Determination of the anatomic communications among compartments within the carpus, metacarpophalangeal and metatarsophalangeal joints, stifle joint, and tarsus in llamas

Stacy A. Semevolos, DVM, MS, and Rhian B. Cope, BVSc, PhD

Objective—To determine the anatomic communications among compartments within the carpus, metacarpophalangeal and metatarsophalangeal joints, stifle joint, and tarsus in llamas.

Sample Population—88 limbs from 22 llamas necropsied because of reasons unrelated to disease of the carpus; tarsus; or metacarpophalangeal, metatarsophalangeal, or stifle joints.

Procedure—1 compartment (randomly assigned) of each joint was injected with blue latex solution. Communication between joint compartments was determined by observation of latex in adjacent compartments following frozen sectioning.

Results—Of the 44 carpi, 30 (68%) had anatomic separation between the radiocarpal and middle carpal joints, whereas the remaining 14 (32%) had communication between the radiocarpal and middle carpal joints. In the metacarpophalangeal or metatarsophalangeal joints, medial and lateral joint compartments remained separate in 83 of 88 (94%) joints injected. The tibiotarsal and proximal intertarsal joints communicated in all tarsi examined, whereas 14 of 38 (37%) communicated between the proximal intertarsal and distal intertarsal joints. Communication between the distal intertarsal and tarsometatarsal joints was detected in 17 of 25 (68%) specimens; all 4 tarsal joints communicated in 11 of 42 (26%) specimens examined. Examination of 33 stifle joints that were successfully injected revealed communication between the femoropatellar, medial femorotibial, and lateral femorotibial joints.

Conclusions and Clinical Relevance—These data suggest that it is important to determine the joint communications specific to each llama prior to treatment of septic arthritis. The metacarpophalangeal or metatarsophalangeal joint compartments may be considered separate, although the lateral and medial compartments infrequently communicate along the proximal palmar or plantar aspect. (*Am J Vet Res* 2005;66:1437–1440)

Joint disease develops in New World camelids of all ages and can be caused by injury to the joint, bacterial infection, or degenerative osteoarthritis. To treat joint disease, it is imperative to know which anatomic communications or separations exist among joint compartments. In addition, there are important differences in joint compartment communications among species.[1-4] Information regarding anatomic features of New World camelids is limited, and to the authors' knowledge, no comprehensive evaluation of the joints and their compartmental communications has been done.[5] Because this information is lacking, practitioners have to make decisions about the treatment of joint diseases on the basis of anatomic features of other species. This becomes most critical during the treatment of septic joints, when insufficient knowledge of joint interconnections could lead to inadequate resolution of the infection.

Several recent reports[2-4,6-9] have included descriptions of techniques for determining the communications among joint compartments in horses and cattle. The most common technique involves the injection of latex solution into a single joint compartment, flexing the joint repeatedly, and then freezing the limb prior to sectioning; detection of latex in adjacent (noninjected) joint compartments is evidence of anatomic communication between compartments.

The objective of the study of this report was to determine the anatomic communications among compartments within the carpus, metacarpophalangeal and metatarsophalangeal joints, stifle joint, and tarsus in llamas. It was predicted that the anatomic communications within these joints of the llama would be similar to those previously determined in Dromedary camels, ruminants, or horses.[1-4,6-8,10-13] In the stifle joint, the prediction was that the femoropatellar, medial femorotibial, and lateral femorotibial compartments would all intercommunicate. In the tarsus, it was predicted that the tibiotarsal and proximal intertarsal joints would communicate but the distal intertarsal and tarsometatarsal joints would be separate compartments. In the carpus, the middle carpal and carpometacarpal joints were expected to communicate, whereas the radiocarpal joint would be separate from the former. In the metacarpophalangeal and metatarsophalangeal joints, the prediction was that the medial compartment would not communicate with the lateral compartment.

Materials and Methods

Fresh cadavers of 22 adult llamas that had died or were euthanatized (for reasons other than joint disease) were used in this study; euthanasia was performed by use of an overdose of pentobarbital. All 4 limbs of each llama were prepared for evaluation. A solution[2] of blue latex[a] (3 parts), water (1 part), and 10% formalin (1 part) was injected into

Received September 20, 2004.
Accepted November 8, 2004.
From the Departments of Clinical Sciences (Semevolos) and Biomedical Sciences (Cope), College of Veterinary Medicine, Oregon State University, Corvallis, OR 97331.
Funded by the Willamette Valley Llama Foundation.
Address correspondence to Dr. Semevolos.

each area of interest: in both carpi, stifle joints, tarsi, and metacarpophalangeal and metatarsophalangeal joints of each llama. One joint compartment was randomly assigned to be injected, and that compartment was injected at least 9 times in different joints. A 20-mL syringe and 18-gauge needles were used for the injections, and all injections were made by 1 investigator (SAS). The injections were made until moderate distension of the joint was palpable and back pressure was apparent on the syringe plunger. To distribute the latex solution, the joint was flexed throughout its range of motion 75 times. The limb was placed in a cooler (4°C) for 24 hours and then placed in a freezer for at least 48 hours. A band saw was used to cut the metacarpophalangeal and metatarsophalangeal joints transversely and the carpi, tarsi, and stifle joints sagittally into 1-cm-thick sections. After sectioning, the distribution of latex solution in the areas of interest was examined visually by 1 investigator (SAS) and communications between joint compartments were determined on the basis of detection of latex in joint compartments other than that which was injected.

The joint compartments of the carpus included the radiocarpal, middle carpal, and carpometacarpal joints. With the carpus flexed to open the joint space, the radiocarpal joint was injected at a position lateral or medial to the extensor tendons. The middle carpal joint was injected at a position lateral to the extensor tendons in a divot created between the intermediate carpal, ulnar carpal, and fourth carpal bones. The carpometacarpal joint was injected on either side of the extensor tendons by directing the needle axially toward a divot between the third and fourth carpal bones and the third and fourth metacarpal bones. The metacarpophalangeal and metatarsophalangeal joints were divided into the medial and lateral compartments; with the joint flexed, 1 compartment was injected dorsally either axial or abaxial to the extensor tendon. The joint compartments of the tarsus included the tibiotarsal, proximal intertarsal, distal intertarsal, and tarsometatarsal joints. The tibiotarsal and proximal intertarsal joints were injected dorsally, either medial or lateral to the extensor tendon; the proximal intertarsal injection site was more distal, located at the junction of the tibial tarsal and central tarsal bones. The distal intertarsal joint injection was made medially between the edge of the central tarsal bone and the second tarsal bone. The tarsometatarsal joint was injected laterally between the fourth tarsal and fourth metatarsal bones. Alternatively, the tarsometatarsal joint was injected medially between the second tarsal and third metatarsal bones, but it was difficult to differentiate the tarsometatarsal joint from the distal intertarsal joint at this location. The stifle joint compartments included the femoropatellar, medial femorotibial, and lateral femorotibial joints. The femoropatellar joint was injected at a position medial or lateral to the patellar ligament (middle), with the needle directed proximally under the patella. The medial and lateral femorotibial joints were injected just cranial to the palpable junction of the distal femoral condyle and the proximal portion of the tibia. For all stifle joint injections, it was important to use a 1.5-inch needle to avoid inadvertent injection of latex into the fat pad.

Results

In the 44 carpi examined, 30 (68%) had anatomic separation between the radiocarpal and middle carpal joints, whereas the middle carpal and carpometacarpal joints always communicated with each other. Examination of the remaining 14 (32%) carpi revealed communication between the radiocarpal and middle carpal joints. Communication between the joints of the carpus and the carpal sheath was detected in 28 (64%) of the injected carpi, predominantly through the palmar aspect of the radiocarpal joint. In 1 specimen, the middle carpal joint communicated along its palmar aspect with the carpal canal. The extensor tendon sheath was inadvertently injected in 10 of the 44 (23%) carpi. On comparison of paired carpi from each llama, differences in joint communications between the 2 limbs were detected in 6 of 22 (27%) llamas.

In the metacarpophalangeal joints examined, the medial and lateral joint compartments remained separate in 40 of the 44 (91%) joints, whereas the remaining 4 (9%) had communication in the proximal portion of the palmar joint capsule. In the metatarsophalangeal joints examined, the medial and lateral compartments were separate in 43 of the 44 (98%) joints, whereas 1 had communication along the proximal portion of the plantar joint capsule. However, in those metacarpophalangeal or metatarsophalangeal joints in which the compartments communicated, the latex did not infiltrate the entire contralateral compartment but remained confined to the proximal palmar or plantar portion of that compartment. On comparison of paired metacarpophalangeal joints from each llama, differences in compartment communications between the 2 limbs were detected in 4 of 22 (18%) llamas. On comparison of paired metatarsophalangeal joints from each llama, differences in compartment communications between the 2 limbs were detected in 1 of 22 (4.5%) llamas.

In the 42 tarsi examined, all (100%) had communication between the tibiotarsal and proximal intertarsal joints, whereas 14 of 38 (37%) had communication between the proximal intertarsal and distal intertarsal joints. Communication between the distal intertarsal and tarsometatarsal joints was detected in 17 of 25 (68%) specimens. There was communication among all 4 compartments at the tibiotarsal-to-proximal intertarsal, proximal intertarsal-to-distal intertarsal, and distal intertarsal-to-tarsometatarsal joint junctions in 11 of 42 (26%) tarsi. In 2 specimens, injections of latex solution resulted in infiltration of the extensor tendon sheath and poor joint penetration; therefore, these joints were excluded from the analysis. On comparison of paired tarsi from each llama, differences in compartment communications between the 2 limbs were detected in 4 of 17 (23%) llamas.

In the 41 stifle joints examined, 33 (80%) had communication among the femoropatellar, medial femorotibial, and lateral femorotibial joints. In the remaining 8 (20%) specimens, the injected latex solution locally infiltrated the fat pad and did not distribute throughout the joint compartments.

Discussion

In the present study, several important differences in joint communications were detected in llamas, compared with findings in other species. First, communication between the radiocarpal and middle carpal joints examined was detected in a greater percentage of carpi of llamas (32%), compared with the percentage of carpi of cattle (13%) reported previously.[3] Second, in the metacarpophalangeal and metatarsophalangeal joints, the medial and lateral compartments were most often separate in llamas; this is contrary to the finding in cattle, in which the medial and lateral compartments communicated in 186 of 188 (99%) specimens.[2] In llamas, the percentage of tarsi in which communication between the proximal intertarsal and distal intertarsal joints and between the distal intertarsal and tarsometatarsal joints was detected was higher, compared with the percentage of tarsi of horses reported previously.[7] Finally, when successfully injected with latex solution in the present study, the stifle joint was determined to be 1 compartment in llamas, which is similar to descriptions of stifle joints in sheep and Dromedary camels.[1,13]

The carpus is composed of 3 basic joint compartments: the radiocarpal, middle carpal, and carpometacarpal joints. In horses, the middle carpal joint and carpometacarpal joint communicate and the radiocarpal joint is a separate compartment.[11] In cattle, results of a previous study[3] indicated that there was communication among the radiocarpal, middle carpal, and carpometacarpal joints in 13% of carpi (18/137 specimens) examined, whereas there was communication only between the middle carpal and carpometacarpal joints in the remainder of specimens. In the present study, a greater percentage of carpi in llamas had communication between the radiocarpal and middle carpal joints, compared with the previously reported findings in cattle or horses.

The carpal canal contains the carpal sheath, which is a synovial sheath that surrounds the superficial and deep flexor tendons.[14] This sheath is separated from the carpal joints by the palmar carpal ligament.[15] In the present study, the high percentage of specimens in which there was communication between the carpal sheath and the radiocarpal joint was not expected and should be considered when treating septic conditions of the radiocarpal joint or carpal sheath in llamas.

Extensor tendon sheaths envelop the extensor carpi radialis and common digital extensor muscles and the lateral digital extensor tendons along the dorsal surface of the carpal region.[12] New World camelids have a tough, fibrous, dorsal carpal pad that inhibits palpation of the extensor tendons. This may explain the inadvertent injection of latex solution into the extensor tendon sheath that occurred in 10 of the 44 (23%) carpi investigated in our study.

In cattle, the metacarpophalangeal and metatarsophalangeal articulations are formed by the third and fourth metacarpal or metatarsal bones, 2 pairs of sesamoid bones along the palmar or plantar aspect, and 2 proximal phalanges.[12] Although there are 2 metacarpophalangeal and metatarsophalangeal joint compartments in ruminants, communication between these compartments has been detected in 99% of specimens examined.[2] However, in Dromedary camels, the joint capsules of the medial and lateral joints are not interconnected.[1] Results of our investigation indicated that the medial and lateral compartments of the metacarpophalangeal and metatarsophalangeal joints were usually separate in llamas, similar to the structure of the metacarpophalangeal and metatarsophalangeal joints in Dromedary camels. In the few metacarpophalangeal or metatarsophalangeal joints of llamas in which the medial and lateral compartments communicated, the communication was present at the proximal palmar or plantar aspect, which is similar to the site of communication in those joints in cattle.[2] Within the metacarpophalangeal and metatarsophalangeal joints of llamas, confinement of the latex solution to the proximal palmar or plantar aspect of the contralateral (noninjected) compartment suggests functional separation of compartments in those joints with compartment communication.

The tarsus has 4 joint compartments, and the tibiotarsal and proximal intertarsal joints communicate in most species. In species other than llamas, the distal intertarsal and proximal intertarsal joints are typically separate structures, whereas the distal intertarsal and tarsometatarsal joints communicate in some tarsi. Not unexpectedly, the tibiotarsal and proximal intertarsal joints consistently communicated in the tarsi obtained from llamas; however, the relatively high percentages of specimens with proximal intertarsal-to-distal intertarsal joint communication and distal intertarsal-to-tarsometatarsal joint communication were not anticipated. In addition, a higher percentage of tarsi of llamas had connections between all 4 compartments at the tibiotarsal-to-proximal intertarsal, proximal intertarsal-to-distal intertarsal, and distal intertarsal-to-tarsometatarsal joint junctions, compared with findings of previous investigations[7,8,11] of joint communication in other species.

The stifle joint is comprised of 3 different compartments; communications between these compartments vary among species. In horses, the lateral femorotibial joint is generally separate from the medial femorotibial and femoropatellar joints.[9] In cattle, communication among all 3 compartments has been detected in approximately 57% of stifle joints (58/102 specimens).[4] In Dromedary camels, the joint capsule is undivided, resulting in 1 joint compartment.[1] In llamas, a similar finding of 1 stifle joint compartment has been reported[10]; however, in that report, there is no mention of how that finding was determined. Results of the present study have confirmed this previous finding in llamas. Examination of the stifle joints that were successfully injected in our study revealed communication among the 3 joint compartments in all specimens. Infiltration of the freely movable tibial fat pad has been reported to inhibit needle penetration into the stifle joint capsule.[5] Potential reasons for fat pad infiltration during injection of stifle joints include the use of a needle that is too short or injection at a site between the patella and tibia that is too far dorsal. Therefore, it is recommended to use a 1.5-inch needle and position it close to the bone when injecting the stifle joint of llamas.

The findings of our study provide critical information for the treatment of joint disease and injury in New World camelids. With knowledge of the anatomic communications within joints, practitioners will be able to properly medicate only the affected joint compartments, which is especially important for the treatment of septic joints and osteoarthritis. Our data indicate that the stifle joint of llamas can be considered as 1 large compartment. In contrast, the compartments of the metacarpophalangeal or metatarsophalangeal joints may be considered to be separate, although the lateral and medial compartments infrequently communicate along the proximal palmar or plantar aspect. Finally, because communication may be present among all joint compartments within the carpus or tarsus of llamas and differences in joint communications can be detected within each animal, it is important to determine the actual communications among joint compartments of each individual llama prior to treatment of joints with septic arthritis. Therefore, in llamas, fluid samples should be obtained from each joint compartment for cytologic evaluation or compartments should be injected with sterile contrast medium for radiographic determination of joint communications before instituting appropriate treatment.

a. Ward's Natural Science, Rochester, NY.

References

1. Smuts MM, Bezuidenhout AJ. The joints and ligaments. In: *Anatomy of the dromedary*. Oxford, England: Clarendon Press, 1987:49–58.
2. Desrochers A, St-Jean G, Cash WC, et al. Characterization of anatomic communications of the fetlock in cattle, using intra-articular latex injection and positive-contrast arthrography. *Am J Vet Res* 1997;58:710–712.
3. Desrochers A, St-Jean G, Cash WC, et al. Characterization of anatomic communications among the antebrachiocarpal, middle carpal, and carpometacarpal joints in cattle, using intra-articular latex, positive-contrast arthrography, and fluoroscopy. *Am J Vet Res* 1997;58:7–10.
4. Desrochers A, St-Jean G, Cash WC, et al. Characterization of anatomic communications between the femoropatellar joint and lateral and medial femorotibial joints in cattle, using intra-articular latex, positive-contrast arthrography, and fluoroscopy. *Am J Vet Res* 1996;57:798–802.
5. Fowler ME. Clinical diagnosis: examination and procedures. In: *Medicine and surgery of South American camelids*. 2nd ed. Ames, Iowa: Iowa State University Press, 1998;69–88.
6. Ford TS, Ross MW, Orsini PG. Communications and boundaries of the middle carpal and carpometacarpal joints in horses. *Am J Vet Res* 1988;49:2161–2164.
7. Sack WO, Orsini PG. Distal intertarsal and tarsometatarsal joints in the horse: communication and injection sites. *J Am Vet Med Assoc* 1981;179:355–359.
8. Bell BT, Baker GJ, Foreman JH, et al. In vivo investigation of communication between the distal intertarsal and tarsometatarsal joints in horses and ponies. *Vet Surg* 1993;22:289–292.
9. Vacek JR, Ford TS, Honnas CM. Communication between the femoropatellar and medial and lateral femorotibial joints in horses. *Am J Vet Res* 1992;53:1431–1434.
10. Van Hoogmoed L, Snyder JR, Vasseur P. Surgical repair of patellar luxation in llamas: 7 cases (1980–1996). *J Am Vet Med Assoc* 1998;212:860–865.
11. Stashak TS. Diagnosis of lameness. In: Stashak TS, ed. *Adams' lameness in horses*. 4th ed. Philadelphia: Lea & Febiger, 1987;100–156.
12. Dyce KM, Sack WO, Wensing CJG. The forelimb of the ruminants. In: Dyce KM, Sack WO, Wensing CJG, eds. *Textbook of veterinary anatomy*. Philadelphia: WB Saunders Co, 1987;697–728.
13. Allen MJ, Houlton JEF, Adams SB, et al. The surgical anatomy of the stifle joint in sheep. *Vet Surg* 1998;27:596–605.
14. Dyce KM, Sack WO, Wensing CJG. The forelimb of the horse. In: Dyce KM, Sack WO, Wensing CJG, eds. *Textbook of veterinary anatomy*. Philadelphia: WB Saunders Co, 1987;542–575.
15. Cauvin ER, Munroe GA, Boyd JS. Endoscopic examination of the carpal flexor tendon sheath in horses. *Equine Vet J* 1997;29:459–466.