NEVA STREAM: DIAGNOSTIC IMAGING AND ORTHOPAEDICS

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EARLY EXPERIENCE WITH ROBOTIC COMPUTED TOMOGRAPHY IN STANDING HORSES

Beginning disclosure: We've been collaborating with 4DDI, the company selling this equipment, for approximately 3 years. We (meaning me personally or the University of Pennsylvania) do not hold any financial interest in the company.

Computed tomography (CT) is unequivocally the best current technology for accurate anatomic diagnosis of skeletal structures. The anatomic detail of bone pathology provided by CT is markedly superior to MRI although the latter clearly can provide more physiological information. One of the greatest advantages of CT is its speed. A huge amount of information can be gathered in a matter of seconds. Unfortunately the traditional form of CT, i.e. fitting the body part in a closed "donut, has required general anesthesia for horses and largely eliminated this enormous potential advantage. The most widely used design for creating 3-D x-ray images is using helical CT in which a high output x-ray tube emits a "fan-beam" that is detected by an array of detectors to create a "slice". Another option uses lower radiation and flat panel detectors to create multiple complete volume images that are then reconstructed. This is termed "cone beam" CT. Although there are some specific limitations of cone beam CT, it allows a different approach and it also exposes the patient and personnel to significantly less radiation.

Computed tomography with either technique involves taking a large number of radiographs from all directions and then using a computer to integrate all these images into a 3 dimensional reconstruction and certain thickness "slices". The basic physics demand a rotating x-ray tube and opposite x-ray detector so the simplest design is definitely a "donut" with these two spinning around the body part. Conceptually, however, the rotating tube and detector could be separated and controlled separately IF (only if) the physical relationship between the two could be controlled with extreme precision. Modern robots in the automotive industry and elsewhere are amazingly controllable, precise (in the µm range) and reliable so the marriage of robots to cone-beam computed tomography is very attractive.

We have been doing CT diagnostics and extensive CT-assisted surgery for well over a decade so we have long recognized its value. The possibility of expanding its use to the standing patient was (and is) exciting. The technology is not at all perfect and there remain questions about its future improvements, potential and limitations. Perhaps the single greatest challenge for any standing imaging modality is dealing with motion. Even a horse that appears to be standing perfectly still is actually moving enough that sub-millimeter resolution would be impossible without mathematical motion correction algorithms. The current system we use involves four 3-D cameras focused on markers attached to the horse's body part. The motion of the body part in its x-y-z coordinates can mathematically define how to "move" each radiographic image to make an accurate 3-dimensional image. This is both complex and limited but there is every reason to believe that it can be vastly improved.

The current process takes a matter of minutes but the actual scan takes seconds. The horse is moderately sedated (nearly always detomidine +/- butorphanol depending on response), led to a space between the robotic arms. The reflective markers taped on the body part are calibrated to define their coordinates. The tube and detector heads on the robot arms are moved into position and adjusted to optimize the position of the subject between them. We use two lead-clad humans, one near the head and the other near the pelvis to help assure the horse stands still. The robotic excursion and image capture then takes about 20 seconds. Post-processing of captured images combined with motion correction takes about 5-10 minutes but this should become much quicker with further software development.

The full capacity of the technology is still uncertain. We currently can only do limbs (carpus/tarsus and distally) , head and neck (but still struggling with C6-C7). It is theoretically possible to do the elbow and stifle in a standing horse but it may well require general anesthesia. It is important to emphasize that robotic CT *can* be done with the horse under general anesthesia. That should lessen the necessity for extensive motion correction and also allow robotic excursions that are not feasible in a standing horse. The quality of this CT is not yet truly equivalent to the images obtained with "traditional" helical CT under general anesthesia but it has proven to be diagnostic. We have performed comparative scans (robotic and traditional) on about ___ horses. The robotic CT images have consistently been "diagnostic" in those horses but are still not equivalent aesthetically.