N Harcourt-Brown
30 Crab Lane Harrogate
North Yorkshire HG1 3BE
United Kingdom

The aim of orthopaedic surgery, in any animal, is to attempt to return a 'broken' animal to normal function. In some cases this may not be possible, practical, or even necessary. Injured wild birds and sporting birds must be returned to normal function; failure to do so in an injured wild bird will make release back to the wild impossible. In comparison, pet parrots do not need to search for food or need to fly, and more adventurous techniques can be considered, even though they may not give a 'perfect' result.

These lectures will be confined to the examination, diagnosis, and treatment of limb injuries and lameness of captive parrots and birds of prey, with some reference to injured wild birds and pet caged birds.

LAME BIRDS

It is uncommon for bruising or a sprain to cause lameness that lasts long enough for the bird to be brought to the veterinarian. Only make this diagnosis if you are sure that other causes of lameness have been ruled out. Never jump to conclusions or think that a single problem is the whole answer. The bird may have an obvious injury or cause of lameness but always examine the rest of the bird. Long term captive birds are often nutritionally deficient and newly imported birds, young birds, or wild birds can be affected by infectious diseases that can make the bird clumsy and more likely to injure itself.

Birds will be brought by clients in cages, traveling boxes, jessed and on the fist, or loose and unrestrained. However all birds should be restrained and under control whilst in the waiting room.

A full clinical history should be obtained:

- Species, breed, sex, and age;
- Length of time in owner's possession, wild caught or captive bred and who bred the bird, or where it was purchased;
- Diet and housing;
- How did the lameness occur: observed traumatic event, sudden or insidious onset. Sudden onset lameness in a growing bird might still be a reflection of a long-standing growth problem; and
- Record which limb(s) is involved.

Whilst taking a history from the owner watch the bird. Note abnormal behaviour - is the wing placement normal or does it favour one leg? Owners frequently refer to a bird having a dropped wing, this just means that its wing is 'hanging' or held in the wrong position.

If possible examine the bird without restraint. This is easy in trained falconry birds or pet parrots. Observe the whole bird at rest, as it may not be possible to perform a full clinical examination easily.

For birds of prey with wing injuries that are brought by the falconer on his 'fist', ask him to unsettle the bird by rotating his fist a little and observe the symmetry of the wings' movements. This will occasionally reveal minor leg injuries too often by a reduction in the ability of the bird to grip with its foot. I find it better to hold the bird 'on my fist' as this tells me about the bird's grip and allows me to move the bird about as I want.

Catch the bird: use a towel and veterinary common sense. It is vital to avoid further injury to the limb. It is a two person job to examine a conscious bird. I tend to trust falconers to hold their birds but not most parrot owners.

First of all, carry out a general clinical examination to assess the bird's state of health. Lie a bird of prey on its back on a towel and use this to cover the bird's head so that it cannot see. Parrots can be held and assessed but usually need a general anaesthetic for a full examination. Examine the affected limb and compare with the normal limb. Birds are very strong and it may not be possible to ascertain the full extent of the injury. Great care must be taken not to exacerbate the damage especially if the limb has a fracture(s). The signs of a fracture are similar to those in mammals: disability, deformity, crepitus, swelling.

Pain is usually a less obvious sign.

Also look for:

- Damage to the integument, traumatic or pathological;
- Site of fracture;
- Note whether the fracture is:
    - Compound
    - Close to a joint or has joint involvement

Are there any neurological deficits? If it cannot move the limb, can it feel the extremity? Pinching involving a finger nail will nearly always elicit a response - if it cannot feel this you should worry. Some birds do not respond on day 1 so if it cannot feel try again tomorrow.

Wild birds: nutritional status and intercurrent disease must be considered as well as long standing injuries. In the UK nearly all injured wild birds have failed the fitness test. Only on major migration routes can one consider exhaustion as a possibility, and even then the bird should be thought to be unwell as well as exhausted. Parasites change the behaviour and survival of birds Saumier et al. (1986).

All traumatically injured wild birds must have fluids: *per os* or intravenous bolus of glucose and electrolytes. A dose of fenbendazole at 100 mg/kg and a dose of broad-spectrum antibiotic such as marbofloxacin at 10 mg/kg or trimethoprim/sulphonamide at 30mg /kg SC.

Place the bird in a warm, dark cardboard box and, if thin, feed an appropriate, high-energy food 30 minutes later. Critical Care Formula (VetArk) is good but if the bird is unwell beware of it refluxing up the oesophagus and down the trachea. If it is collapsed, an IV bolus of glucose saline would be better.

Do not perform surgery on injured wild birds for the first 24 hours unless there are special reasons. First aid is of greater benefit. A good proportion of injured wild birds will die in the first 24 hours due to their illnesses no matter what one does; hasty surgical interference will make the numbers greater and also waste veterinarian's time.

Examination of a conscious bird will allow diagnosis of only a proportion of the causes of lameness. It is often possible to diagnose fractures and dislocations but minor fractures and injuries to joints and their associated structures can only be assessed by examining the unconscious bird.

General anaesthesia and examination of the unconscious and relaxed bird, followed by radiography is mandatory in all cases where the cause of lameness is serious, equivocal, and persistent, or where there is a fracture or dislocation.

Place the anaesthetised bird on its back and start by examining the wings. Take hold of the tip the longest primary feathers of each wing and gently pull both wings simultaneously into full extension. Note the 'feel' and the symmetry of this procedure; it is a very sensitive test of wing damage. On one wing and then the other, examine each long bone and then each joint separately; repeat, examining both wings at the same time. The wing joints will often have a good degree of laxity when flexed but are usually unable to be moved dorsoventrally when extended. Many caged parrots do not fly much so they may well have reduced wing spread but it should be equal on both sides. If it is not obvious which wing is affected take note of the plumage. Uneven feather wear can point to a problem in one wing and not the other.

Re-examine the integument covering the ventral aspect of the wings and body especially in the axilla. Examine any scabs or areas where there is exudation: old and dried or fresh. Do not cut feathers, pluck the small ones and wet the large ones: use dilute benzalkonium chloride or similar antiseptic. If the skin is torn be very careful whilst plucking as it is easy to make the tear worse. When plucking, hold the skin and pluck against the tension. Do not attempt to pluck too many feathers at once.

Old, dried-out bone has a very black appearance. Investigate hard sharp raised scabs and irrigate with saline to soften the area for examination. Beware of pneumatised bones: humerus and femur in birds of prey, in parrots the femur contains bone marrow but the humerus is pneumatised.

The legs can be examined in a similarly. Extend both together by pulling on the claw of the third digit. Then release. Again, either resistance or failure to return to normal position is significant. Palpate the long bones and the joints. Examine the plantar aspect of the feet. Long-term pressure causes the skin to lose its texture, the digital pads flatten and the scutes lose their form, the skin may be so thin as to reveal subcutaneous structures. Unilateral changes suggest that the bird is lame on one leg, usually the leg that has the least affected plantar surface. The longer that the bird has been affected by lameness and/or illness the more obvious the changes.

Turn the bird over. Examine the integument. Palpate the vertebral column, especially at the synsacral vertebral junction. If there is any doubt, wet the feathers to check for bruising in this area.

The next step is radiography: whole body ventrodorsal and lateral views, then specific limb radiographs. Comparable radiographs of the contralateral limb are often useful if only to help the owner understand what the normal view looks like. It is also useful to make a 'library' of normal views of common species which can be used in a similar manner. Always attempt two views, which may be difficult for elbow and carpus. However, there are cases where the bird will have to be held using lead gloves with the radiologist near to the primary beam. Birds with joint injuries may need radiographs with the joint under strain.

PRINCIPLES OF FRACTURE REPAIR

In comparison with mammals, the bones of the thoracic and pelvic limbs of birds are very strong for their weight. The structure of the avian bone causes fracture repair problems that are somewhat different to those encountered in mammals.

The bones of the pelvic and thoracic limbs are most commonly repaired after fracture. Fractures may be simple, greenstick, comminuted or compound; they are usually caused by trauma but may be caused by infection, neoplasia or metabolic disease. Therefore all fractures must be assessed radiographically as well as by clinical examination. It is advisable to radiograph the whole bird as well as the fracture site. Many injured birds have more than one problem.

The aims of fracture repair are to aid healing by promoting the formation of an intact, strong bone, with no involvement with the surrounding structures. These aims are complicated by a number of factors:

The rate of healing of avian bone is very rapid, and in wild birds a significant amount of scar tissue and bony callus can form in seven to 10 days. This can happen before the injured wild bird is presented for treatment. Some birds recover with no intervention.

Many fractures are comminuted and the bone has broken into a large number of splinters that may be difficult or impossible to reconstruct.

Greenstick and folding fractures are frequently seen at the distal femur, mid to distal-tibiotarsus, and mid-tarsometatarsus, however because they are usually caused by nutritional osteodystrophy they are invariably multiple and involve other areas of the body too. This can cause major complications. If the fracture is new the bird must have vitamin D and calcium supplementation, if possible, for 24-48 hours prior to surgery.

External immobilisation of the limb above and below the fracture site will immobilise the joints. In many cases this would allow scar tissue to form around the joint and permanently reduce the ability of the joint to function. Even joints that are uninvolved with the fracture can be affected in this manner. Immobilisation may also allow callus to incorporate other moving tissues, e.g. flexor tendons in the tarsometatarsal groove or synostosis formation between the radius and ulna. Immobilisation of joints must therefore be avoided if at all possible. Robert Jones bandages are even more inappropriate for birds than they are for dogs and cats.

A large number of fractures are compound, especially in injured wild birds. The protruding bone is usually desiccated and dead. The exposed medullary cavity is a portal of entry for bacteria, and occasionally fungi or foreign bodies. The bone that is dead or going to die must be removed: use rongeurs. The medullary cavity must be picked clean if possible: lavage usually tends to wash material deeper into the cavity where it is trapped by the internal struts. Lavage is also contraindicated in pneumatised bones. Dead tissue surrounding the fracture site should also be debrided and irrigated with normal saline.
Purulent material in birds is solid and does not flow; the provision of drainage in cases where pus is present is ineffective. Repaired compound fractures should be radiographed weekly during the

healing process and purulent material should be removed surgically when it forms.

Assessment for fracture repair must take into consideration the future function of the bird. For instance, caged, captive parrots do not need the capabilities of a hunting hawk. It must be possible to return wild birds to their normal habitat with a good chance of survival. Nothing less than perfection will give them a good chance of survival. Many studies (Swennen and Duiven, 1983; Dijkstra et al., 1990) show that increasing the time spent hunting for food decreases survival rates. The majority of wild birds with limb fractures require euthanasia and not treatment.

Birds for release must have proved their ability to fly and hunt and must be fit. This is almost impossible to achieve without flying at hack for a period. Sharpe (1996) looked at bird banding records and proved how difficult it is to successfully rehabilitate wild birds. In his study, the mean survival time of oiled sea birds was 9.6 days after release.

Flying at hack is a falconer's term for keeping the bird in a release pen, then allowing the bird, once released, to return for food until it is able to hunt successfully. This may take several weeks. Training the bird to fly to take food from a kite is even more useful.

METHODS OF FRACTURE REPAIR

To prevent scarring and adhesions the limb must be allowed to move as soon as possible during the healing period. The fracture must therefore be rigidly supported but the joints allowed to work freely. It is useful to keep the birds restrained by their husbandry rather than by physical methods.

Analgesia

Non-Steroidal Anti-Inflammatory Drugs are now routinely used to alleviate pain in veterinary and human medicine and surgery. Carprofen has been used in poultry to show a significant effect on birds with painful limbs (McKeown, 1999). Pharmacokinetic studies on plasma levels after administration at 4 mg/kg. Using oral administration the plasma levels peaked and fell within 8 hours. The plasma peak was not thought to be therapeutic. After intravenous administration the plasma levels fell rapidly, within 4 hours.

Subcutaneous administration gave a plasma peak at 1.5 - 2 hours after administration and it fell slowly over 18-24 hours. The birds showed signs of analgesia for up to 18 hours.

Carprophen can be used to control pain by subcutaneous administration for 4-5 days. Probably pre-operative SC administration is best.

Again, in chickens, self-administration studies have been carried out using unmedicated food, food + opiate, and food + carprophen (Danbury et al., 2000). When given the choice the birds preferred the carprophen.

A recent study looked at Tramadol in Bald Eagles (Souza et al., 2009). They found that in these large birds 5 mg/kg orally twice daily should give pain relief. They based this belief on pharmacology rather than pain-relief studies as above.

Fractures

Parrots are less likely to be presented with fractures than falconer's birds or wild birds. Fractures that are caused by fights and bites are often affected by skin damage and bruising. The skin can have its blood supply disrupted becoming affected by dry gangrene; it will die. This possibility should be reflected in the prognosis. The larger the area of damaged skin the greater the possibility of skin death. Bruises in birds may be bloody but quickly turn green - this is 'normal'.

There have been many descriptions of fracture repair. The following procedures are not the only methods that could be used for each fracture but will give satisfactory results in the majority of cases and should be possible in most veterinary practices. Some techniques, such as intramedullary PDS rods, shuttle pins, plates and screws, are not discussed.

Osteoporosis

This is usually seen in productive adult birds on a poor diet. It is very likely that there has to be considerable bone loss before osteoporosis is visible on radiographs. In birds, the usual signs are poor contrast between bone and soft tissue and a loss of cortical bone. When osteoporosis is seen to be a contributory factor to a fracture DO NOT fix the fracture on day one. Support the fracture as necessary and supplement calcium and phosphorus intake. Give some access to vitamin D/sunlight (Stanford, 2004).

Cage restraint

Some fractures, usually of the wing, are best treated with no fixation. This reduces the potential for scarring and movement limiting adhesions. Young birds with greenstick fractures of wing or leg bones, single fractures of the radius or ulna, or fractures of the digits are often treatable in this manner. Young parrots can stay in their 'bucket'. Adults of all species need confining, eagles and similar birds in a small shed, falcons and hawks need a box rather than a wire mesh cage. If possible, the box should have close together, movable sides that are positioned sufficiently close to force the bird to keep its wings folded. As the bird heals the sides are moved apart so that the wing may be moved for preening, and finally allowed to stretch full length but not bear weight. Long periods of dark are useful in aiding restraint but the bird must be in good light, twice daily, to allow feeding. Falconer's birds that are trained (but not usually Goshawks, *Accipiter gentilis*) and pet parrots are good candidates for this method of restraint, but many wild birds of prey prove remarkably tractable too. Falcons can also be left hooded for long periods, which keeps them tractable and calm. Most parrots should go into a cage of sensible size.

Splint

This is usually the most inappropriate method of repair; few fractures benefit from the application of a splint, except as a temporary restraint before full assessment and fixation. Mid to distal tarsometatarsal fractures in birds of prey are repairable using an L-shaped finger splint. A ball bandage is a useful splint for fractured phalangeal bones if required, see later.

Strapping the wing to the body is useful occasionally. Strap only the affected wing and leave the other free or the bird cannot balance easily. Beware of feather damage, especially in wild birds and of the 'good' wing. This technique is not very satisfactory, as it encourages adhesions and loss of function if the fracture is close to the joint.

A modified Schroeder-Thomas splint can be used on the leg to support the whole limb and is especially useful in growing parrots where it can hang through a sling.

Radial and ulnar fractures

It is common for the ulna to be fractured, usually when the bird's wing hits something hard whilst flying or flapping. Even though it is on the trailing edge of the wing and much larger than the radius, the ulna can be fractured on its own. If the radius is undamaged the ulna will heal using with 'cage-restraint'. Strapping is not necessary and would increase the risk of the formation of a synostosis. The bird should be kept in a cage for four weeks with sufficient space to stretch its wings for grooming etc. but not enough to flap them. The ulna usually heals very well; I have not had one that hasn't!

Even though it is a smaller bone it is less common for the radius to be fractured on its own. If the fracture is mid shaft with little displacement then cage restraint will be sufficient. If the fracture is close to the elbow the biceps tendon distracts the proximal fragment and moves it sufficiently to prevent healing. Distal fractures can also displace significantly. In both cases the bone should be supported by an internal intramedullary Kirschner wire. This should be inserted in a retrograde manner exiting the pin from the carpal region and running the blunt end of the pin to the other end of the medullary cavity. The surgical approach should be decided by palpation: the short fragment tends to protrude through the muscles - follow this down to the distal fragment. The pin must not enter the elbow joint and the carpus should be flexed whilst the pin is placed. The pin should be cut short, bent over and covered by the skin. Post-operatively the bird should be kept in cage restraint until the pin is removed in 4-6 weeks. As with a fractured ulna, immobilisation of the wing tends to cause problems and is not necessary. It is worth bearing in mind that the inner layer of bone receives its nourishment from the marrow cavity so filling this with a pin compromises the healing.

Some birds fracture both radius and ulna. In small birds (e.g. budgerigars), there is often so much swelling that this supports the fracture sufficiently for it to heal with just cage restraint. In larger birds it is possible to immobilise the wing with strapping.

Immobilisation will allow the bones to callus but can also encourage the radius and ulna to fuse whilst healing (synostosis). This fusion prevents the wing from functioning correctly and it is very difficult to reverse. A fracture of both radius and ulna requires proper stabilisation either by pinning the radius, which combined with cage restraint is sufficient. Pinning the ulna is more difficult as the bone has a large medullary cavity and has a significant curve making intramedullary pin support less satisfactory. However external fixation with small half-pins drilled in form the dorsal aspect will stabilise the bone and allow the wing to move, a synostosis is unusual (see tibiotarsus fractures for the technique).

Internal Fixation

As a general orthopaedic rule all internal fixation materials should be removed when radiographic union has taken place. Cerclage wire can be left. In my opinion, intraosseous bone cement, especially in pneumatised bones, and other unremovable non-reabsorbable implants are best avoided.

Tibiotarsal Fractures

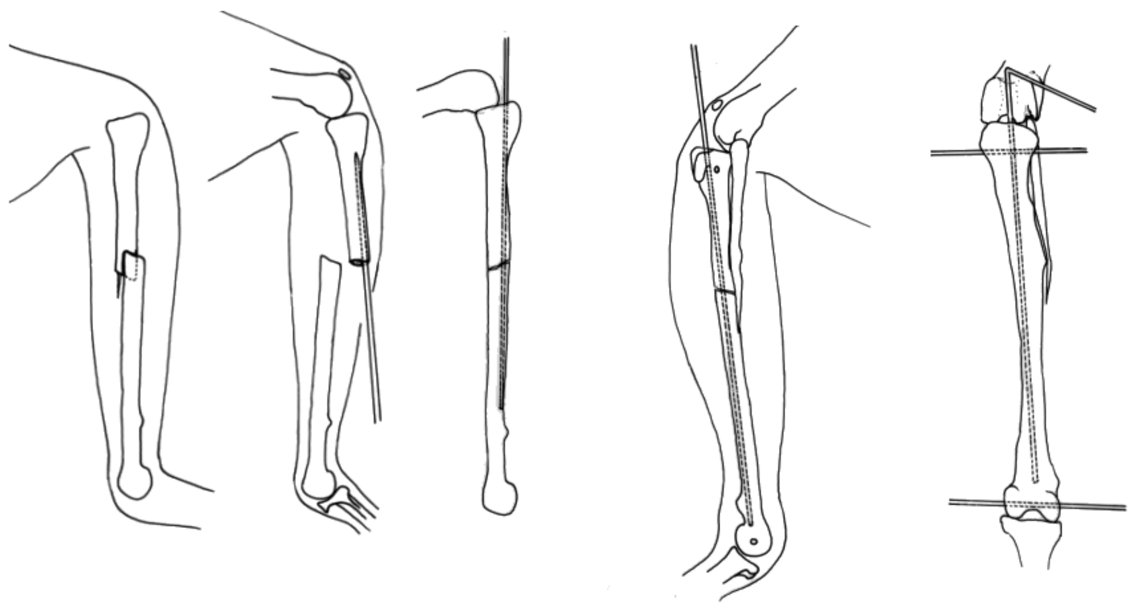
In most birds the tibiotarsus is the major weight-bearing long bone. In captive birds it is fractured commonly, usually by external trauma. In these cases it usually results in a simple fracture just distal to the fibular crest. However, some birds catch their identity ring on a protruding wire. This causes a spiral, comminuted fracture of the distal third of the tibiotarsus. Both these fractures require internal fixation and some antirotational stabilisation; the latter fracture is more challenging. An intramedullary pin combined with external fixation is the best method of stabilising these fractures.

Repair of a mid-shaft fracture of the tibiotarsus

Although there are a number of techniques that have been described for fixing this fracture the quickest, easiest, and most reliable is an intramedullary pin tied in to an external fixation frame connected to proximal and distal full-pins.

Under general anaesthesia prepare the surgical site by plucking the feathers rather than cutting them. It is best to tense the skin and pluck out feathers in small numbers going against their direction of growth. Sterilise the site with chlorhexidine in IMS (Vetasept Animalcare York UK). Sterile plastic drapes (Kruse UK) are very useful: they are light-weight and cover the bird with a sterile non-strike through layer that is transparent enough to watch the bird breathing etc. For this technique it is necessary to have access to both lateral and medial aspects of the leg.

Surgical approach: it is possible to place the intramedullary pin normograde from the proximal tibiotarsus. This technique is difficult to perform and most surgeons find it quicker and easier to open the fracture site via a craniomedial approach between the cranial tibial and medial gastrocnemius muscles. These muscles are held together by superficial fascia only. Once through the skin, cut the fascia and the gastrocnemius can be easily dissected away from the cranial tibial muscle. The cranial tibial muscle is attached to the shaft of the tibiotarsus but usually the fracture has stripped the muscle from the shaft, making the surgical approach easier. An arthroscopy hook or small Hohmann's retractor help to raise the proximal fragment and gain access to the medullary cavity.



Use an intramedullary pin with one point. Insert the trochar pointed end into the medullary cavity of the proximal fragment. Run the pin up the cranial surface of the medullary cavity so that it leaves the tibiotarsus outside the knee joint. Flex the knee during this procedure.

Reduce the fracture. The blunt end of the pin is placed into the distal fragment. Using a blunt end, rather than a pointed end, tends to prevent the pin leaving the medullary cavity and penetrating the intertarsal joint. It is very easy to push a pointed pin through the articular surface of the distal tibiotarsus transfixing the tibial cartilage and some of the flexor tendons that run through it. This will cause temporary or even permanent disability of the foot.

External fixation with two full-pins will prevent rotation at the fracture site and also prevents comminuted fractures from overriding. Kirschner wires of 1.6 or 1.2mm diameter are suitable. Positive profile threaded full-pins are currently only available down to 2mm in size, these are suitable for large birds of prey

Insert the proximal pin from the lateral aspect. Palpate the fibula. Place the pin cranial to the fibula and proximal to the fibular crest. This avoids the arteries, veins and nerves that run between the fibula and tibiotarsus. The fibula and tibiotarsus are not tightly connected at the knee joint. Normal knee movement will be prevented if the fibula is transfixed, usually resulting in a fracture of the fibula. Placing the pin too close to the knee joint will allow it to penetrate the joint capsule and cause a continuous leak of joint fluid. If this occurs, remove and replace the pin a little more distal.

The distal full-pin should be drilled from the lateral to medial condyle; careful placement will not affect other structures including the joint capsule. Do not place the distal pin through the shaft of the distal tibiotarsus, it will strike the intramedullary pin and will usually be forced cranially. The pin can then trap the common digital extensor tendon against the bony supratendinal bridge.

Repair the muscle layers and skin using 3/0 Vicryl Rapide, this suture lasts 2 weeks. The intramedullary pin should be bent laterally and tied into an external fixation rod. Larger birds can have small clamps with connecting rods; smaller birds a plastic tube or Penrose drain filled with methylmethacrylate or chemical metal can take the place of a rod. It may help to place length of redundant stainless steel pin inside the Penrose drain. The medial connecting bar should be as short as possible. If it is too long it will traumatise the body wall.

The leg should be bandaged for a few days to limit post-op swelling and then it is unbandaged. It is critical to attend to the pin/skin interface on a regular basis. A fibrinous crust will form around the pin and force the skin away from the pin. If this is not removed it grows and allows infection to track down the pin and into the tissues below, causing the pin to loosen. The crust should be removed with dilute chlorhexidine skin scrub, cotton buds and a small probe.

The repair must be subjected to a staged disassembly. If there are two full-pins and an intramedullary pin, remove both full-pins at about 3 to 4 weeks and cut the intramedullary pin short; leave enough length to pull it out when there is radiographic union in another 2 to 4 weeks. The bird must wear a collar or it will preen out the intramedullary pin. Cutting the pin short will make it difficult to remove. Leaving the pin will cause problems such as arthritis, tendinitis etc.

It is possible to repair a midshaft tibiotarsal fracture using only external fixation with positive profile threaded half-pins. For maximum stability at the fracture site, there need to be three pins above and three pins below the fracture site and the pins should each penetrate two cortices. Drawbacks to this technique are that it is very difficult to reduce the fracture and maintain the line of the bone. If this technique is used the half-pins should be held in removable clamps and then post-operative radiographs should be taken. If the proximal and distal fragments are misaligned the clamps can be loosened and the readjusted. Don't do it!

If the tibiotarsus is badly aligned it will affect the bird's ability to bear weight, promoting bumblefoot of the good foot.

Spiral, comminuted fracture of the distal third of the tibiotarsus

These fractures are more common in falcons than hawks and are also seen in parrots when they catch their leg band or a nail or similar. The fracture is complicated by a lack of soft tissue so the bone has usually penetrated the skin. Breeding birds often hide in the nest box after their leg is broken so that the fracture may not be found for several days. Desiccated bone, or bone that has protruded from the fracture site should be cut off; trying to clean desiccated, infected bone, even with antibiotic therapy, seldom prevents osteomyelitis. Occasionally the fracture occurs between the medial and lateral anchor points of the retinaculum of the cranial tibial muscle, or worse still the supratendinal bridge. This worsens the prognosis as the repair must be perfectly aligned so that a minimum of callus forms. Post-operatively the intertarsal joint must not be prevented from moving or adhesions will permanently cripple the bird.

As with a midshaft fracture an intramedullary pin and two full-pins is usually the easiest way of fixing a distal tibiotarsal fracture. Try to disturb the fracture 'envelope' as little as possible. The surgical approach is usually medial as this area is covered by skin only. Place the intramedullary pin in a retrograde manner, exiting it through the proximal fragment as described above. Reduce the fracture and slide the blunted end of the pin to the extremity of the medullary cavity. Use a pin that has a sufficient diameter to fill the medullary cavity of the distal tibiotarsus completely. Avoid entering the intertarsal joint. Place the full pins in the cranioproximal tibiotarsus and across the distal condyles. Open fractures carry a poor prognosis. In most wild birds euthanasia is the most reasonable action for bird and clinician. If you have to go ahead, use long-term antibiosis: Marbofloxacin (5 - 10 mg/kg SID) is first choice. Clindamycin and or clavulanate-potentiated amoxycillin can be useful as well.

Radiography at 2 week intervals is advisable, especially if there is possible infection. A staged deconstruction should be undertaken - it is usually best to remove intramedullary pin first but be guided by the bird's behavioural requirements, clinical signs, and radiography. If possible remove all the clamps etc and find out which pins are loose – remove these first. There is nothing more frustrating than removing a solid pin to find out the one that is left is wobbling!

If the tibiotarsus is fractured so that only the epicondylar area is intact and there is no medullary cavity, it is possible to repair it using a modified cross-pin technique. This will cause difficulties while the pins are in place as many parrots walk on the caudal tarsometatarsus as well as their foot. It is also possible to place the pins in the joint which is likely to produce a septic arthritis.

Fractures of the humerus and femur

Fractures in these bones are often comminuted or spiral. Both have the potential to shorten the bone by over-riding. External fixation pins are vital to preserve the length of the bone. An intramedullary pin keeps the line of the bone as well as adding extra stiffness to the repair. Humeral fractures are the common fracture of wild birds, less so in captive raptors and parrots. The humerus has a large pneumatised medullary cavity.

Fractures will lead to emphysema.

To repair a midshaft humeral fracture, use an intramedullary pin combined with two or three threaded half-pins, depending on the fracture and the size of the bird/bone. Place the bird in sternolateral recumbency so that the broken wing can be extended and flexed during surgery. The surgical approach is dorsal. The surgical site should be plucked, removing the small feathers from the elbow to well above the shoulder, and sterilised. Make a skin incision over the fracture site and do not manipulate the skin too much. There is very little soft tissue covering the distal third of the humerus. There is a large nerve dorsal to the bone. There is also one ventral to the bone that must also be avoided. The vascular supply is also ventral.

It is impossible, and undesirable, to fill the medullary cavity with the intramedullary pin; use a 1.6-2.0 mm Kirschner wire, trochar pointed at one end. Elevate the proximal fragment and place the intramedullary pin retrograde keeping the pin close to the craniolateral surface so that it avoids the shoulder joint. The fracture is then reduced and the blunt end of the pin is pushed to the distal end of the medullary cavity, do not enter the elbow. Once the fracture is reduced, it is important to get the correct alignment for the humerus. The wing should be flexed into its normal resting position against the body and this places the humerus in its correct alignment. Plastic drapes are very flexible and make this technique easy. The site of the external pins should be decided and the skin and any underlying soft tissue should be cleared from the bone. A drill guide must be placed onto the bone to avoid the thread catching surrounding soft tissue. The external pins must be drilled into the cortex slowly. Place one proximal half-pin at the level of, and caudal to, the pectoral crest (the most prominent and palpable part of the proximal humerus). This allows penetration of two cortices and it keeps the pin away from the joint. The most distal half-pin should be placed across the condyles. Connect the proximal and distal pins with IMEX clamps and a rod. In large birds e.g. many raptors and macaws it may be necessary to add more pins at this stage. It is only possible to use half-pins, unlike the tibiotarsal fractures, so the stiffness of the fixation is compromised. Van Wettere, Redig et al (2009) found that the stiffest and easiest fixation in Red-tailed Hawks (a 0.7 to 1.5 Kg raptor) was to place a half pin in the proximal fragment relatively close to the fracture site and then place two pins in the distal fragment. These three pins were tied in to an intramedullary pin. It is possible to place a drill guide through the pin-hole in the clamp to prevent soft tissue injury during pin placement.

Two recent publications looked at the mechanics of this technique using a bone model and then cadaver humeri using an intramedullary pin tied-in to half-pin (interface pin) fixation. In VanWettere, Wallace et al. (2009) using a tie-in configuration, a thicker diameter of connecting bar and increasing the number and thickness of the fixation pins all contributed to a stiffer frame. VanWettere, Redig et al. (2009) found that increasing the number fixation pins from 1 to 2 per bone segment increased the stiffness in torque, compression and safe load torque but not in axial compression. None of this is really surprising. But the real point of interest is that in a 2 half-pin construct, placing the proximal pin distally in the proximal fragment significantly increased the stiffness in torque and axial compression. Two pins in each fragment is very useful if the fracture is inherently unstable.

This technique was not compared to using proximal and distal full-pins (centre-face) tied-in to an intramedullary pin.

The femur is not pneumatised in parrots but is in raptors. It has a very large medullary cavity. Mid-shaft femur fractures can be stabilised either by using several intramedullary pins - stack pinning - or preferably by a single intramedullary pin tied into two positive profile threaded half-pins placed at each end of the bone. The surgical approach is lateral between the lateral iliotibial muscle and iliofibularis muscle. These muscles separate easily but due care must be given to the nerves and blood vessels that are covered by these muscles. The intramedullary pins are placed in a retrograde manner exiting through the proximal femur. The hip joint must be in extension to prevent the intramedullary pin from fixing the femur to the antitrochanter. The distal threaded half-pin is placed across the condyles and the proximal pin is placed so that the tip emerges on the medial side of the femur distal to the hip joint. In large birds with comminuted fractures it is better to use several half-pins but there is an increased risk that pins placed in the midshaft region will become incorporated into the surrounding muscles whose movements will cause the pins to loosen.

Fractures of the proximal humerus and femur

should be reduced and stabilised with one or two pins combined with a figure 8 compression wire. The technique is as follows: drill the hole in the lateral wall of the distal fragment; place the wire (22 or 24 g orthopaedic) making sure that it forms a loop that goes to the medial part of the medullary cavity; place one or two pins (0.8-1.2mm Kirschner wires) normograde or retrograde on the lateral aspect of the medullary cavity; reduce the fracture and run the pin(s) into the distal fragment's medullary cavity, make sure the pins are long enough to end distal to the wire. Incorporate the pin(s) outside the bone in the proximal loop of wire, tighten both sides of the figure 8, this should pull the pins to the lateral wall as well as reduce the fracture. The protruding end of the pin should be bent over caudally or cranially and embedded in the bone.

Fractures of the distal humerus and femur.

Even quite short fragments can be fixed with external fixation tied into an intramedullary pin. If the distal fragment consists of only the condyles and therefore no medullary cavity, the fracture can be fixed using external fixation with modified cross-pins and half-pins. This is only possible in larger parrots but can be a useful technique. Reduce the fracture with two flexible Kirchner wires so that they emerge from the epicondyles and do not affect the movement of the joint. Drill two threaded half-pins across the proximal and distal shaft, a third could be placed across the condyles in a large bird. The pins should be connected to an external pin with clamps or cement, as shown. The curved portion of the supporting bar should not interfere with the movement of the knee.

Coracoid

Flying 'headlong' into something will often cause this fracture. If the bird strikes a solid object with its shoulder then the coracoid is likely to break. The bird is obviously lame on its wing but has no long bone fractures. Careful radiography will show the fracture. In larger parrots it is possible to palpate the bone by placing a finger onto the inside of the thoracic inlet and using the wing to lift the pectoral girdle up and down: the finger in the thoracic inlet will detect crepitus. Cage restraint for a month is usually sufficient to allow the bone to heal. Stabilisation of the fracture has been described using an i.m. pin but the surgical approach is challenging and of questionable merit. Redig et al. (2009) reviewed 198 cases. Only 82 birds survived the first few hours after admission. All these birds were treated conservatively; 81 ended up with full flight capability and were released.

Carpometacarpus

This bone is rarely fractured. Figure of 8 strapping ill allow many fractures to heal. There are other techniques that have been described such as intramedullary pins or suturing foam and VetLite over the fracture site. However, many cases fail due to loss of blood supply or infection. Amputation is usually the salvage technique.

Tarsometatarsus

This bone is uncommonly fractured in parrots but can occur during a fight with another bird or when the identity ring has been caught on a protruding wire. It is possible to reduce the fracture using full-pin fixation; the tarsometatarsus has a medullary cavity in large parrots. The bird must be able to use the foot as freely as possible or the callus will incorporate the flexor and extensor tendons causing permanent disability. It will also occur in raptors where it can be repaired with external fixation or an L shaped splint. If the fracture is above the level of insertion of the cranial tibial muscle or well below, the splint will work although it can be a fiddle. Some birds have the fracture just distal to the insertion of this powerful muscle, which causes the fracture to move in the splint. These cases need external fixation. In hawks, the bone is very thin and C shaped in cross section. A whole prepared bone to examine pre-op. will give the best chance of placing the pins without trapping the extensor tendons in their groove. Falcons and eagles have thicker bones with more medullary cavity but even so, care is needed.

The tarsometatarsus is more commonly fractured in birds the size of Budgerigars and Cockatiels. Bony injuries above or below the intertarsal joint can be treated using a Granuflex (Duoderm) splint. The leg should be held with the bones in apposition and correctly aligned; this usually requires an anaesthetic. Strips of Granuflex (Duoderm) can be used in three layers to make a close fitting malleable splint. This is then strengthened with narrow strips of Zinc Oxide tape and it makes a firm 'cast'. It is necessary to include the foot, especially in fractures below the intertarsal joint. Some of the digits are left sticking out to allow the bird to grip and to prevent adhesions between the callus and digital tendons.

Digits

Many fractures will often be stabilised by the large ventral flexor tendon running in the thick fibrous tunnel and need no further treatment. Serious fractures, which are often compound, will require amputation. In parrots, digits II and III can be strapped together to provide support. A piece of nonadherent bandage, such as Skintact should be used in between the digits as padding. This technique is not usually possible with digits I and IV. A splint made of Granuflex and zinc oxide tape will provide semi-flexible support. In raptors digits II to IV can if need be taped together in a pair but in reality seldom need to be. The tendon sheath and tendon are very effective. If digit I or II is badly broken amputation is not possible. I have found that toes that are very deformed usually have torn the tendon sheath. Repair of the sheath and a Granuflex splint for 4 weeks or so is a useful technique. Very large birds such as eagles and vultures can have external fixation with small half pins. It is very difficult to keep the toe and pins clean. Infection can be a cause of failure in this technique.

COMPLICATIONS SEEN AFTER FRACTURE REPAIR

Malunion

This condition most closely resembles the atrophic malunion seen in dogs and cats. The cause is invariably instability of the fracture whether external or internal fixation is used. Constant movement leads to the bone ends becoming reduced in diameter, rounded, and smooth. No periosteal proliferation is present on either proximal or distal fragments. Healing can be induced by removal of fibrous tissue and cartilage if present. The bone ends are debrided with a burr on a Stratec Mini Air Drill or by using Lempert's rongeurs. The bone is then adequately supported by internal fixation if possible, preferably with some degree of compression. Occasionally external fixation has to be relied upon. Provided that the bones are immobilised, the fracture heals. Early malunions do not require such drastic measures; more complete support of the limb and usually less movement of the bird itself are all that is required to allow the bone to heal. Long-standing malunions are difficult and a bone graft should be considered: the bone may be obtained from the carina of the sternum. The carina may be used as a single large piece laid onto or into site of the malunion. This technique gives surprisingly good results presumably because there is cancellous bone in the fragments.

Osteomyelitis

Many avian fractures, especially in wild birds, are compound. Almost invariably the fracture has become infected prior to the initial examination. If it is possible, the affected bone should be removed at the time of surgery, but often the infection has invaded the medullary cavity and it proves impossible to prevent pus from forming. It is an unfortunate fact that purulent material in avian species collects as a caseous mass that will not clear with drainage. There is rarely formation of a sinus as there is in mammals. In long bones, the cortical bone becomes distorted by the continuing growth of the relatively hard purulent mass in the medullary cavity: this may be seen radiographically. Drainage is ineffective and flushing the medullary cavity can push the infection further into the cavity, especially in pneumatised bones. Single purulent masses may be cured by surgical removal of the lump of purulent material followed by lavage with antibiotic followed by administration of appropriate antibiotic therapy. Lincomycin or clindamycin, marbofloxacin, or clavulanate-potentiated amoxycillin may be given orally and are usually the drugs of choice. I have found bacteriology and sensitivity very unrewarding in these cases but I still try. If the bone is known to be infected, the fracture should be repaired using a full-pin or half-pin fixation technique; if some of the cortex has to be removed there is still support for the weakened bone whilst healing occurs. Multiple caseous masses are usually impossible to remove and the prognosis in these cases is very poor. Unresponsive osteomyelitis should be reappraised for the presence of *Mycobacterium avium*. Impression smears of pus are preferable to laboratory culture for a quick result. Make the smear by repeatedly dotting the pus on the same part of the slide. This technique increases the chance of the acid-fast bacteria showing when stained as it has the potential to concentrate the bacteria.

Occasionally osteomyelitis develops sufficiently to cause the bone to fracture: surgical repair should be accompanied by culture and impression smears or histopathology, which must again include examination for the presence of acid-fast bacteria.

Osteomyelitis can also be caused by *Aspergillus* spp. although this is usually a secondary finding in birds with severe disease. The spread is either haematogenous or via the air sacs into pneumatised bones.

Sometimes, in bones that were fractured and not infected, radiographic evidence of small areas of apparent osteomyelitis frequently occur around the pin during the healing process. Pin removal after the bone has healed will bring a coating of apparently purulent material with it. If antibiotic is administered after pin removal, the radiographic lesions disappear in a few weeks.

Osteoarthritis

Osteoarthritis is rarely seen, but it is usually a sequel to fracture or some other trauma involving a joint. The wear and tear osteoarthritis seen in dogs and humans does not seem to be as common in birds. Meloxicam or carprofen are effective long-term treatments. I use 1 drop of Meloxicam daily or twice daily for a Grey Parrot and it does seem to make the birds happier post-op.

Septic arthritis

This can be a difficult problem and can be seen in any synovial joint. The commonest joint to be affected with a septic arthritis is the distal interphalangeal joint. Infection usually enters from a scab under the claw or from a bite. Some birds can be seen with septic arthritis as a sequel to a compound fracture involving a joint. Occasionally birds develop a septic arthritis that appears to be from a haematogenous infection of an already bruised joint. Septic arthritis is an infrequent event as a sequel to surgery, unless a compound fracture involves the joint. If there are no radiographic changes to the bones of the joint the prognosis can be good but the first signs of bone involvement are a radiodensity of the subchondral bone. The next stage is osteolysis of the joint surface and deeper into the bone. Joints with radiographic evidence of osteolysis do not usually get better. If no osteolysis can be seen, daily irrigation of the joint with normal saline, followed by lincomycin or tobramycin injected into the joint seemed to be helpful. This technique involves an indwelling catheter and is very difficult in the joints of the pelvic limb, but is useful in the wing. The shoulder and the carpus can both be treated like this. Combination with oral antibiotic allows some birds to make a full recovery.

Whilst septic arthritis carries a very poor prognosis, antibiotic treatment should be instituted. Occasionally it works surprisingly well although the joint may be disabled. Finally, unless amputation is possible, severe cases where there is a lot of bone loss should be euthanased. A check should be made for the presence of acid-fast organisms.

Disturbances of growth in bones

The growth plates in birds are different from those in mammals. The process of ossification of the long bones of the pelvic limb of birds has been extensively studied in chickens and turkeys, and to a lesser extent in pigeons and quail. An obvious difference between mammals and birds is that birds do not have a calcified epiphysis until the end of their growth period. The proximal and distal ends of the femur and proximal end of the tibiotarsus therefore appear to be absent on radiographs of growing birds. The distal end of the tibiotarsus and proximal end of the tarsometatarsus look more like the familiar mammalian growth plates, but this is because the tarsal bones are present and form a centre of ossified bone that resembles the mammalian epiphysis.

Young, growing birds are often seen with osteodystrophy; nearly every case is related to incorrect nutrition. Some apparently experienced falconers still refuse to supplement the diet of their birds with vitamin and mineral supplement; others also use large carcases and give too large a quantity so that the birds do not eat the whole carcase and therefore the bone. The clinician should not accept the statement that the owner is "feeding a good mixed diet and has raised many chicks before with no problems" as proof that the adults and chicks are being fed correctly. A deficient diet for the adults will give deficient eggs and the chicks that hatch will have severe difficulty recovering from their poor start. Weakened chicks, with folding fractures or complete fractures of the long bones are seen each breeding season. Falcons grow more quickly than hawks and tend to present with more dramatic problems. In cases of osteodystrophy it is worthwhile examining the ‘good’ food source of the birds of prey. Quail are frequently reared badly and bent bones can be seen in the carcases on radiography. Even the most sceptical falconer will feed a supplement after seeing this. My personal opinion is that many of these quail are vitamin D deficient. Owls are often sold to their new (and inexperienced) owners at five days old with no dietary advice. Parrot breeders often make up their own diet and these diets are frequently low in calcium and vitamin D. Many adult parrots are kept so that they do not get access to unfiltered sunlight, which exacerbates the problem, especially in Grey Parrots. Parrot keepers also tend to use water soluble vitamin and mineral sources and seldom seem able to follow the manufacturer's instructions although they try not to admit to this when questioned.

Affected birds should have a whole body radiograph taken so that all the bird's bones can be assessed for fractures and distortions. Many birds with problems that do not have fractures suffer from subtle deviations of their long bones such as rotation on the long axis of the bone and different growth rates between pairs of bones, such as radius and ulna. Birds with multiple fractures must be euthanased. It should also be remembered that the birds may be suffering from more than a calcium/vitamin D deficiency. For dietary advice BSAVA Manuals: *Psittacine Birds* and *Raptors, Pigeons and Passerines* are very helpful.

Treatment can be based around correction of angular limb deformities using intramedullary and external fixation pins. However great attention must be paid to the deformity of the joints as it is possible to cause problems by placing too much strain on deformed limbs. Many deformities of the ribs, vertebrae, sternum etc do not need correction and it can be surprising how well captive parrots manage with severe deformity of these bones. Hunting birds with deformities do not manage to 'make the grade' although they can be used for breeding.

Further problems are related to the fusion of the metatarsal bones, which takes place as the birds grow. The first metatarsal bone remains small and separate from an early embryonic stage; the fifth metatarsal bone disappears as an entity. The second, third, and fourth metatarsals fuse. No-one has described the sequence of fusion in birds of prey, but in larger hawks the bones are still fusing at 5 weeks and so have separate growing centres. Harris' Hawks often damage one of the growing areas of a single metatarsal bone sufficiently to stop or slow the growth of that side of the limb. The result is a considerable deviation of the tarsometatarsus. The Harris' Hawk is the only species I have seen to suffer from this deviation and there are several possibilities for this. Firstly a large number of these birds are bred, as they are free breeders, and a popular hawk to hunt with. It is possible that this large population of young birds, produced by less experienced breeders, increases the chances of this condition occurring. This seems less likely than the second possibility. Hawks are relatively slow growing in comparison with the falcons, whose growth centres close much sooner. The Harris' Hawks are also much more likely to injure themselves than other hawks; the Harris' Hawks fight more with their siblings and they "sit down" much harder in the nest. Hawks are able to stand up before their growth centres close and it is at this stage that the Harris' Hawks fight more. All the cases seen were around 5 weeks old. Thirdly it may be coincidence, but again this is unlikely.

The deviations can be corrected by opening up the side of the tarsometatarsus where it has stopped growing, and removing a portion of the distorted cartilage from just below the tarsus. The bone is then forcibly straightened, which enlarges the deficit further, and the wound closed with 4\0 chromic catgut. The bone is held for about 10 to 14 days in a plaster cast from just above the intertarsal joint to half way down the tarsometatarsus. This keeps the tarsometatarsus straight. The bird is kept in a towelling sling to allow it to stand on its normal limb without damaging it. Within that period of time the deficit fills with bone and the growing centre that was not badly damaged continues to grow. The bone often remains straight after the cast is removed, usually because the growth has stopped. Because no other damage has occurred to surrounding structures the intertarsal joint functions normally. There is often a slight shortening of the affected tibiotarsus but this does not cause the bird a problem.

Dry gangrene of the skin

Occasionally, after surgery or extensive bruising, the skin around the injured site will lose its blood supply and die. This may be due to trauma but can also be iatrogenic. It happens very suddenly and produces an area of dry gangrene, which may also include deeper structures. Severe cases involving muscles and ligaments around the joints should be euthanased; less severe cases can be treated with debridement of the devitalised tissue and application of Granuflex. Very large areas of skin loss can be regrown with Granuflex. The Granuflex is bandaged or sutured in place and changed regularly, the interval being dependent on how much fibrin etc. is deposited under the Granuflex: usually 3 to 7 day intervals. One hybrid Lanner x Lugger Falcon that lost both the tendons of insertion of m. tibialis cranialis made a good recovery but stood with more than normally straight intertarsal joints. In some areas, such as the head, a sliding skin graft can be used successfully to cover quite large deficits.

Amputation of the digit

In raptors, the only amputation that is commonly performed on the pelvic limb involves the digit. Amputation is usually the last resort for a hunting bird. Loss of function due to irreparable tendon damage, loss of skin or septic arthritis are the usual causes. The digit is amputated leaving as much as possible, however the remaining joints have to be functional or the toe is a useless encumbrance. The skin is incised and retracted cranially from the phalangeal bones. The phalangeal bone is cut with fine bone cutters so that none of the joint is left behind. The flexor and extensor tendons, and their surrounding sheaths, are sutured together over the end of the cut bone. The skin is then sutured over the top of the amputation. The suture material normally used is 3\0 or 4\0 chromic catgut and the suture line and toe should be covered with Granuflex in birds of prey. Parrots often amputate their own toes but if some 'tidying-up' is required, or if performing a surgical amputation, do not cover with Granuflex post-op. It is possible in parrots to amputate the whole foot. This is because they use their beak as an extra foot and because many of them normally bear weight on their hock and the plantar aspect of the tarsometatarsus.

PARAPLEGIA OF THE PELVIC LIMB

Damage to the vertebral-synsacral junction

Subluxation due to trauma is a common cause of paralysis. There is usually a history of an accident and a lateral radiograph reveals separation of one or both joints between the notarium and synsacrum. Occasionally there is paresis and no obvious subluxation. Radiography will show an increased joint space in some of these cases if the bird is 'stretched'. Birds that are only bruised in this area will make a recovery with steroids and antibiotic treatment; more severe injuries have a poor prognosis. Antibiotics should be given to these cases during their recovery.

Some birds are presented with a slowly developing paresis, extending to paralysis, often with a history of trauma some weeks previously. Radiographs reveal an abscess of the intervertebral space(s). These abscesses arise from haematogenous spread of infection to the joint when it is bruised after trauma. As in other cases of septic arthritis the prognosis is usually hopeless. Short-term improvement with antibiotic almost never gives a long-term cure.

Lead Poisoning

Some birds are presented with paresis of the legs and wings. A pathognomonic sign of lead poisoning in birds of prey is that they will sit "holding hands" with themselves; most other birds are just unwell and weak. Radiography usually reveals lead in the gizzard that can be from a variety of sources. The commonest is lead shot from food in birds of prey, and either lead paint, or lead from leaded windows in parrots. If left untreated the bird will start to have convulsions. The typical signs of lead poisoning can be confirmed in these cases by blood lead levels, but response to treatment and a positive radiograph is usually sufficient. Intramuscular injection of undiluted calcium sodium edetate is very effective. The lead should be removed from birds with a non-grinding gizzard, (e.g. falcons and hawks) by a ventriculotomy, and in birds with a grinding gizzard (e.g. parrots and waterfowl) by flushing, although the lead is ground up and removed very rapidly in these cases provided they are treated. All birds may get enlargement and impaction of the proventriculus with lead poisoning. In waterfowl this can be fatal.

In the UK the use of lead fishing weights (but not lead shot for guns) has been banned since 1987 (except for very small and very large weights). In spite of this a recent survey (Waine,2000) of 323 Mute Swans (*Cygnus olor*), which were all the birds admitted to a swan rescue centre over a two year period, showed that only 25% had a below normal level of lead (less than 26 µg/dl) 32% had levels of greater than 100 µg/dl and one was 3040 µg/dl. Lead should still be suspected in any swan, goose or duck presented for examination.

Calcium deficiency can promote an appetite for lead. The lead then enters the bone and is difficult to get rid of. Supplementing birds with calcium rich grit has decreased the incidence of lead ingestion. In parrots I give some grit by gavage with their initial treatment. It is then supplied in their food.

Neuritis

The lumbosacral plexus arises from the synsacral area and runs across the ventral synsacrum and through the pelvis to the limb. The ischiadic nerve supplies the majority of the limb and runs from the synsacrum to the ilioischiadic foramen in close proximity to the middle and caudal divisions of the kidneys. The nerves are close enough to the kidney for a nephritis to cause a neuritis. Birds of any species may be presented with paresis or even paralysis and no history of previous trauma; they often appear unwell. Plain radiographs and an intravenous pyelogram after an intravenous injection of 175-700 mg iodine (iohexol, Omnipaque Nycomed) may show increased renal density and occasionally a difference in functional ability between the divisions of the kidney. A barium meal may be useful to outline renal cysts, neoplasia of the gonad etc. which can cause paresis by pressure. Birds with renal infection and neuritis may have an increased blood uric acid level and a leucocytosis. The preferred antibiotic therapy is co-trimazine (30 mg/kg SC and 12-60 mg/kg PO BID) in spite of the compromised renal function, as this condition is usually coliform related. Occasionally, the disease will progress and a different antibiotic should be tried; in these cases the paresis may be quite marked and the bird may take some weeks or even months to recover full use of its limbs. Some cases can be caused by aspergillosis but will usually be indicated by the very marked leucocytosis.

I have found endoscopy useful. It will differentiate infection tumours etc. Also in larger birds, it is possible to examine the lumbar nerves by pushing the scope between the kidney and the pelvis. Probing the nerves makes the leg respond so at least you know the nerves are ‘working’.

Paramyxovirus

This virus is able to cause a rapid and irreversible paresis usually affecting both wings and legs. PMV 1 is often innocuous in pigeons but is able to cause severe signs in birds of prey. It is therefore advisable only to feed correctly vaccinated pigeons to birds of prey.

SOFT TISSUE INJURIES

Propatagium

This is a vital and complex structure. Injury to this structure causes the bird to be unable to fly. Poor repair of this structure condemns the bird to a flightless existence. The propatagium is frequently injured by the bird flying into wires or electric cables and the injury itself may at first be missed, in a falconer's hunting bird, or may not be seen for some days in an injured wild bird.

The most important injured structure is usually the ligament of insertion of *m. tensor propatagialis pars longus*. This muscle has a short belly and a long tendon of insertion, about 80% of which is extremely elastic. The tendon forms the leading edge of the wing and keeps this edge tensed even when the wing is half opened. The rest of the propatagium is supported by the *m. tensor propatagialis pars brevis*, which can be more complicated in its anatomical structure, varying between genera and even species; it is however less likely to be injured.

The bird is usually presented with the propatagium cut like a piece of pie: the largest wound at the leading edge and the pointed tip of the pie nearest to the elbow. The cut skin edge is frequently desiccated and may be infected. It is unusual for the tendons from the supporting muscles to be obvious.

The bird should be anaesthetised, and the propatagium plucked of its feathers. Hold the skin firmly, close to where the feathers are to be removed and pull a few feathers out at a time with sharp controlled movements. Pull towards the injury or it is possible to tear the skin further. It is important to pluck a large area around the wound so that the injured tendons can be identified. Firstly identify and isolate the tendon from *pars longus* and then debride the area around it of dead tissue. Dissect out the tendon ends, remove dead tendon and suture the tendon together using 4/0 polydioxanone (PDS Ethicon) suture. Use a modified Kessler suture pattern (locking loop) and make sure the tendon ends are squashed together. Large tendons can have the ends gently over sewn. Next, cover at least one surface or preferably both, with skin. The tendon appears to run in a tunnel in the leading edge of the wing and this tunnel should be reapposed if possible on all surfaces to surround the tendon. Use mattress sutures for tunnel and skin repairs. Initially it is more important that the tissue heals than the propatagium is kept at its original length. Next examine to see if there is any injury to *pars brevis* and repair if necessary.

Finally attempt to repair as much skin as possible. Areas with a skin deficit must be covered with a sheet of hydrophilic dressing (Granuflex) which may be sutured into place. Granuflex will not make a complete hole through the propatagium heal; there must be one surface of skin.

It must be noted that failure to suture the tendon leaves the wing with substantial loss of ability to stretch to full extension. If the tendon is not repaired the wing is condemned to being a useless appendage.

At the end of surgery the propatagium may be so shortened that it will only allow the wing to open to half its normal distance. It is now vital that the bird is cage restrained for 10 days; it must not have its wing strapped. The Granuflex should be changed every 5 to 7 days under general anaesthesia. Once the wing has healed the amount of exercise for the wing can be increased until it is allowed to fly in a reduced manner, either on a creance to the fist or in a large aviary. This is usually started about a month to six weeks after the initial surgery. The wing should be checked every few weeks and a comparison made under general anaesthesia. When there is less than 20% difference the bird may be flown free.

It has been interesting to see that repairs to the propatagium, even after a substantial loss of skin and tendon, have been able to fly normally and hunt with no discernible loss of ability. More importantly when examined under anaesthetic the propatagium appears eventually to return to the same length as the opposing wing.

Tendon repair in the pelvic limb of diurnal birds of prey

Falconer's birds are often seen with the flexor or extensor tendons to the digits severed.

This can happen in several ways:

- Squirrel bites. Many birds attempt to "take" Grey Squirrels (*Sciurus carolinensis*). Falconers try to avoid this species as quarry. The Grey Squirrel seems difficult for most birds to kill quickly and the squirrel frequently bites the bird's feet. The squirrel's teeth will sometimes sever the tendon directly, however usually the tendons separate some days later due to infection and subsequent necrosis.

- Infection under a scab around the claw will cause separation of the flexor tendon from the flexor prominence on the distal phalangeal bone. The main flexor tendon of the digit is from either the long flexor muscle of the hallux, as in digit I, or the long digital flexor muscle as in digit III and IV. Digit II is supplied by a combination of both. The main flexor tendon inserts on the flexor prominence. In spite of the digital pad, this bony prominence is very close to the skin surface and the junction with the claw. Infection often invades the insertion of the tendon, causing necrosis of the tissue, allowing the tendon to pull away. The commonest cause of infection is a build up of clotted blood and hair from the bird's normal diet. If the feet are not cleaned by bathing, the clot can cause necrosis of the skin beneath, and infection easily penetrates. In advanced cases the infection invades the terminal phalangeal joint and causes a septic arthritis.

- In some birds the closed (Department of the Environment) ring will constrict the limb in the region of the tarsometatarsus. This constriction is caused by either a build up of organic debris within the ring, or leaving the smaller male ring on the leg of a female. Constriction of the limb by a ring causes gangrene of the local structures; with loss of skin, and also loss of the tendon of insertion of long extensor muscle of the hallux as it runs over the tarsometatarsal bone on the medial aspect of the limb. There is little subcutaneous tissue in this region so the tendon is very vulnerable.

- Brass eyelets in the aylmeri anklets which are not surrounded by sufficient leather or traditional leather jesses that are insufficiently greased can rub a hole in the dorsal aspect of the base of digit I. A wound in this position allows devitalisation of the tendon of insertion of long extensor muscle of the hallux. Because of constant flexor tension and no extension, the digit is pulled permanently under the foot. The bird is unable to grip its perch and stands with the dorsal aspect of digit I in contact with the perch. The skin of the dorsal surface of the digit dies because of pressure necrosis.

- As a sequel to bumblefoot infection, at the metatarsophalangeal junction. One or more of the main flexor tendons will occasionally separate in the sole of the foot where the tendon runs through the plantar flexor canal. The aetiology is usually unclear. Occasionally the cause is a deep infection and degeneration due to bumblefoot. Because of surgical access this tendon separation has always proved impossible to mend.

The flexor and extensor tendons of the digits are very long and over most of their length have no apparent blood supply; nutrition is via the tendon sheath fluid. The insertion has a supply from the bone, which invades for a few millimetres, as does the area where the muscle becomes tendon. In my hands, joining the tendons by end to end anastomosis using a Bunnell tendon suture pattern and various suture material (monofilament nylon, Ethilon; polytetrafluoroethylene or PTFE, Gortex suture; and polyglcolic acid, Dexon) has always failed as there is no healing response at the joined tendon ends. Histological examination of unhealed tendons, which had been sutured, revealed an avascular necrosis of the tendons where they were "joined". There was no sign of inflammation or vascularisation of the area that was required to heal. It is difficult to return a tendon to full function in this manner. The tendon either fails to heal or the digit is very restricted in its movement. Examination of healed tendons but with stiff digits shows that the tendon has adhered to the tendon sheath and allowed vascularisation. To allow the tendon to heal, a blood supply to the affected site must be obtained from the tendon sheath in a controlled manner. It is often necessary to wait for several weeks after the initial traumatic incident to allow vascularisation to occur. Alternatively the severed ends can be stitched to the tendon sheath soon after the initial injury and joined later. The best suture material for this technique is 4/0 PDS. Once the tendon ends are vascularised, usually 3 - 4 weeks after the initial injury, they can be joined; providing the new blood supply is preserved, the tendon will heal. The technique is similar to conjunctival grafting in ophthalmic surgery, where a blood supply is provided for an avascular tissue by a bridge from a vascular one. The blood supply can be dissected out, preserved and taken to with the tendon to the anastomosis. It is important to attempt to repair the tendon sheath. A ball bandage applied for 3 to 4 weeks is useful to allow some degree of movement without allowing the full muscular force to disrupt the repair. Complete immobilisation of the digit will still result in a stiff digit, full use of the digits too early will pull the anastomosis apart.

Avulsion of the extensor prominence can be corrected by drilling small holes through the extensor prominence and the fragment and reducing the fracture by suturing with 4\0 PDS through the holes. The bone will heal and give good function of the limb. This technique does not rely on the tendon healing.

A full account of tendon repair (Anatomy plus Surgery on 35 successful cases) was presented at the 3rd Raptor Conference, Johannesburg, 1998 and is contained in Raptor Biomedicine III.

Some of the text of these notes has been taken from the pelvic limb chapters in the BSAVA Avian Manuals and is used with their kind permission (even though I wrote it!). Some is from the FRCVS thesis: N Harcourt-Brown.

SUGGESTED READING

General

BSAVA Manual of Raptors, Pigeons and Passerines
BSAVA Manual of Psittacine Birds 2nd edn.

Both are easily available in Europe (British Small Animal Veterinary Association, Cheltenham, Glos. UK) and the USA (Iowa State Uni. Press) and are excellent, comprehensive books for use in practice.

NH Harcourt-Brown: FRCVS Thesis 1994 Diseases of the Pelvic Limb of birds of prey. *A comprehensive examination of the subject with a large amount of original work*. Available from RCVS library. This now available as a CD ROM, *Birds of Prey: anatomy, radiology, and clinical conditions of the pelvic limb.* ISBN: 0-9636996-9-5 Zoological Education Network or Harrison's Bird Foods.

Anatomy

Handbook of avian anatomy: Nomina Anatomica Avium, (2nd Edition J. J. Baumel Ed.) Nuttall Ornithological Club, Harvard University, Massachusetts.
Extremely useful: the fundamental anatomical text. It standardises and defines the names of anatomical structures.

Birds their Structure and Function. A S King and J McLelland, (1984) Baillière Tindall, London.
A 'cheap', good, anatomical overview.

Form and Function in Birds. Editors A S King and J McLelland Academic Press London. Volumes I-IV.
Expensive but the most comprehensive text available.

A Colour Atlas of Avian Anatomy. J McLelland (1990) Wolfe Publishing Ltd Aylesbury, UK.
A very useful book using high quality photographs to give an excellent guide to general avian anatomy.

Physiology

Sturkie's Avian Physiology. 5th Edition. Editor G C Whittow (2000) Academic Press, Harcourt Science and Technology Company, California.
Much useful information including a chapter on flight

Radiology

Atlas of Avian Radiographic Anatomy. Smith, S. A. and Smith, B. J. (1992). Saunders and Co., Philadelphia.
There are some very clear illustrations in the book

Atlas of Diagnostic Radiology of Exotic Pets. Rübel G, Isenbügel E and Wolvekamp P. (1991).Wolfe Publishing Limited, London.
A useful set of normal and pathological radiographs illustrating birds from many genera

Surgical Approaches

Avian Surgical Anatomy: Thoracic and Pelvic Limbs. Orosz, S. E., Ensley, P. K., and Haynes, C. J. (1992). Saunders, Philadelphia.
A useful guide for the beginner

General Avian Surgery

Avian Medicine 2nd edn. Editor: J Samour 2007 Elsevier
There are some good sections on surgery

Raptor Biomedicine II, Editors: P. T. Redig, J. E. Cooper, J. D. Remple, and D. B. Hunter. Chiron Publications, Keighley, W. Yorkshire.

Raptor Biomedicine III, Editors SJ Lumeij, PT Redig, M Lierz, and JE Cooper. Zoological Education Network Florida.
Useful, covering many aspects of treatment of birds of prey

Danbury, T.C., Weeks, C.A., Chambers, J.P., Waterman-Pearson, A.E., Kestin, S.C. (2000). Self-selection of the analgesic drug carprophen by lame broiler chickens. *Veterinary Record* **146**: 307-311

Dijkstra, C., Bult, A., Bijlmsma, S., Dann, S., Meijer, T., Zijlstra, M. (1990). Brood manipulations in the kestrel (*Falco tinnunculus*): effects on fitness of parents and offspring. *Journal of Animal Ecology*. **59**: 269-286

McGeown, D., Danbury, T.C., Waterman-Pearson, A.E., Kestin, S.C. (1999). Effect of carprofen on lameness in broiler chickens. *Veterinary Record*. **144**: 668-671.

Redig, P.T., Francisco, O.N., Froembling, M., Martinez, L.C., Ponder, J.B. (2009). Coracoid fractures: an assessment of conservative management. Proceedings of the European Association of Avian Veterinarians, Ghent, Belgium. pp 78-80.

Saumier, M. D., Rau, M. E. and Bird, D. M. (1986). The effect of Trichinella pseudospiralis infection on the reproductive success of captive American kestrels (Falco sparverius). *Canadian Journal of Zoology*. **64**: 2125-2135.

Sharpe B. E. (1996). Post-release survival of oiled, cleaned sea birds in North America. *Ibis* 118 pp. 222-228.

Souza, M.J., Martin-Jimenez T., Jones M.P., Cox S.K. (2009). Pharmakokinetics on intravenous and oral tramadol in the bald eagle (*Haliaeetus leucocephalus*) *Journal of Avian Medicine and Surgery*. **23**: 247-252

Swennen and Duiven (1983). Characteristics of Oystercatchers killed by cold stress in the Dutch Wadden Sea. *Ardea* **71**: 155-159

Waine, J.C. (2000). Lead poisoning in swans. *Veterinary Record* **147**: 460.

Van Wettere, A.J., Wallace, L.J., Redig, P.T. et.al. (2009). Mechanical evaluation of various external skeletal fixator-intramedullary pin tie-in configurations using a tubular plastic bone model. *Journal of Avian Medicine and Surgery*. **23**: 263-276.

Van Wettere, A.J., Redig, P.T., Wallace, L.J., et. al. (2009). Mechanical evaluation of external skeletal fixator – intramedullary pin tie-in configurations applied to cadaveral humeri from Red-tailed Hawks (*Buteo jamaicensis*). *Journal of Avian Medicine and Surgery*. **23**: 277-285.