One Small Step for Mags

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Class of 2018

Clinicopathologic Conference

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August 25th, 2017

MISSISSIPPI STATE UNIVERSITY™
COLLEGE OF VETERINARY MEDICINE

Introduction

Salter-Harris fractures are bone fractures which involve the epiphyseal plate or physis in an immature animal.[11] In order to fully understand and effectively treat epiphyseal plate fractures it is important to have a basic understanding of the microscopic anatomy and physiology of the growth plate itself. An epiphyseal plate has four layers of different cell types which include resting cells, proliferating cells, hypertrophic cells, and finally a layer in which endochondral ossification occurs.[5, 11] The space between the cells of the epiphyseal plate is occupied by cartilage matrix. It is the cartilage matrix that provides strength for the growth plate and not the layers of growing cells. Portions of the third layer of cells and the entire fourth layer of cells within the epiphyseal plate are reinforced through calcification which dramatically increases the resistance to fracture. This principle explains why often the epiphyseal plate shears completely along the transition zone between the third and fourth layer of cells which allows all of the layers of growing cells to remain intact and together. This increases the likelihood of the physis remaining open and continuing to grow with minimal disruption.[11] However the ability of the physis to remain open depends on a number of other factors as well. Five original Salter-Harris fracture types were described and present routinely in veterinary medicine due to the relative weakness of the epiphyseal plate compared to surrounding bone. These fractures are common in immature animals and special consideration must be given to surgical stabilization of open physeal fractures due to the possibility of damaging the physis which can result in disruption of the growth of the affected bone.[8, 11] If disruption is severe enough it can result in varying degrees of loss of function depending on the age of the dog and the contribution of the damaged physis to the length of the bone.[9, 11]

History and Presentation

Mags is an approximately 4 month old mixed breed intact female dog presented to Animal Emergency and Referral Center in Flowood, Mississippi on 11/19/2016 after being hit by a car two days prior to arrival. Upon presentation she was non-ambulatory and radiographs revealed multiple fractures present which included right distal condylar fracture, left cranial acetabular fracture, left ischial tuberosity fracture, bilateral sacroiliac fractures, and multiple pelvic fractures. Radiographs also showed evidence of pulmonary contusions present. Superficial abrasions were present on limbs and ventrum. Rectal examination revealed normal anal tone and palpable pelvic fractures. Capillary refill time was 2 seconds. Blood serum chemistry was found to be within normal limits with a hematocrit of 28 percent. SpO2 was 89 percent. Blood pressure was 103/57 with a MAP of 72. Lactate was 2.6. No arrhythmias were evident on ECG. FAST scan of the abdomen revealed no evidence of free fluid present. A partial neurologic examination was performed, but conscious proprioception was difficult to evaluate due to the patient being non-ambulatory. Reflexes and pain were present in all four limbs.

Mags was transferred to MSU-CVM Animal Health Center on 11/21/2016 for surgical treatment. She arrived with an intravenous catheter and a urinary catheter in place. Upon arrival she weighed 17kg and was bright and alert with a pulse of 160, respiratory rate of 24, and a temperature of 101.3 F. A FAST scan of her abdomen revealed few abnormalities and lung sounds were mildly exaggerated upon auscultation. Pre-surgery radiographs confirmed the originally diagnosed fractures were present including a Salter-Harris type I fracture of the right distal humerus. Abrasions were observed on her limbs and she was still deep pain positive and had normal patellar reflexes. PCV was found to be 21 percent at this time with a total protein of 6.6. Lactate was 0.9. A subsequent blood serum chemistry was performed revealing multiple abnormalities including a CK of 9085 U/L (normal range is 50-300), ALT of 319 U/L (normal is 10-90), and ALP of 221 U/L (normal is 11-140). A complete blood count also revealed several abnormalities including a PCV of 20 percent (normal is 34-60). A coagulation profile was performed and was within normal limits.

Pathophysiology

The epiphyseal plate in an immature animal is softer and therefore weaker than other areas of the bone which predisposes the physis to fractures.[2] The Salter-Harris classification system was developed to categorize these fractures and is useful in part to assess prognosis for return to function in canine patients. Five original classes of physeal fractures were used in the Salter-Harris classification system and more recently a sixth classification has been described.[8] Salter-Harris type I fractures involve complete fracture through the physis. Salter-Harris type II fractures involve the physis and metaphysis. Salter-Harris type III fractures involve the physis and epiphysis commonly with articular involvement as well. Salter-Harris type IV fractures involve the epiphysis, physis, and metaphysis. Finally, Salter-Harris type V fractures describe crushing injury to the physis. These are the five original Salter-Harris categories however; a new type IV classification has been added to include partial physeal damage which results in only a portion of the physis closing prematurely leading to asymmetrical growth. The epiphyseal plate, or growth plate, closes at varying ages in an immature dog which can range from 8 months to 18 months in giant breed dogs.[9] Salter-Harris fractures type I and II account for about 65 percent of physeal fractures in immature dogs while type III and IV Salter-Harris fractures account for about 25 percent of physeal fractures.[7] Type I has the best prognosis and type V has the worst prognosis. Generally, the prognosis for complete return to function decreases in order from Salter-Harris type I to type V fractures although this depends on many factors including patient signalment.[8] If not properly treated physeal fractures in a developing juvenile animal can result in the affected bone to be significantly reduced in size for the duration of the animal's life. This can lead to severe osteoarthritis, loss of function of the affected limb, or a permanently abnormal gait.[11] Even if some growth plate damage is expected it is important to note that if the final length is less than 20 to 25 percent of its original potential then the gait may not be obviously affected.[8] Physeal damage to the distal ulna commonly results in clinical signs later in the animal's life. Several common scenarios present which can be attributed retroactively to premature epiphyseal closure, although these conditions are rarely identified before deformity or lameness appear.[11,12] One such example can be observed in the case of valgus or lateral deviation of the carpus due to the radius and ulna being fused. Physeal damage to the ulna can result in the ulna ceasing in growth with the radius continuing to grow causing the carpus to deviate laterally. This condition is termed progressive shortening.[8] Although this is one of the more common angular deformities, others exist as well.

The approximate time of physeal closures has been studied and documented in dogs along with the percentage of growth that each physis contributes to the final length of the bone. These are important factors to consider regarding both treatment and prognosis for a specific case. The values exist as a range because breed specific variations do occur.

TABLE 2 **Approximate Closure Times of the Growth Plates in the Long Bones of an Average (25–30 kg) Dog**

Forelimb			Hindlimb		
Growth Plate	Age at Closure		Growth Plate	Age at Closure	
	Earliest	Latest		Earliest	Latest
Scapular tuberosity	12 wk	5 mo	Greater trochanter	6 mo	11 mo
Proximal humerus	10 mo	12 mo	Proximal femur	6 mo	12 mo
Distal humerus	5 mo	8 mo	Lesser trochanter	9 mo	12 mo
Proximal ulna	5 mo	8 mo	Distal femur	6 mo	11 mo
Anconeal process	4 mo	5 mo	Proximal tibia	6 mo	12 mo
Distal ulna	6 mo	11 mo	Tibial tubercle	10 mo	12 mo*
Proximal radius	5 mo	9 mo	Distal tibia	5 mo	11 mo
Distal radius	6 mo	11 mo	Medial malleolus	4 mo	5 mo
Accessory carpal bone	10 wk	5 mo	Proximal fibula	6 mo	11 mo
Metacarpal bones	5 mo	7 mo	Distal fibula	5 mo	11 mo
Phalanges	4 mo	7 mo	Tuber calcaneous	11 wk	8 mo
			Metatarsal bones	5 mo	8 mo
			Phalanges	4 mo	8 mo

*Clinical experience shows that the growth plate of the tibial tubercle may close as late as 15 to 18 months in giant-breed dogs.

TABLE 3 **Approximate Contribution of the Growth Plates to the Growth of Canine Long Bones**

Forelimb		Hindlimb	
Growth Plate	Percentage	Growth Plate	Percentage
Proximal humerus	80	Proximal femur	25
Distal humerus	20	Distal femur	75
Proximal radius	40	Proximal tibia	55
Distal radius	60	Distal tibia	45
Proximal ulna	0–15	Proximal fibula	60
Distal ulna	85–100	Distal fibula	40

Note. Tables 2 and 3 Reprinted from “The Epiphyseal Plate: Physiology, Anatomy, and Trauma”, by Von Pfeil and DeCamp, 2009

Diagnostic Approach and Considerations

Diagnosis involves radiographic evidence of physeal damage. The ability to diagnose a Salter-Harris fracture depends on the amount of displacement or must be diagnosed in comparison to the contralateral limb. Type V Salter-Harris fractures involving compression damage to the growth plate are difficult to diagnose soon after injury and are often only discovered later when clinical signs develop. Studying the thickness of the epiphyseal plate or the deviation of the epiphysis is often necessary to confirm diagnosis. Type VI Salter-Harris fractures are typically the result of bony bridging which leads to a portion of the epiphyseal plate closing prematurely and is usually a retroactive diagnosis.[13] When a physeal fracture is present, quick and accurate diagnosis is crucial for proper treatment. Type I, II, and III fractures have a good prognosis for minimal disruption to the physis with proper and timely treatment. Types IV, V, and VI are very likely to result in significant damage to the physis and will usually lead to premature closure of the physis regardless of treatment option is chosen.[3] Diagnosis is most important in very young animals as the disruption to the epiphyseal plate will be greatly magnified.[4]

Treatment and Management

Treatment of Salter-Harris fractures depends greatly on the diagnosis and correct categorization of the fracture. Timing is of great importance in regards to the degree of disruption to the physis. Reduction of physeal fractures in immature dogs is most effectively accomplished within the first 24 hours following injury. Physeal injuries more than 10 days old may actually be more effectively treated with corrective osteotomy in order avoid to the forceful reduction at this point which can lead to partial damage and varus or valgus deformities because of uneven growth.[8] Treatment involves reduction and stabilization of the fragments without excessive manipulation during surgery. Excessive use of instruments in order to achieve purchase on the fragments can be counterproductive to physeal function. Therefore, it may not be necessary to achieve perfect reduction when dealing with a Salter-Harris fracture, depending on articular surface involvement (Type III and IV fractures). Gentle manipulation and adequate apposition is preferable to complete reduction if the former is accomplished with less manipulation. The choice of orthopedic implants used to reduce physeal fractures also requires special consideration.[9] Epiphyseal plate fractures are most commonly reduced using internal fixation sometimes along with external coaptation. The diameter of implants used should be no larger than necessary as disruption to the growth plate is proportional to the size of implants used.[11] The location and type of physeal fracture determines which orthopedic options are available. An ideal internal orthopedic implant for use in physeal fracture would be small, smooth Kirschner wires placed perpendicularly to the growth plate. This minimizes surface area disruption of the hypertrophic epiphyseal plate and also prevents binding to the implant due to it being smooth.[3] The bone will continue to grow in length during the healing process so it is necessary for the new bone growth to be able to slide along the implant as opposed to being locked by the implant which can cause premature closure. Threaded internal implants should be avoided as should implants which lock the bone into a fixed position and do not allow for expansion through natural growth. Internal Kirschner wires which are threaded have the effect of allowing bone to heal around the threads and become locked to the threads thereby causing closure of the physis. Plates that span the physis are to be avoided as well for the same reason. If, due to lack of options, it is necessary to use one of these less desirable implants then they should only remain in place until union is achieved in order to allow growth along the physis to resume.[8] External fixation has also proven effective in reduction and stabilization of distal humeral physeal fractures. External fixation has the added benefit of not needing a secondary surgery in order to remove the implants as they can usually be removed through the skin.[1]

Several newer methods of Salter-Harris fracture stabilization have recently been described. In one study a hinged trans-articular external fixator was placed to stabilize a proximal tibial fracture in a dog. In this case the patient was able to retain full range of motion even with an external fixator spanning the joint.[6]

In another study the use of chondrocyte allograft transplantation was documented as a method for treating damaged growth plates. This method did prove effective at potentially preventing bony bridge formation leading to premature closure of the physis.[10]

Case Outcome

Outcome of Salter-Harris fractures varies greatly depending on numerous factors. The overall health of the patient upon presentation along with the viability of the tissue around the fracture site determines whether optimal treatment of the fracture is a valid option. Some patients, especially those sustaining trauma to more than one area, must to be properly stabilized before the fractures are dealt with. Epiphyseal plate injuries are relatively time sensitive if preservation of a viable open physis is to occur. Therefore although it is ideal to reduce and stabilize them as quickly as possible, this is not always an option. Another consideration is the type of Salter-Harris fracture present. Return to full function is expected and commonly achieved with types I, II, and III with minimal reduction in overall length of the fractured bone. With the remaining types IV, V, and VI some degree of premature closure and loss of function is common and difficult to avoid.[8]

Mags presented with severe trauma to multiple areas of her body. She sustained substantial hemorrhage and was closely monitored for anemia with her PCV reaching a low of 13 percent after being rehydrated upon arrival at AERC. She was not oxygenating well at first and her initial SpO2 readings were at 89 percent. Rapid surgical correction of her multiple fractures was not an option for her as she required several days of stabilization prior to surgery. Eventually when she was transferred to MSU-CVM Animal Health Center she was deemed stable enough to undergo orthopedic surgery five days following her initial injuries. On 11/22/2016 Mags was put under general anesthesia and prepared for surgery. Her sacroiliac luxations were corrected through the use of a lag screw to stabilize her right luxation and a cancellous screw to stabilize her left luxation, both placed in a closed fashion using fluoroscopic guidance. The left acetabular fracture was reduced and stabilized by using a SOP locking plate. Lastly her humeral fracture was reduced and stabilized. Care was taken to avoid excessive manipulation of the epiphyseal plate while two Kirschner wires were inserted into the distal humerus using a cross pinning technique to minimize disruption to the epiphyseal plate. Post-operative radiographs revealed adequate reduction and pin placement regarding the distal humerus. A Spica splint was placed around the right forelimb and was examined and changed on a daily basis until discharge. Mags remained at the hospital for the following 7 days until she was discharged on 11/28/2016. She was still relatively non-ambulatory at this time, but she was stable and her fractures seemed to be healing well.

On 12/9/2016 Mags returned after being referred by her veterinarian for pin migration. Radiographs were taken and revealed significant migration of the lateral Kirschner wire and that the fracture fragments were no longer in adequate apposition. Her elbow was swollen and draining as well and she was diagnosed with osteomyelitis. The decision was made to take her immediately to surgery following bloodwork results. She was placed under general anesthesia and the right elbow area was prepped. The lateral Kirschner wire was very loose and was removed. An incision over the lateral aspect of the elbow was made and a sample of the purulent material present was submitted for culture and sensitivity analysis. The elbow was thoroughly flushed and debrided. The fracture fragments were reduced and an external fixator was placed to stabilize the elbow. A Penrose drain was inserted into the incision site and left to drain distally. Radiographs were taken following surgery which confirmed adequate reduction of the humeral fracture fragments. Mags remained on Clavamox until the results of the culture revealed a growth of Enterobacter cloacae. She was then switched to enrofloxacin which was found to be effective against this specific pathogen.

Mags returned for radiographs on 1/4/2016 and 1/25/2016. The right humerus looked to be healing well and the external fixator was removed without complications. The osteomyelitis also resolved and Mags was able to return to very near full function in all four limbs.

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