**Interventional Surgery Using Computed Tomography (CT)**

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**Introduction**

Computed tomography has proved to be valuable in the diagnosis of lameness associated with distal limb pathology in the horse and has been reported to adequately detect and characterize bone injury, subchondral osseous lesions and occult osteochondral defects.\(^1^\)\(^6^\) CT images have also been used to help interpret the configuration of comminuted fractures and allows accurate assessment of the number and direction of fracture lines within the bone.\(^6^\)\(^8^\) However, the applications of CT as an aid for equine orthopaedic diagnosis and surgery remain scarce. Its use is limited because of the price, availability, difficulty to transport the scanner into surgical theatre, and the contraindications of general anaesthesia in some patients. Therefore, since 2002, our objectives have been: (1) to develop and experiment a CT scan that would enable imaging of the distal extremities of the standing sedated horse; (2) to design a CT scan that could be easily transported including into the surgical theatre; (3) to assess its ability to identify bony and soft tissue lesions on clinical cases, both in standing and recumbent position; (4) to use that initial experience of diagnosis with CT to develop, test in vitro and apply on clinical cases techniques for pre-operative planning with computed tomography; (5) to develop CT computer-assisted three-dimensional visualization that would allow surgeons to explore the surgical field and lesions in various projections prior to the operation; (6) and ultimately to develop, test and refine techniques of Minimal Invasive (MI) CT Computer Assisted Surgery that are applicable in daily private equine practice.

**Diagnosis with CT**

The system that we use is the XCT 3000 (Norland-Stratec Medical Sys.). It is a pQCT (peripheral quantitative computerized tomography) scanner. pQCT is a method of assessing bone mineral density which uses multiple cross-sectional x-rays to reconstruct a volumetric model of the bone density distribution. We modified the original scanner to allow horizontal and vertical use. It is mounted on a frame that is moved with electric motors. Wheels and brake have been added to the structure. This resulted in a scanner of 200 kg which is mobile, can be moved within the hospital and transported in a small car. The system has been described elsewhere by Desbrosse and al.\(^9^\) We have shown that CT scanning of the foot in the standing horse is possible. Our initial experience with the XTC 3000 suggested that it allowed excellent visualisation of bony structures but was not suitable to evaluate soft tissues, as the XTC 3000 is basically used to measure bone density and geometrical parameters of bone. However, intra-venous contrast-enhanced computed tomography was used in recent clinical cases and was found to be very useful to identify inflammatory lesions of the soft tissues in the distal limb.
CT Assisted Surgery

CT and pre-operative planning on the standing horse

Different pathologies of the foot may require surgical treatment, such as keratoma, osteitis, and fracture of the navicular bone or the distal phalanx. Surgical landmarks should be ideally identified before surgery on the standing horse, to avoid prolonged anesthetic time and to reduce the number of control radiographs. Identification of the anatomical landmarks of the lesion should also be as accurate as possible to facilitate minimally invasive surgery. This is possible with CT. The technique was experimented in vitro before application on clinical cases. We showed for example that standing CT can be used to determine accurately anatomic landmarks for lag screw insertion in sagittal fractures of the distal phalanx with greater precision than radiography. Results showed that CT was more accurate to identify the parameters for screw insertion \( U = 23.50, p< 0.05, r = -0.45 \). With CT assisted technique, surgical time was also shorter \( U = 0.000, p< 0.05, r = -0.87 \) and control radiographs were not necessary. CT pre-operative planning has been performed on clinical cases of distal phalanx fracture \( (n = 1) \), keratomas \( (n = 2) \), subchondral bone cyst in MC 3 \( (n = 1) \), and OA in a fetlock joint \( (n = 1) \).

CT under recumbency

179 CT scans have been performed in our practice between January 2002 and April 2008. In 109 cases, it was carried out under general anesthesia to document the lesion before the intervention. It is our opinion that the obtained information was useful for the surgery in 64 cases.

1. CT to refine lesion identification before surgery

CT has been useful in a wide range of surgical cases to identify more accurately anatomical landmarks of lesions that had been diagnosed with other imaging modalities (radiography, ultrasonography). The surgical plan was confirmed or changed and a minimally invasive approach was used. This was the case for intervention on keratomas \( (n = 1) \), subchondral bone cysts \( (n = 3) \), osteochondral fragments \( (n = 9) \), and fractures (simple P1 fractures \( [n = 2] \), fractures of carpus \( [n = 2] \), fractures of tarsal bones \( [n = 2] \), and a stress fracture of the cannon bone \( [n = 1] \)). It has also been used for arthrodesis of distal intertarsal joints \( (n = 1) \) and to localize the joint space before arthrodesis of the distal interphalangeal joint \( (n = 1) \).

2. CT to identify the lesion before surgery

Lesions that were poorly or not visible with other modalities could be identified before surgery with computed tomography. The surgical plan was either refined or changed according to the CT findings. In our experience, CT has been useful in several cases. It has enabled detection of exostosis of MC/MT 3 at the proximal insertion of the suspensory ligament, bone changes that were not radiographically and ultrasonographically evident \( (n = 4) \). In four cases \( (n = 4) \), CT gave information about where on proximal MC/MT 3 it was useful to perform osteostixis. Osteoma of the cannon bone \( (n = 2) \) and
sequestra (n = 2) have been identified and removed. The 3D relationship of splints with MC/MT 3 and the suspensory ligament has been assessed in six cases (n = 6). The configuration of fractures has been documented: accessory carpal bone (n = 2), proximal phalanx (n = 4), middle phalanx (n = 2), navicular bone (n = 1), distal radius (n = 1), third metacarpal bone (n = 1), proximal tibia (n = 1) and femur condyle (n = 1). CT was also used to assess soft tissues. A foreign body (n = 1) penetrating the coronary band has been evaluated before surgery. Intra-venous contrast-enhanced computed tomography has been used in one case of foot penetration (n = 1) and one injury to the soft tissues in its palmar/plantar aspect (n = 1).

3. *CT to assess the immediate surgical result and evaluate healing*

Computed tomography has also been used to assess either the result of the surgical procedure immediately after the intervention or the response to the surgical treatment during the follow-up period. 3-dimensional visualisation confirmed complete removal of splints and sequestra (n = 5). Bone healing after fracture has been assessed on the standing horse or on the horse under GA before cast change (n = 3).

*CT Computer Assisted Minimally Invasive Surgery*

More recently, CT Computer Assisted Surgery has been developed in our practice, experimented in vitro and applied on clinical cases. We have adapted a 3D medical software (Volview) that allows 3D planning of surgery with assessment of its implications on neighbouring anatomical structures and accurate determination of distances such as the length of the implants. The limb can be maintained in the scanner during surgery and the CT scan can be used to guide the procedure. CT Computer Assisted Surgery has been used on the above cases for the fractures of the navicular bone, P1, P2, P3, and for the arthrodesis of the distal interphalangeal joint.

**Conclusion**

The XCT 3000 may gain increasing popularity for both research studies and clinical applications. It is particularly useful to measure distances and lengths accurately and to assess 3-dimensional configuration of lesions. However, research is required to compare XCT 3000-assisted surgery with other modalities.

**References**


