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Palmar arthroscopic approach and intra-articular anatomy of the bovine carpal joints

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Abstract

Objective: To describe the palmar arthroscopic approaches to the bovine carpus and document the visible intra-articular structures in each approach.
Study design: Ex vivo study.
Sample population: Thirty fresh cadaveric bovine forelimbs.
Methods: Computed tomography (CT) and gross dissection were performed on 4 carpi. Latex models were produced from 6 carpi to define the gross anatomy and arthroscopic portals to the palmar carpal pouches. Ultrasonography and arthroscopy were performed on 20 carpi to document visualization of the local anatomy.
Results: A single palmar pouch was present on both sides of each joint on gross dissection and evaluation of latex models. The relationship between pouches and palmar structures was observed by CT. Small anechoic areas identified on ultrasonography increased after joint distension. Palmar arthroscopy of the antebrachiocarpal joint enabled visualization of the palmar surfaces of radial, intermediate, and ulnar carpal bones; distal radius; ulnar styloid process; palmar radiocarpal ligament; and articulation of accessory and ulnar carpal bones. Palmar arthroscopy of the middle carpal joint enabled inspection of the palmar aspects of ulnar, intermediate, radial, fused second and third and fourth carpal bones, palmar carpometacarpal ligament, and the short lateral collateral ligament. Palmar aspects of the fourth and fifth metacarpal bones were explored through the palmarolateral approach to the middle carpal joint. Instrument portals for each pouch were created under arthroscopic guidance.
Conclusion: Palmar arthroscopy of the adult bovine carpus enabled visualization of the clinically relevant palmar intra-articular structures.
Clinical significance: Palmar carpal arthroscopy should be considered as an adjunct to dorsal approach for the diagnosis and treatment of bovine carpal diseases.

1 | INTRODUCTION

The carpal joint in cattle comprises the antebrachiocarpal, middle carpal, and carpometacarpal joints. Bones composing the carpus include the distal radius, styloid process of ulna, proximal row of carpal bones (radial, intermediate, ulnar, and accessory carpal bones), distal row of carpal bones (fused second and third carpal bones and fourth carpal bone), proximal extremity of the fused third and fourth metacarpal bones, and rudimentary fifth metacarpal bone.[1] The middle and carpometacarpal joints reliably communicate between the fourth and fused second and third carpal bones. In 13% of cases, the antebrachiocarpal and middle carpal joints communicate between the ulnar and intermediate carpal bones.[2]

Lameness originating from carpal pain is common in cattle.[3] Diagnostic procedures include physical examination, diagnostic imaging (including radiography and ultrasonography), arthrocentesis, and laboratory analysis of synovial fluid (including bacteriologic culture and cytological examination).[4] In early stages of septic disease process, radiography reveals only nonspecific soft tissue swelling and widening of the joint space, whereas subchondral bone lysis, osteomyelitis, and bony proliferation may become evident only 10–14 days later.[5] Ultrasonography offers the advantages of early recognition of the disease process through evaluation of synovial fluid (increased volume and echogenicity), cartilage and subchondral bone contour, and periarticular soft tissue involvement. Therefore, ultrasonography is a useful diagnostic procedure to perform prior to an arthroscopic examination.[6] Sources exist that describe both normal and pathologic ultrasonographic findings of the bovine carpus,[6,7] but a detailed anatomic or ultrasonographic description of the bovine palmar pouches is lacking.

Arthroscopic examination of the carpal joint in cattle is frequently indicated for diagnostic and prognostic evaluation (septic arthritis and less frequently in cases of osteochondritis dissecans, degenerative joint disease, subchondral bone cysts, and cartilage or ligament injury) and therapeutic intervention (dislodging of free osseous fragments, debris, and fibrin).[8–11] Arthroscopy has all the advantages of minimally invasive surgery. It improves evaluation of the articular cartilage, allows evaluation of joint capsule pouches and intra-articular structures, decreases hospitalization time, supports extensive joint lavage by flushing large volumes of fluid, and speeds up recovery.[8] Despite these advantages, arthroscopy is not routinely performed in cattle because of prohibitive equipment cost and the requirement for general anesthesia.[8] Arthroscopic approaches to the bovine joints are extrapolated from horses; however, significant periarticular and intra-articular anatomical differences exist between the 2 species.[12] Few reports describe the use of surgical arthroscopy for the treatment of carpal septic arthritis in cattle,[10,13–15] and the normal arthroscopic anatomy of the dorsal carpal pouches has only recently been described.[16] Although the bovine palmar carpal pouches are large and can serve as pockets for accumulation of fibrin and debris,[17] description not only of the arthroscopic approaches but also of the normal anatomy of the palmar carpal pouches in cattle is lacking.

We hypothesized that arthroscopic evaluation of the palmar compartments of the antebrachiocarpal and middle carpal joints would be possible in adult cattle. The objective of the present study was to describe in detail the arthroscopic approaches and the normal arthroscopic anatomy of the antebrachiocarpal and middle carpal joints in adult cattle.

2 | MATERIALS AND METHODS

2.1 | Study design

The study was carried out on the carpal regions of 15 Holstein–Friesian cattle cadavers (median age 5 years [range, 3–9]) that had been euthanized for reasons unrelated to orthopedic disorders. Limbs were disarticulated at the shoulder joint to maintain orientation of carpal soft tissue structures and were examined fresh within 6 hours. Computed tomography (CT) examination and gross dissection were performed (n = 4), and latex models were created (n = 6) to clarify the regional anatomy. Ultrasonographic and arthroscopic investigations were performed (n = 20), and visible structures were reported.

2.2 | Anatomical study and CT

Survey CT examination (Mx8000 IDT 16-slice helical CT scanner; Philips, Hamburg, Germany) was performed on 4 carpi obtained from 2 cattle cadavers. The limbs were placed on the CT table to mimic lateral recumbency. Acquisition variables were 120 kV, 352 mA, slice thickness of 1.3 mm, slice increment of 0.6 mm, rotation time of 1 second, pitch of 0.63, and matrix size of 512×512. The transverse CT images were reconstructed to a 3-dimensional image to illustrate the relationship between the osseous and soft tissue structures. After CT was performed, limbs were dissected (MGT) to determine the boundaries, surface landmarks, arthroscopic portals, proximity of neurovascular structures to arthroscopic portals, and the intra-articular anatomy of the bovine palmar carpal pouches.

Latex models (n = 6) were created to delineate the arrangement of the palmar carpal pouches. Red-colored latex (Kiwoplast; Wolf & Co, Vienna, Austria) was injected through the dorsolateral[16] aspect of the antebrachiocarpal (40 mL) and middle carpal joints (50 mL) with a 14 gauge, 1.5-inch (3.8-cm) needle. The latex mixture consisted of 3 parts of white latex colored with red pigment (Biodur, Heidelberg, Germany), 1 part water, and 1 part acidified 10% formalin. All joints were injected by the same person (MGT). Synovial fluid was aspirated to ensure proper placement of the needle in the joint, and latex was injected until the palmar pouches were visibly distended. After injection, the carpal joint was flexed and extended several times, and gentle massage was applied to the dorsal aspect of the joint to distribute the injected latex into the palmar pouches. Limbs were frozen (−18°) for 1 week and then thawed at room temperature (25°) for about 24 hours[16] and dissected to expose the latex-filled pouches. The palmar carpal pouches were identified and described, and their relations to the adjacent carpal bones, tendons, ligaments, and neurovascular structures were reported. Potential sites for arthroscopic portals were recorded.

2.3 | Ultrasonography

To assume a safe and correct arthroscopic access to the palmar carpal pouches, a B-mode ultrasonographic examination (Eickemeyer Magic 5000 digital ultrasound machine; Eickemeyer Veterinary Equipment, Tuttlingen, Germany) was performed with a 5–10 MHz linear transducer. Limbs (n = 20) were tied distal to the fetlock joint, positioned to mimic a dorsal recumbency in a live animal, and secured via a metal frame fixed to the elbow joint. The carpal region was shaved and cleaned, and coupling gel was applied. Ultrasonography was performed (UH) prior to and after joint distension.

2.4 | Arthroscopy

Distension of the palmar carpal pouches was achieved by using Ringer's solution by inserting an 18 gauge needle into the corresponding dorsal joint pouch as previously described.[16] Arthroscopic portals were identified via anatomical landmarks and ultrasonography. A 5-mm incision was created through skin, flexor retinaculum, and joint capsule with a No. 11 scalpel blade. The arthroscopic sleeve and blunt obturator were carefully advanced into the joint with a twisting motion. Fluid egress through the open stopcock of arthroscopic sleeve confirmed joint entry and then the obturator was replaced by a 4-mm 30° angle view arthroscope (Storz GmbH, Tuttlingen, Germany). Visualization of the articular cartilage confirmed intra-articular positioning of the arthroscope. The joint was systemically evaluated (WB and UH), and anatomic landmarks, starting point, visible structures, and complications were reported. Representative images and videos were recorded (Aida Vet DVD; Karl Storz Endovision, Tuttlingen, Germany). Instrument access to each pouch was accomplished and evaluated for access to intra-articular structures with a probe. To establish the instrument portals, an 18 gauge needle was inserted, and the needle tip was viewed with the arthroscope. Skin and subcutaneous tissues next to the needle were incised with a No. 11 blade. The cannula and blunt obturator were inserted into the joint capsule in the same direction as the guide needle. The obturator was then removed, and the probe was inserted.

After arthroscopy, the joints were dissected to detect the entry site and structures that had been penetrated during portal creation and to verify the examined intra-articular structures. Fluid extravasation and iatrogenic damage to articular surfaces were observed and recorded.

3 | RESULTS

3.1 | Anatomical study

No anatomical variation was found between the right and left carpi (Figures 1,2). The palmar joint capsule was enforced by the flexor retinaculum and extended 4–6 cm proximally (attached to the radial transverse crest) and 6–8 cm distally (attached to metacarpi) beyond the level of the carpus. Latex imprinting of the carpal joints identified 1 palmaromedial pouch (PMP) and 1 palmarolateral pouch (PLP) for each joint (the antebrachiocarpal, middle carpal, and carpometacarpal joints). The PMP in the antebrachiocarpal and middle carpal joints was larger than the PLP. The middle carpal joint communicated with the carpometacarpal joint through the PLP in all limbs and between the fourth carpal and fused second and third carpal bones in 2 joints. The PMP of the carpometacarpal joint appeared small on the latex model and was inaccessible during dissection, where the joint capsule and flexor retinaculum were firmly attached to the articular surfaces leaving almost no space in between.

3.2 | Antebrachiocarpal joint

Both the PMP and PLP were voluminous between the radial transverse crest proximally and the palmaroproximal third of the accessory, ulnar, intermediate, and radial carpal bones distally, where the capsule and flexor retinaculum were firmly attached to bones beyond these levels. The PLP was bounded laterally by the lateral collateral ligament and medially by the palmar radiocarpal ligament. The pouch enclosed the ulnar styloid process, palmarolateral aspect of distal radius, palmar aspect of ulnar carpal bone, and the dorsal aspect of the accessory carpal bone. The arthroscopic portal for the PLP was identified proximal to the accessory carpal bone palmarolaterally to the ulnar styloid process and between the palpable tendons of the lateral digital extensor and the long head of ulnaris lateralis muscles.

The PMP was bounded medially by the medial collateral ligament, palmary by the flexor carpi radialis tendon, and laterally by the palmar radiocarpal ligament. The pouch enclosed the radial styloid process, medial parasagittal ridge, and median glenoid cavity of the distal radius and the proximal aspects of radial and intermediate carpal bones. The arthroscopic portal for the PMP was determined palmar to the medial collateral ligament and the palmaromedial aspect of the distal radius.

3.3 | Middle carpal joint

The palmar joint capsule and flexor retinaculum were firmly attached to the carpal bones at the level of the middle carpal joint. The PLP was voluminous only at the articular surfaces of carpal bones (articulation of the ulnar and intermediate carpal bones with the fourth carpal bone), and the distal branch of the short lateral collateral ligament was enclosed by the joint capsule. The PLP was bounded laterally by the lateral collateral ligament, palmary by the accessoriometacarpal ligament, and medially by the joint capsule and the flexor retinaculum. The arthroscopic portal for the PLP was defined about 2 cm distal to the accessory carpal bone and 2 cm proximal to the fifth metacarpal bone between the tendon of the long head of the ulnaris lateralis muscle and the accessoriometacarpal ligament.

The PMP was voluminous between the distopalmar border of the intermediate and radial carpal bones proximally and the proximopalmar aspect of the fused second and third carpal bones distally. The PMP was bounded medially by the medial collateral ligament, palmary by the flexor carpi radials tendon, and laterally by the palmar carpometacarpal ligament. The arthroscopic portal for the PMP was located 2–3 cm proximal to the third metacarpal bone and palmar to the medial collateral ligament and the tendon of the extensor carpi obliquus muscle.

Cautious dissection of the periarticular structures revealed important neurovascular structures in the vicinity of palmar pouches that are vulnerable to iatrogenic damage

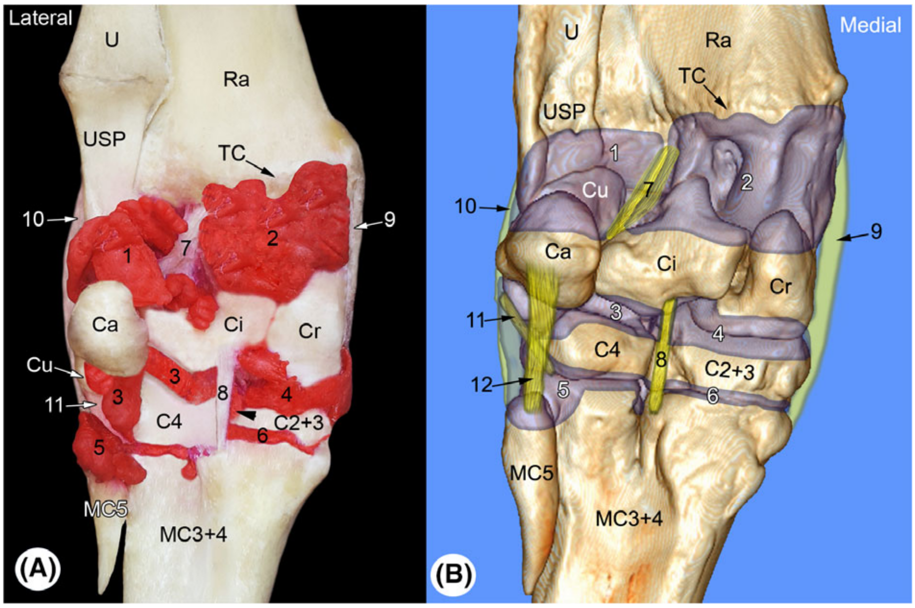

FIGURE 1 Latex model of the left palmar carpal pouches **(A)** and a 3-dimensional computed tomography recording **(B)** of the left carpus illustrating the distribution of the palmar pouches in relation to carpal bones in adult cattle. Palmarolateral (1) and palmaromedial (2) outpouchings of the antebrachiocarpal joint, palmarolateral (3) and palmaromedial (4) outpouchings of the middle carpal joint, palmarolateral (5) and palmaromedial (6) outpouchings of the carpometacarpal joint, palmar radiocarpal ligament (7), palmar carpometacarpal ligament (8), medial collateral carpal ligament (9), lateral collateral carpal ligament (10), distal branch of the short lateral collateral carpal ligament (11), accesoriometacarpal ligament (12), accessory carpal bone (Ca), intermediate carpal bone (Ci), radial carpal bone (Cr), ulnar carpal bone (Cu), fused second and third carpal bones (C2 + 3), fourth carpal bone (C4), third and fourth metacarpal bones (MC3 + 4), rudimentary fifth metacarpal bone (MC5), distal radius (Ra), transverse crest of distal radius (TC), ulna (U), ulnar styloid process (USP) communication between middle carpal and carpometacarpal joints (arrow head)

during arthroscopic entry. The dorsal branch of the ulnar nerve emerged between the ulnaris lateralis and flexor carpi ulnaris tendons about 2 cm proximal to the accessory carpal bone and ran distally across the joint in close proximity to the PLP of the middle carpal joint until entering the groove between metacarpal bone and interosseous IV. Medially, the radial artery and vein ran subcutaneously on the mediopalmar aspect of the carpal joint and were in close proximity to the medial arthroscopic portals to the antebrachiocarpal and middle carpal joints.

3.4 | Ultrasonography

The antebrachiocarpal, middle carpal, and carpometacarpal joints were imaged in both transverse and longitudinal planes; however, pouches were best evaluated in the longitudinal plane (Figure 2). The pouches were recognized as small anechoic fluid-filled areas at the level of the palmar joint spaces. After experimental filling, the distended synovial cavities were imaged as well demarcated anechoic areas. The palmar pouches of the antebrachiocarpal joint were recognized as a triangular anechoic area bounded deeply by the hyperechoic bone surfaces. The PLP of the antebrachiocarpal joint was visualized proximal to the accessory carpal bone that had hyperechoic contour and deep acoustic shadowing. At this level, tendons of the lateral digital extensor and ulnaris lateralis muscles were observed running distally. The PMP pouch of the antebrachiocarpal joint was imaged palmaromedial to the radial styloid process between the medial collateral ligament and the tendon of the flexor carpi radialis muscle, which appeared as echogenic structures showing a strong linear pattern of parallel fiber bundles in the longitudinal plane. The PLP of the middle carpal and carpometacarpal joints were seen about 2 cm distal to the accessory carpal bone and palmar to the lateral collateral ligament. Pouches were recognized as anechoic areas between the hyperechoic bone surfaces. The PMP of the middle carpal joint was viewed palmar to the extensor carpi obliquus tendon and palmar to the medial collateral ligament. The anechoic joint space was seen between the hyperechoic bone surfaces of the radial and the fused second and third carpal bones. The medial collateral ligament had an echogenic linear pattern and was more echogenic than the extensor carpi obliquus tendon.

3.5 | Arthroscopy

Arthroscopic portal creation was determined on the basis of topographic landmarks gained from the anatomical study and assisted by ultrasonography. The PLP of the antebrachiocarpal joint was best evaluated while the joint was extended. Angles of 50°-60° and 45° between the antebrachium and metacarpal bones were used to explore the PMP of the antebrachiocarpal joint and the PLP and PMP of the middle carpal joint, respectively.

3.6 | Antebrachiocarpal joint-PLP

The joint was initially flexed to about 45°, and a stab incision was created as determined in the anatomical study

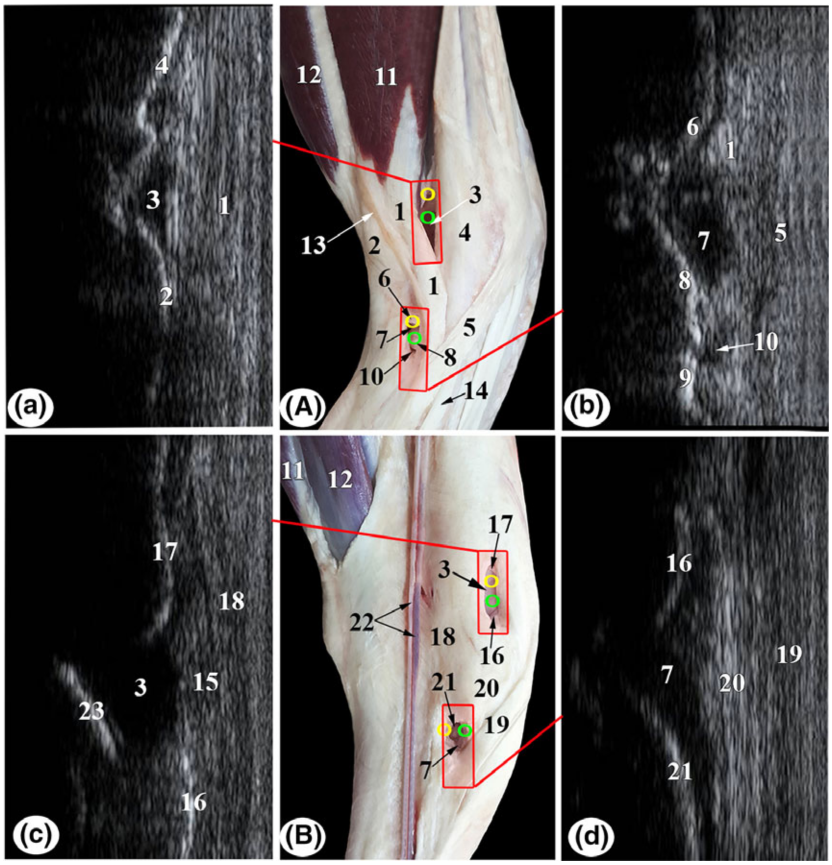

FIGURE 2 Applied longitudinal ultrasonograms of the palmarolateral **(a,b)** and palmaromedial aspects **(c,d)** of the carpus in a 5-year-old cow corresponding to the respective red rectangles on the right lateral **(A)** and left medial **(B)** aspects of the gross dissected forelimb specimens. All images are oriented with proximal to the top and palmar to the left. Landmarks for each joint approach are illustrated for insertion of the arthroscope (yellow O) and instrument (green O). Ulnaris lateralis tendon (1), accessory carpal bone (2), antebrachiocarpal joint cavity (3), ulnar styloid process (4), lateral collateral ligament (5), ulnar carpal bone (6), middle carpal joint cavity (7), fourth carpal bone (8), metacarpal bone (9), carpometacarpal joint cavity (10), ulnaris lateralis muscle (11), flexor carpi ulnaris muscle (12), dorsal branch of the ulnar nerve (13), lateral digital extensor tendon (14), flexor carpi radialis tendon (15), radial carpal bone (16), distal radius (17), flexor retinaculum (18), extensor carpi obliquus tendon (19), medial collateral ligament (20), fused second and third carpal bones (21), radial artery and vein (22), intermediate carpal bone (23)

(Figure 3). The arthroscope was inserted in a palmarolateral-dorsomedial direction and advanced beneath the tendon of the long head of the ulnaris lateralis muscle; the limb was then extended. After entry of the arthroscope, the proximal articular surface of the ulnar carpal bone was apparent (17/20). The arthroscope was advanced medially to investigate the proximopalmar surface of the ulnar carpal bone until the medial facet of the bone was seen where the palmar radiocarpal ligament (14/20; between the palmarodistal aspect of radius and ulnar carpal bone) was observed to prohibit inspection of the intermediate carpal bone. The arthroscope was directed proximally to inspect the palmarodistal aspect of the radius and withdrawn laterally until the synostosis (17/20) between the radius and ulna (represented by a cleft) was identified. After the arthroscope approached the entry site, the joint was flexed to 45° to advance the arthroscope beneath the lateral digital extensor tendon; then the joint extended to investigate the palmarolateral aspect of the ulnar styloid process. The arthroscope was directed distally to inspect the articulation of the ulnar and accessory carpal bones but was limited medially by the attachment of the joint capsule to the mediopalmar aspect of the ulnar carpal bone and laterally by the accessoriocarpoulnar ligament (9/20) connecting the ulnar and accessory carpal bones. An instrument portal was created distal to the arthroscopic portal and proximal to the accessory carpal bone. The instrument portal allowed instrument access to the palmarodistal aspect of the pouch, accessory carpal bone, ulnar carpal bone, palmar radiocarpal ligament, and distal portion of the ulnar styloid process.

3.7 | Antebrachiocarpal joint-PMP

With the joint flexed to about 50°-60°, the arthroscope was introduced in a palmaromedial-dorsolateral direction and advanced laterally beneath the flexor carpi radialis tendon (Figure 3). After entry of the arthroscope, the articulation of the distal radius, lateral facet of radial carpal bone, and medial facet of intermediate carpal bone were identified (17/20). The arthroscope was advanced more laterally to investigate the proximopalmar wedge-shaped articular surface of the intermediate carpal bone. Additional lateral insertion of the arthroscope allowed examination of the palmar radiocarpal ligament

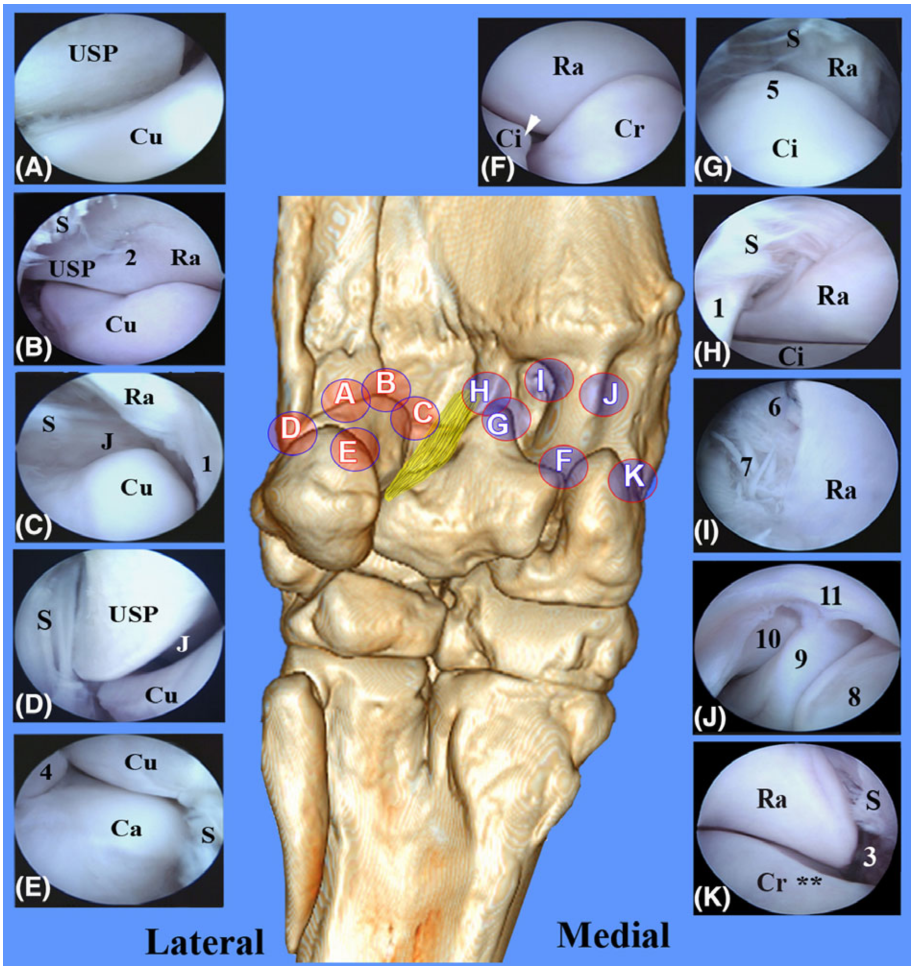

FIGURE 3 Intra-articular arthroscopic views of the palmarolateral **(A-E)** and palmaromedial **(F-K)** aspects of the left antebrachiocarpal joint of a 5-year-old cow. Areas visualized by the arthroscope are represented on the computed tomography recording with red and blue circles corresponding to the respective numbers of arthroscopic views. Accessory carpal bone (Ca), intermediate carpal bone (Ci), medial facet of the intermediate carpal bone (white head arrow), radial carpal bone (Cr), lateral facet of the radial carpal bone (**), ulnar carpal bone (Cu), joint cavity (J), distal articular surface of radius (Ra), synovial membrane (S), ulnar styloid process (USP), palmar radiocarpal ligament (1), a cleft indicating fusion between radius and ulna (2), medial cul-de-sac (3), accessoriocarpoulnar ligament (4), proximopalmar wedge-shaped surface of Ci (5), synovial fossa on distal radius (6), synovial plica (7), radial styloid process (8), medial parasagittal ridge (9), median glenoid cavity of distal radius (10), transverse crest of distal radius (11)

(14/20). The arthroscope was then directed proximally to inspect the junction between the lateral facet of the intermediate carpal bone and the lateral parasagittal ridge of the distal radius (16/20). Medial withdrawal of the arthroscope enabled visualization of the median glenoid cavity (16/20) on the palmaromedial aspect of the distal radius. Also in this view, a synovial plica (11/20) was occasionally observed attached to the synovial fossa. Continued withdrawal of the arthroscope allowed visualization of the palmar aspect of the radius. Additional withdrawal of the arthroscope toward the entry site with the arthroscope directed mediodistally allowed viewing of the proximolateral portion of the radial carpal bone. Sweeping of the arthroscope from proximal to distal allowed investigation of the medial portion of the radial carpal bone, medial cul-de-sac, and radial styloid process. An instrument portal was created distal to the arthroscopic portal, which allowed the radial carpal bone, medial facet of intermediate carpal bone, and distal aspect of the radius to be reached with the probe.

3.8 | Middle carpal joint-PLP

With the carpus flexed to about 45°, the arthroscope was inserted in a palmarolateral-dorsomedial direction (Figure 4). Arthroscopic investigation began by sliding the arthroscope under the long head of the ulnaris lateralis tendon. After entry of the arthroscope, the ulnar carpal bone, the fourth carpal bone, and the distal branch of the short lateral collateral ligament were identified (13/20). By moving the arthroscope medially, the fourth carpal bone (17/20) was inspected, including its lateral facet (articulating with ulnar carpal bone) and medial facet (articulating with intermediate carpal bone). Additional medial insertion of the arthroscope enabled viewing of the medial aspect of the fused second and third carpal bones (12/20). The arthroscope was then directed proximally and withdrawn laterally to investigate the palmar articular surface of the intermediate carpal bone (12/20). Continued withdrawal of the arthroscope allowed inspection of the articulations among the intermediate, ulnar,

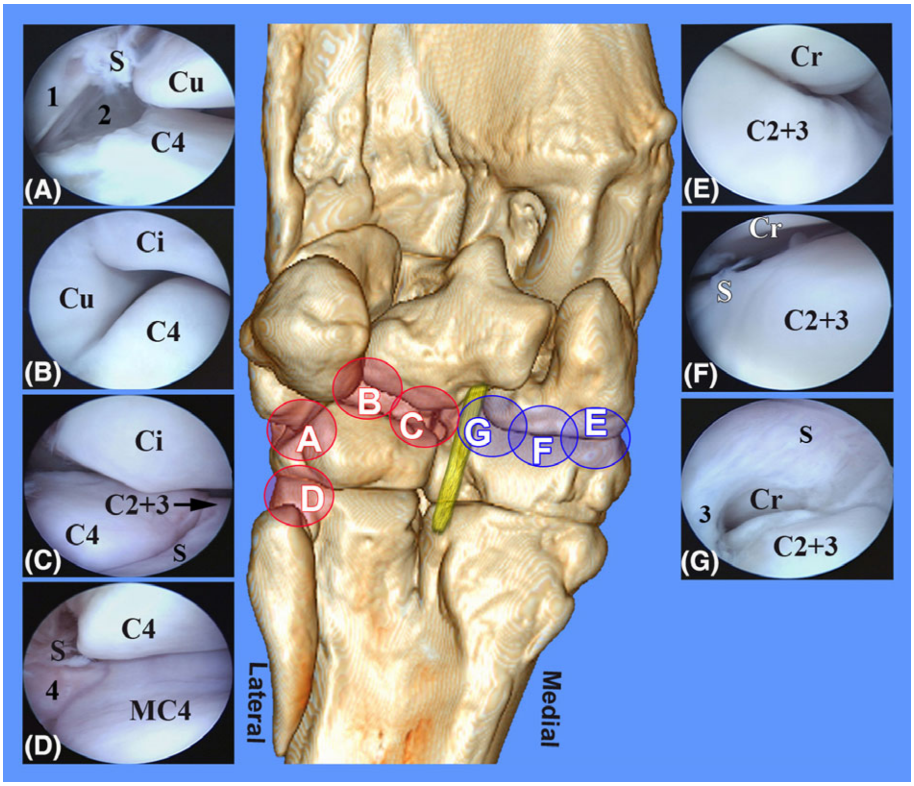

FIGURE 4 Intra-articular arthroscopic views of the palmarolateral **(A-C)**, palmaromedial **(E-G)** of the left middle carpal joint, and palmarolateral **(D)** aspects of the left carpometacarpal joint of a 5-year-old cow. Areas visualized by the arthroscope are represented on the computed tomography recording with red and blue circles corresponding to the respective numbers of arthroscopic views. Intermediate carpal bone (Ci), radial carpal bone (Cr), ulnar carpal bone (Cu), fused second and third carpal bones (C2 + 3), fourth carpal bone (C4), fourth metacarpal bone (MC4), synovial membrane (S), distal branch of the short lateral collateral ligament (1), lateral cul-de-sac (2), palmar carpometacarpal ligament (3), rudimentary fifth metacarpal bone (4)

and fourth carpal bones (16/20). By driving the arthroscope laterally and proximally, the palmar surface of the ulnar carpal bone was examined (16/20). Directing the arthroscope distally allowed inspection of the articulation of the fourth carpal and fourth metacarpal bones; the fifth metacarpal bone was inspected (16/20). Driving and sweeping of the arthroscope farther laterally allowed inspection of a large cul-de-sac lateral to the short lateral collateral ligament. An instrument portal was positioned distal to the arthroscopic portal in the PLP of the carpometacarpal joint. The instrument portal allowed the fourth carpal bone, distal portion of the ulnar carpal bone, and short lateral collateral ligament to be reached with the probe. The fourth and fifth metacarpal bones were also reached with the probe.

3.9 | Middle carpal joint-PMP

Arthroscopic investigation of the PMP of the middle carpal joint was a challenge because of the proximity of neurovascular structures to the arthroscopic portal (Figure 4). The arthroscope was introduced in a palmaromedial-dorsolateral direction. After the arthroscope was in the pouch, the majority of the palmar articular surface of the fused second and third carpal bones were seen (16/20). Additional lateral advancing and sliding of the arthroscope beneath the flexor carpi radialis tendon allowed the mediopalmar portion of the fused second and third carpal bones to be investigated. More lateral insertion of arthroscope allowed visualization of the palmar carpometacarpal ligament (12/20). The arthroscope was directed proximally to inspect the distal articular surface of the radial carpal bone (17/20). An instrument portal was created medially and in the same transverse plane as the arthroscopic portal. The instrument portal allowed the fused second and third carpal bones and the radial carpal bone to be reached with the probe.

Dissection of carpi after arthroscopy revealed minimal periportal fluid infiltration in 17 joints and marked extracapsular fluid accumulation in 3 joints. Periarticular fluid accumulation restricted maneuverability of the arthroscope and visibility of the intra-articular structures. This complication was managed by enlarging the portal opening and massaging the joint to improve fluid egress and support the drainage of the extracapsular fluid. Iatrogenic cartilage damage (excoriations 3–4 mm in length) was observed on the palmar articular surface of the intermediate and radial carpal bones (3 carpi) in the middle carpal joint, but lesions were superficial and of limited concern.

4 | DISCUSSION

The current study describes the anatomical arrangement of the palmar carpal pouches and the surgical technique and normal findings of the arthroscopic approaches to the palmar aspect of the bovine carpus after ultrasonographic examination. A palmarolateral and a palmaromedial portal were developed for each of the antebrachiocarpal and middle carpal joints. These entries allowed visualization of the most clinically relevant synovial structures. Although ultrasonography of the bovine carpus has been previously described,[6,18] the palmar carpal pouches have received little attention so far. Ultrasonography was used to image the palmar carpal pouches prior to the arthroscopic examination and was judged to be a valuable tool for identifying the arthroscopic portals with better precision. In addition, ultrasonography was useful for evaluation of soft tissues, bone surfaces, and articular cartilage integrity prior to arthroscopic examination.

Precise localization of the arthroscopic portal in relation to the perisynovial structures was essential to slide the arthroscope into the palmar synovial compartments and assisted in identifying a path around the synovial outpouchings. Using ultrasonography is not an alternative to a thorough knowledge of regional anatomy, and interpretation of ultrasonographic images requires an accurate knowledge of the gross anatomy. To the best of our knowledge, no detailed descriptions of the bovine palmar carpal pouches are available. Therefore, the anatomical landmarks, periarticular arrangement, and arthroscopic portals to the bovine palmar carpal outpouchings have been identified and described in this study.

In all limbs, portals were easily established, and relevant anatomical landmarks could indeed be identified. Limb positioning was an important factor that influenced visualization of the palmar carpal structures. The antebrachiocarpal joint in cattle has an oblique articular surface directed palmaromedially.[12] During joint flexion, the proximal row of carpal bones slides medially relative to the distal articular surface of the radius, leading to narrowing of the lateral joint compartment.[19] In addition, the ulnar styloid process projects beyond the level of the radius, which tightens the joint cavity during flexion.[1] Therefore, the PMP of the antebrachiocarpal joint was investigated with the joint flexed to 50°-60°, and the PLP was evaluated while extended. In the middle carpal joint, maximal joint flexion resulted in collapse of the joint space, which substantially interfered with both visibility and maneuverability. Therefore, the joint was best examined with the joint flexed to about 45°.

Arthroscopic exploration of the bovine palmar carpal pouches was accomplished through a single portal centered on both sides of the antebrachiocarpal and middle carpal joints. A similar technique has been described in horses;[20] however, arthroscopic access to the PLP of the antebrachiocarpal joint in cattle was located between the tendons of the lateral digital extensor and the long head of ulnaris lateralis muscles and in the middle carpal joint access was between the tendon of the long head of ulnaris lateralis muscle and the accessoriometacarpal ligament. In horses, the PLP of the antebrachiocarpal joint was explored palmar to the lateral collateral ligament and in the middle carpal joint was accessed between accessoriocarpoulnar and the accessorioquartal ligaments.[20]

Arthroscopic investigation of the PLP of the antebrachiocarpal joint provided good access to the palmar aspect of the ulnar and intermediate carpal bones, lateral synovium, and the palmar and lateral aspects of the ulnar styloid process. The undivided PLP, distal position (articulates only with the ulnar carpal bone), and shape (short, thick, and rounded) of the accessory carpal bone[1] (in comparison to horses, in which it articulates with the distal radius and the ulnar carpal bone) allowed a free space to maneuver the arthroscope in the PLP and also provided a space for instrument access. In horses, visualization of the intermediate carpal bone is not possible.[20] The presence of a trilobed PLP and the proximal position of the accessory carpal bone (articulating with the radius) constricts the joint space and limits viewing of the ulnar carpal bone.[20] Moreover, in a previous study in cattle, viewing the lateral aspect of the ulnar styloid process and the lateral synovial membrane was not possible from a dorsolateral approach.[16]

Arthroscopic exploration of the palmar aspect of the middle carpal joint was not technically difficult and could be performed without synovectomy. Positioning was found to be an important factor in allowing complete inspection of the palmar aspects of the ulnar, intermediate, fourth, and fused second and third carpal bones and the distal branch of the short lateral collateral ligament and the fourth and fifth metacarpals. In horses, the second and third carpal bones are not fused,[1] and synovectomy is required to visualize the third, intermediate, and fourth carpal bones; short lateral collateral ligament; and fourth metacarpal bone.[21]

In the present study, marked fluid escape into the surrounding subcutaneous tissues was observed in 3 joints. Fluid extravasation made arthroscopic manipulation difficult as a result of increased soft tissue depth. Subcutaneous accumulation of fluid might be a result of a relative decrease in elasticity in cadaveric limbs. Deeper structures could be viewed first and then more superficial structures because of the risk of accidental removal of the arthroscope and displacement of egress fluids into the soft tissues. In addition, enlargement of the instrument portal allowed adequate fluid egress.

In the current study, a learning curve existed associated with ultrasonography and arthroscopy of the bovine palmar carpal pouches. The anatomical study including the latex model was instrumental for identifying the topography of the joint and to recognize the intra-articular structures of the palmar carpal pouches in cattle. Arthroscopic portal creation was assisted by ultrasonography, and instrument portals were established under arthroscopic control. This cautious procedure may explain the low incidence of cartilage damage and absence of gross neurovascular lesions and confirm the minimally invasive character of the technique used in the present study.

Possible limitations of our study include the relatively few carpi evaluated. Although only 20 joints were evaluated, the ability to thoroughly investigate the intra-articular structures was highly repeatable. This improvement may be attributed to increased surgical proficiency. In addition, the study was performed in cadaveric limbs. Our technique must be evaluated in clinical cases to evaluate the ability to perform arthroscopic manipulation in traumatized or diseased joints. Furthermore, neurovascular and/or musculotendinous damage was evaluated through gross dissection. Histopathological examination would be helpful for detection of microscopic lesions.

In conclusion, arthroscopic evaluation of the palmar carpal pouches was performed successfully in bovine cadaver specimens. Multiple important arthroscopic bovine species-specific characteristics were identified regarding the shape of the distal radius, ulnar styloid process, articulation of accessory and ulnar carpal bones, and fusion of the second and third carpal bones. The technique allowed visualization of the most relevant intra-articular structures of the palmar carpal joints in cattle. Additional investigations are warranted to validate this technique in diseased joints.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

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