Avian Orthopedics - Using Anatomy for Tie-In Fixator Placement

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Abstract: During placement of an external skeletal fixator, it is necessary to minimize trauma while introducing transfixation pins. To achieve this goal, one must study the anatomy of the bones and surrounding tissues and apply this knowledge during surgery. The cross sectional views, underlying musculotendinous and neurovascular tissues can be considered for defining safe, hazardous, and danger zones for transfixation pin placement. With these zones mapped on the femur, tibiotarsus, humerus, and ulna, recommendations are made for placement of a Kirschner-Ehmer apparatus that minimize post-operative discomfort.

Introduction

External skeletal fixators (ESF) are excellent options for avian fracture repair. An ESF provides rigid stabilization, while minimizing rotational, shearing and bending forces. An ESF will allow use of the affected limb during recovery, especially since many of the materials used are lightweight. This decreases the amount of ankylosis and tendon contraction related to coaptation and internal fixation techniques. Utilizing good surgical technique, there is minimal soft tissue, articular, and periarticular damage. Complications identified with ESF are pin tract infection, fixator problems (premature pin loosening, unstable configuration, iatrogenic fractures), and soft tissue trauma during implantation. By improving surgical technique, these complications can be minimized.

After deciding to use an ESF for fracture repair, we must be careful to avoid the many gross anatomical barriers. The four long bones will be reviewed. Obvious features to avoid with the femur include the large iliotibialis muscles and femorotibialis medius cranially, the body wall medially, and the large flexor cruris muscles and the puboischiofemoralis pars medialis caudally. Concerns for the tibiotarsus are the fibula laterally, the body wall medially and proximally, and the gastrocnemius muscle caudally. Structures of the humerus that must be avoided are the patagial tendons and biceps brachii cranially, the body wall medially, and the triceps brachii caudally. On the ulna there are the patagial tendons and radius cranially, the body wall medially, and the metacarpals, phalanges, and primary feathers caudally that will interfere with transfixation pin placement.

The large sliding muscles mentioned above, should not be penetrated by transfixation pins. This will cause pain and discomfort, premature pin loosening, excessive pin tract drainage, and prolonged return to function. These are general guidelines to follow when contemplating ESF placement, but there are other structures of concern, such as smaller muscles, tendons, nerves, and vessels. The purpose of this report is to gain an
understanding of the detailed anatomy of the four long bones for practical use for placement of an ESF.

**Zone Definition**

The detailed anatomy of the long bones should be taken into consideration when placing an ESF. In order to avoid neurovascular or musculotendinous structures, cross sectional anatomy was examined on five areas of each bone. Then zones were arranged around the structures as if they were to receive a well seeded transfixation pin. There are three zones:

- **Safe zones** are defined as those areas that only skin covers the bone. Percutaneous placement of cross pins is acceptable within these zones.
- **Hazardous zones** contain musculotendinous structures that should not be penetrated. If it is necessary to enter these zones, then blunt dissection should be used to reach bone prior to pin placement.
- **Danger zones** should not be used when placing an ESF. These zones contain significant neurovascular bundles and/or musculotendinous structures.

**Femur:** The femur has many restrictions for an ESF. No safe zones exist. This requires the surgeon to enter hazardous zones. The body wall, large iliotibialis muscles, femorotibialis medius, large flexor cruris muscles and puboischiofemoralis pars medialis prevent transfixation pin placement cranially, caudally, and medially, the lateral femur must be used. The ischiatic vein, artery, and nerve start caudolateral and course laterally until the distal one third of the femur. At this point (Figure 1d) the ischiatic nerve divides into the tibial and fibular nerves, which are caudolateral to the shaft of the femur. The ischiatic vein and artery continue with the fibular nerve.

With this information, the best surgical placement of transfixation pins would be laterally but slightly cranial. This would avoid the ischiatic neurovascular bundle. If a straight lateral approach was performed, then the ischiatic vein may be encountered at the proximal third of the femur. Since this is the only corridor for ESF placement, a Type I K-E device is recommended. It must be emphasized that a small surgical approach to the bone must be made for each transfixation pin.

**Tibiotarsus:** The fibula, large gastrocnemius muscle, and proximally, the body wall are restricting partial lateral and medial and total caudal placement of transfixation pins. There are only two areas located distally that can be considered within safe zones (Figure 2e). Therefore, hazardous zones will be entered, just as they were in the femur. On the proximal tibiotarsus there is a large danger zone laterally and caudally. It is defined by the fibula, fibular nerve, cranial tibial vein and artery, tibial nerve, and the popliteal vein and artery (Figure 2a). Slightly distal to this cross section, the tibial nerve and popliteal vein and artery course caudal to the tibiotarsus to open a hazardous zone lateral to caudolateral. This neurovascular bundle continues to travel caudomedial. Distally, the medial metatarsal vein starts caudomedial and turns craniomedial.
There is still a concern laterally for the fibula and associated neurovascular bundle on the proximal tibiotarsus. The cranial tibial artery and fibular nerve move cranial to the shaft of the tibiotarsus distally. Most distally it returns to the craniolateral position. The fibula terminates at the distal one third of the tibiotarsus.

The zones that are most attractive for an ESF on the tibiotarsus are the hazardous zones located laterally and medially. The safe zones on the distal tibiotarsus (Figure 2e) should be utilized for placement as well. The medial and lateral zones are in the same plane, which allows the use of a Type II K-E. A Type II K-E provides more rigid fixation with less torsional forces, and gives the surgeon the ability to apply compressive or distractive forces at the fracture site. The transfixation pins should travel from lateral and slightly caudal to medial and slightly cranial. This accomplishes two goals: 1) The medial part of the K-E will not interfere with the body wall proximally as much as a straight lateral approach. 2) Surgeons can take advantage of the hazardous zone that is located caudolaterally on the proximal tibiotarsus. This area is found between the two proximal cross sections (Figures 2a&2b). The most proximal pin should also be directed distally when being introduced lateral to medial. This will prevent the connecting material of the ESF from rubbing against the body wall.

**Humerus:** The humerus has restrictions for ESF placement which include the patagial tendons, biceps brachii, body wall, and the triceps brachii. This only leaves the lateral side available for transfixation pins. There are available safe zones on the distal one third of the humerus, which should be used as a guide for pin placement more proximal. The proximal two thirds of the humerus have hazardous zones which will be penetrated. On the proximal cross section (Figure 3a), a lateral danger zone contains the axillary nerve and subscapular artery. This zone also contains the deltoid crest of the humerus, which would surely splinter if a pin was introduced into it. The radial nerve starts caudally with the triceps brachii but then courses laterally midshaft with the deep radial artery. Distally, the deep radial artery moves craniolaterally while the radial nerve stays lateral, until the last cross section where it joins the radial artery once again.

The optimal ESF for the humerus is a Type I K-E starting caudolateral to craniomedial. Hazardous zones are entered on the proximal humerus. As previously stated, each pin entry site should have a separate incision with blunt dissection to the bone before placement. The radial nerve courses through this recommended approach on Figure 3d. A transfixation pin should not be introduced at this level, and can be placed distal or proximal with the same orientation as previously described. Before driving pins into this area, the radial nerve should be identified, either visually with an open approach or palpated in a closed technique.

**Ulna:** The ulna has restrictions for ESFs medially by the body wall, cranially by patagial tendons and the radius, and caudally by the metacarpals, phalanges, and primary and secondary feathers. An investigation of the lateral and caudal aspects of the ulna demonstrates safe zones for a K-E apparatus. On the fourth cross section of the ulna (Figure 4d), a caudal hazardous zone forms from many of the flexor tendons of the
The ulnar nerve and deep ulnar vein create a danger zone caudally on the fifth cross section (Figure 4e). On the diagrams it appears the caudal ulna is functional for transfixation pin use, but the secondary feathers, metacarpus, and primary feathers interfere. The lateral safe zone on the ulna has a consistent straight path its entire length, which makes it ideal for a Type I K-E. A straight lateral to medial approach is the accepted technique. A Type II K-E for the ulna has been described in birds, but it is very close to the body wall and violates the danger zones.

**Kirschner – Ehmer Apparatus With Intramedullary Pin “Tie in”**

Adding an intramedullary (IM) pin and incorporating it into the K-E apparatus has proved to be helpful. Placing the IM pin first, provides alignment for the transfixation pins to be introduced. After the transfixation pins are placed, pins are generally bent toward the fracture site, including the IM pin. The structure takes the form of an “I beam”. The IM pin is parallel to the long bone with the transfixation pins forming struts from the bone to the IM pin. There is enough transfixation pin bent to be incorporated into the connecting bar with the external part of the IM pin.

This structure minimizes bending forces that may still be present with a K-E apparatus only. The K-E with IM pin “tie in” allows the bird to use the affected limb during the recovery period. This minimizes muscle atrophy, ankylosis, and tendon contraction. During fracture healing, there is a point when some movement at the fracture site is desired. De-staging, or a dismantling of the ESF over time, can be performed when a small callus is present radiographically. This process is referred to as dynamization, which gradually increases the load bearing of the bone.

The bones that are best to use this type of ESF are the femur, humerus, and ulna. While there have been reports of using a TIF for the tibiotarsus, placing an IM pin there may interfere with normal stifle movement. That makes the preferred technique a Type II K-E, especially with the safe zones available on the distal third of the bone.

**Summary**

1. Know the anatomy and corresponding zones of the femur, tibiotarsus, humerus, and ulna.
2. Use safe zones to your advantage.
3. When hazardous zones are entered, make separate incisions and blunt dissection for each transfixation pin.
4. Do not enter danger zones.
5. Do not penetrate the large sliding muscle masses described for the femur, tibiotarsus, and humerus.
6. Locate the radial nerve when repairing the humerus.
7. Use a Type I K-E on the femur, humerus, and ulna.
8. Use a Type II K-E on the tibiotarsus.
9. When possible, incorporate an IM pin into the Type I K-E.
There are many other factors to consider when using eternal skeletal fixators, such as size of the patient, classification of the fracture, transfixation pin type, diameter and number, pin insertion technique, and crossbar material. The focus of this report was to study the cross sectional anatomy avian long bones, in order to develop standard locations for transfixation pins. By following these guidelines we can decrease soft tissue impalement, and decrease morbidity in avian patients.

References

Cross-Sectional Anatomy of the Femur

Figures 1a-e: Hazardous and danger zones at five levels of the femur. There are no safe zones for pin placement. Blunt dissection should be used to enter hazardous zones laterally.
Cross-Sectional Anatomy of the Tibiotarsus

Figures 2a-e: Safe, hazardous, and danger zones at five levels of the tibiotarsal bone. Lateral hazardous zones will be entered for ESF (External Skeletal Fixator) placement.
Cross-Sectional Anatomy of the Humerus

Figures 3a-e: Safe, hazardous, and danger zones at five levels of the humerus. Lateral hazardous and safe zones will be used for ESF placement.
Cross-Sectional Anatomy of the Radius and Ulna

Figures 4a-e: Safe, hazardous, and danger zones at five levels of the ulna. Safe zones can be used the entire length of the ulna.