Simon 2004). Preservation of bone mass was demonstrated in animals with osteotomy gaps and a significantly reduced size of gap was noted versus controls using 15Hz for three hours a day (Ibiwoye, Powel, Grabiner et al. 2004). The prevention of osteoporosis due to ovariectomy was demonstrated with PEMF at 7.5 Hz, for 8 hrs/day, for 30 days versus controls. This same setting was utilized in an earlier study, which demonstrated its ability to heal fracture non-union (Yang, Chang, Liu et al. 1994). However, one study found that PEMF at 100Hz for 4 to 8 hours a day for 2 to 4 weeks was effective in promoting bone formation around a rough surfaced implant (Matsumoto, Ochi, &

Abiko 2000). A study looking at the combined use of PEMF, ice and exercise following fractures found that the combination group had better pain reduction and joint ROM than an ice and exercise group or a PEMF and exercise group (Cheing, Wan, & Lo 2005). This study utilized 50Hz for 30 minutes per day. Other studies have found no effect with PEMF on healing of fractures, using similar settings. Clearly more research needs to be conducted on different types and settings of PEMF machines to better aid in clinical decision making for practitioners.

Electrical stimulation: Some studies utilise implantable electrodes (Clark 1987), but as this is not generally considered standard physiotherapy practice, this section will address use of surface neuromuscular electrical stimulation (NMES). A NMES protocol used in rabbits (surface electrodes placed 3 cm proximal to the fracture site and the other proximal to the first electrode, using 25mA of current, at a pulse width of 50μseconds, at 4 hertz with an on cycle of 20 seconds, and off cycle of 15 seconds and a ramp of 5 seconds, one hour daily, beginning on day 4 post-op for 25 days). demonstrated an increase in mineralised callus by 2 weeks, and a significant increase in callus mineral content and mineralised callus compared to controls by 8 weeks (Park & Silva 2004). Bone had greater torsional parameters, for stiffness, maximum torque withstood, and required a greater amount of energy to create failure (Park & Silva 2004). It is reported that the cathode should be placed closest to the site of the fracture and the anode near to the first electrode for proper application (Childs 2003).

Weight bearing and early mobilization: A study of the effects of weight-bearing on healing of cortical defects in the canine tibia (Meadows, Bronk, Chao et al. 1990) found significantly less woven bone formed in the defects in the non-weight-bearing tibia than in the weight-bearing tibia. This was determined to be due to the disuse response in the underloaded tibia, in which less bone formed, rather than to the formation of more bone in the weight-bearing tibia. In one review paper, it was found consistently that early mobilisation was preferable over rest in human patients and the authors recommended that mobilisation may be able to be employed more often and perhaps more vigorously (Nash, Mickan, Del Mar et al. 2004). They did, however, caution that it would also be naïve to assume that mobilisation is better than immobilisation in all circumstances. Other studies on humans and animals have found similar findings and have reported that early mobilisation has the potential to result in earlier recovery of mobility and strength, facilitation of an earlier return to activities and did not affect fracture alignment (Meadows, Bronk, Chao et al. 1990; Kamel, Iqbal, Mogallapu et al. 2003; Feehan & Bassett 2004; Nash, Mickan, Del Mar et al. 2004; Cheing, Wan, & Lo 2005; Davidson, Kerwin, & Millis 2005).

Regarding Quadriceps Contracture

a) Pathophysiology

Quadriceps contraction is essentially a muscular contracture and adherence to the underlying bone following a femoral fracture with or without surgical fixation, whereby the muscle become taut and adherent, resulting in a characteristic hind limb hyperextension. The pathophysiology behind this condition includes the presence of fibrous adhesions that cause a 'tie down' of the vastus intermedius muscle over the fracture site, muscle atrophy, disuse osteoporosis and degenerative joint changes.[2, 3, 4, 10] The adhesions of the muscle result in stiffness within the muscle and the adjacent stifle joint.[2, 3, 4]

Lack of movement and muscular unloading will cause a disuse osteoporosis. In disuse osteoporosis there appears to be a decreased number of osteoblasts and an increased recruitment of oestoclasts.[2, 3, 4] Disuse osteoporosis can been seen as early as 2 weeks following immobilization.[2, 3, 4]

Further to the fibrous adhesion in the muscle is the occurrence of muscle disuse atrophy.[2, 3, 4] The muscle atrophy is most pronounced in the type I muscle fibres of the vastus lateralis muscle.[2, 3, 4]

Immobilizations will also result in joint changes.[2, 3, 4] Within 4 days, the articular surfaces in apposition display microscopic changes such as deep fibrillation, and deep erosion of the cartilage.[2, 3, 4] By day 6 there is a massive decrease in cartilage proteoglycan synthesis and content with subsequent cartilage softening.[2, 3, 4] As early as two weeks following immobilization, non-contact articular interfaces can be replaced by pannus (which matures to fibrous tissues) and fibrous ankylosis and occasional cartilaginous and bony ankylosis may occur after months of immobilization.[2, 3, 4] The immobility may also lead to a progressive contracture of the joint capsule and periarticular fibrous connective tissue, patellar tendon, ligaments and fascia.[2, 3, 4]

Lastly, growth disturbances can ensue following a quadriceps contracture. Multiple changes throughout the affected limb in a young animal can include hip subluxation, bone hypoplasia, increased femoral torsion, hypertrophy of the ligament of the femoral head, significant decreases in blood flow of the femoral head and progressive degenerative changes in the hip joint.[2, 3, 4]

Reversibility of some of these signs can be attained if the condition is detected early enough. Joint changes can be reversed is the immobilization period is less than 4 weeks.[2, 3, 4] Muscular disuse atrophy can also be reversed, but the recovery period may be 2 – 4 times longer than the period of immobilization.[2, 3, 4] As well, disuse osteoporosis may take as much as 5 – 10 times longer than the period of immobilization for recovery and may be of some degree of permanence if the immobilization lasts longer than 12 weeks.[2, 3, 4] Growth disturbances are likely to be permanent.

b) Predispositions

There are a few factors which may predispose the animal to developing a quadriceps contracture. At greatest risk of developing this condition are young animals, often 3 – 6 months old.[2, 3, 4, 13, 18] Trauma to the quadriceps muscle, femoral artery and nerve as well as comminuted fractures, incomplete fracture reduction, fracture instability or osteomyelitis have been sited to heighten the occurrence of quadriceps contractures.[2, 3, 4, 13] Additionally, this problem may ensue following casting, traction, bandaging or other forms of prolonged immobilization in an extended limb position or pain that limits stifle flexion following surgical repair of the fracture site. [2, 3, 4, 13]

c) Prevention

Identification and management of those animals at risk (see above) may aid in prevention of the formation of a quadriceps contracture. Incorporated into the surgical repair could be a plastic sheeting over the femur and under the quadriceps muscles that would disallow attachment of the muscle mass to the bone. [2, 3, 4, 18] A 90/90 flexion bandage for the stifle and hock may be utilized for animals at risk or routinely for 10 days post operatively following femoral fracture repair.[13] Alternately a dynamic flexion apparatus which incorporates an external fixateur to the pelvis or femur and elastic bandages attached to the distal limb that promote hind limb flexion while allowing active extension for ambulation have been described in the literature as effective preventions or treatments for these cases.[10, 16]

d) Physiotherapy management in a developing quadriceps contracture

When in suspect of the development of a quadriceps contracture, physiotherapy can be utilized to draw attention to the condition and alert the veterinary surgeon to the need for a short term 90/90 flexion bandage.[13] Physiotherapy can then endeavour to address and/or prevent issues such as disuse atrophy, joint nutrition, joint range of motion and disuse osteoporosis. Neuromuscular electrical stimulation (NMES) may be utilized over the hamstrings (biceps femoris, semitendinosis and semimembranosis) in order to enhance stifle joint flexion[1], or over the quads (vastus lateralis in particular) to improve muscular strength and prevent disuse atrophy.[6] The NMES may also aid in fracture healing and hence prevent the disuse osteoporosis.[15] Joint nutrition may be enhanced by physiological and accessory motion joint mobilizations.[11, 18] Disuse osteoporosis could be combated with facilitated periods of limb use and early mobilization which have the potential to result in earlier recovery of mobility and strength, facilitation of an earlier return to activities and should not affect fracture alignment.[5,7, 9, 11, 14] This might accomplished by forced ambulation when the 90/90 bandage is off, perhaps utilizing a noxious or aggravating stimuli to the non-affected limb or other weight shifting exercises.[8]

Summary

Physiotherapy should be an integral part of fracture management, both to optimize healing and return to function but also for early identification of complications such as quadriceps contractures. It is imperative that animals at greatest risk of developing this condition be put on a physio treatment regime immediately post-operatively.

References:

1. Baker, LL. (1987) 'Clinical use of neuromuscular electrical stimulation.' In *Clinical Electrotherapy*. Nelson RM, Currier DP eds. (Appleton & Lange: Los Altos, Ca, USA).
2. Bardet JF. (1987) 'Quadriceps contracture and fracture disease.' *Vet Clin N Am Sm Anim Pract*. 17 (4): pp 957 – 973.
3. Bardet JF. (1995) 'Fracture disease.' In *Small Animal Orthopedics*. Olmstead ed. (Mosby: St Louis, USA).
4. Bardet JF, Hohn RB. (1983) 'Quadriceps contracture in dogs.' *J Am Vet Med Assoc*. 6: pp 680 – 685.
5. Childs SG. (2003) 'Stimulators of bone healing.' *Orthop Nurs*. 22 (6): pp 421 – 428.
6. Currier DP. (1987) 'Electrical stimulation for improving muscular strength and blood flow.' In *Clinical Electrotherapy*. Nelson RM, Currier DP eds. (Appleton & Lange: Los Altos, Ca, USA).
7. Davidson JR, Kerwin SC, Millis DL. (2005) 'Rehabilitation for the orthopedic patient.' *Vet Clin Sm Anim Pract*. 35 (6): pp 1357 – 1388.
8. Hamilton S, Millis DL, Taylor RA, Levine D. (2004) Therapeutic exercises. In *Canine Rehabilitation and Physical Therapy*. Millis DL, Levine D, Taylor RA eds. (Saunders: St Louis, Miss, USA).
9. Kamel HK, Iqbal MA, Mogallapu R, et al. (2003) 'Time to ambulation after hip fracture surgery: relation to hospitalization outcomes.' *J Gerontol*. 58A (11): pp 1042 – 1045.
10. Liptak JM, Simpson DJ. (2000) 'Successful management of quadriceps contracture in a cat using a dynamic flexion apparatus.' *Vet Comp Orthop Traumatol*. 13: pp 44 – 48.
11. Maitland G, Hengeveld E, Banks K, English K. (2005) *Maitland's Vertebral Manipulation*. (Elsevier Butterworth Heinmann: Toronto).
12. Meadows TH, Bronk JT, Chao EYS et al. (1990) 'Effects of weight-bearing on healing of cortical defects in the canine tibia.' *J Bone Joint Surg*. 72A (7): pp 1074 – 1080.
13. Moses P. (2006) 'Module 1. Canine Orthopaedics.' In *Pathological Conditions in Animals II*. McGowan, Moses, Malikides eds. (University of Queensland, Australia).

14. Nash CE, Mickan SM, Del Mar CB, Glasziou PP. (2004) 'Resting injured limbs delays recovery: a systematic review.' *J Fam Pract*. 53 (9): pp 706 – 712.
15. Park SH, Silva M. (2004) 'Neuromuscular electrical stimulation enhances fracture healing: results of an animal model.' *J Orthop Res*. 22: pp 382 – 387.
16. Wilkens BE, McDonald DE, Hulse DA. (1993) 'Utilization of a dynamic stifle flexion apparatus in preventing recurrence of quadriceps contracture: A clinical report.' *Vet Comp Orthop Traumatol*. 6: pp 219 – 223.
17. Wright JR. (1981) 'Correction of contracture of the quadriceps muscle.' *Vet Med Sm Anim Clin*. April: pp 523 – 526.
18. Zusman M. (1986) 'Spinal manipulative therapy: review of some proposed mechanisms, and a new hypothesis.' *Aust J Phyty*. 32 (2): pp 89 – 99.