The objective of this report was to provide an anatomic description of the equine palmar lateral outpouching of the middle carpal joint by comparing its arthroscopic and magnetic resonance (MR) contrast arthrography appearance and to define the structures within the palmar lateral outpouching of the middle carpal joint that can be assessed arthroscopically. MR contrast arthrography was performed on seven cadaveric limbs; images were compared with those obtained during arthroscopic exploration of the palmar lateral outpouching of the middle carpal joint. Gross dissection was performed to confirm identification of intra-articular structures. The MR images compared well with the arthroscopic and gross appearance of the palmar lateral outpouching of the middle carpal joint. Portions of the ulnar carpal bone, fourth carpal bone, fourth metacarpal bone, lateral palmar intercarpal ligament, and lateral collateral ligament of the carpus were identified within the palmar lateral outpouching of the middle carpal joint in all limbs. In addition, in three limbs areas of the third carpal bone and intermediate carpal bone could be seen. MR arthrography was a useful tool for helping to define the anatomy of the palmar lateral outpouching of the middle carpal joint. The arthroscopic approach to the palmar lateral outpouching of the middle carpal joint is technically easy, but the intra-articular anatomy can be confusing. Use of a motorized arthroscopic blade to remove excess synovial tissue is necessary to view all of the structures within the palmar lateral outpouching of the middle carpal joint. Arthroscopic removal of osteochondral fragments from this location may be facilitated by the information obtained from this study.

Key words: arthroscopy, carpus, horse, MRI.

Introduction

Carpal osteochondral fractures are a common cause of lameness in race horses. The arthroscopic techniques for their removal and the intra-articular anatomy of the dorsal aspect of the equine carpus have been described. Carpal osteochondral fractures occur primarily in the dorsal aspect of the affected joint; however, palmarly located carpal osteochondral fragments do occur. We know of no comprehensive description of the magnetic resonance (MR) imaging anatomy of the palmar aspect of the equine carpus.

The arthroscopic approaches to the carpal joints have been described. Accessible structures reportedly located within the palmar lateral outpouching of the middle carpal joint are portions of the ulnar carpal bone and the fourth carpal bone. It is also reported that, it is not possible to see the third carpal bone, intermediate carpal bone, or the lateral palmar intercarpal ligament within the palmar lateral outpouching of the middle carpal joint. However, it has been our experience that the lateral palmar intercarpal ligament can be seen within the palmar lateral outpouching of the middle carpal joint.

It has been shown that palmar carpal osteochondral fragments occur most commonly in the palmar lateral outpouching of the middle carpal joint. Horses with palmarly located carpal osteochondral fragments have an improved outcome if these fragments are surgically removed. It has been our impression that although the arthroscopic approach to the palmar lateral outpouching of the middle carpal joint is technically easy, the anatomy can be confusing. This is largely due to the extensive synovial tissue present that inhibits visualization of underlying structures. Therefore, a thorough description of the intra-articular anatomy and the arthroscopic appearance of the palmar lateral outpouching of the middle carpal joint is warranted to aid in intra-articular orientation and facilitate osteochondral fragment removal.

MR imaging studies performed on the equine carpus have revealed a good correlation of the MR images with gross anatomical descriptions of this region; however, none of these studies have specifically examined the palmar
aspect of the carpal joints.\textsuperscript{12–14} MR contrast arthrography may improve the visualization of intra-articular tendons, ligaments, articular margins, and loose bodies.\textsuperscript{15,16} For these reasons, MR contrast arthrography would appear to be ideal for characterizing the intra-articular anatomy of the palmar lateral outpouching of the middle carpal joint.

The objectives of our study were: (1) to develop a MR imaging protocol that would aid in the anatomic description of the palmar lateral outpouching of the middle carpal joint; (2) to provide a complete anatomic description of the palmar lateral outpouching of the middle carpal joint by comparing its arthroscopic and MR contrast arthrography appearance in cadaveric limbs; and (3) to define the structures within the palmar lateral outpouching of the middle carpal joint that can be assessed arthroscopically. Our hypotheses were: (1) MR contrast arthrography will be a useful method for describing the anatomy of the palmar lateral outpouching of the middle carpal joint pouch; (2) during arthroscopy, the presence of abundant synovial tissue within the palmar lateral outpouching of the middle carpal joint makes orientation and identification of structures difficult; and (3) areas of the palmar lateral outpouching of the middle carpal joint that are accessible arthroscopically include the ulnar carpal bone, fourth carpal bone, and lateral palmar intercarpal ligament.

**Materials and Methods**

Twelve adult equine forelimbs were obtained from 10 horses euthanized for reasons unrelated to disease of the carpus (horse age range 2–20 years; six thoroughbreds, two standardbreds, one thoroughbred cross, one Arabian; six females, four neutered males; six right limbs, six left limbs). Limbs 1–5 were used to develop the MR contrast arthrography protocol. For MR imaging, forelimbs were kept cool and imaged within 48 h of euthanasia. Before imaging, the middle carpal joint of each specimen was injected with 25–40 ml of a 2 mmol/l gadolinium-DTPA solution* using a 20-gauge needle placed dorsally between the extensor carpi radialis tendon and the common digital extensor tendon, with the carpus flexed. The gadolinium contrast media was injected into the joint until distention of both the dorsal and palmar lateral outpouchings of the middle carpal joint occurred and there was resistance to injection. Images were obtained using a 0.25T system†. It was decided to use a high resolution, T1 weighted, 3D spin echo pulse sequence obtained in the transverse plane with 0.7 mm isotropic voxels (300 TR, 24 TE) for the imaging-arthroscopy comparison. This resulted in images with a 0.7 mm slice thickness; total imaging time was 91 min per limb. Image data was reconstructed into dorsal and sagittal plane images.

*In limbs six to 12 the palmar lateral outpouching of the middle carpal joint was evaluated with MR contrast arthrography and arthroscopy. Data collected from each MR imaging examination included: (1) the dimensions of the palmar lateral outpouching of the middle carpal joint (depth obtained by measuring the maximal area of joint distention in a dorsal to palmar direction as seen in the sagittal plane; width obtained by measuring the maximal area of joint distention in a lateral to medial direction as seen in the dorsal plane, and height obtained by measuring the maximal area of joint distention in a proximal to distal direction as seen in the sagittal plane); (2) the bony surfaces located within the palmar lateral outpouching of the middle carpal joint; and (3) the ligamentous structures located within the palmar lateral outpouching of the middle carpal joint.

After completion of imaging the limbs were stored at –20°C and thawed at room temperature before arthroscopic evaluation. The limb was positioned as if the horse were in lateral recumbency with the limb extended and the lateral side of the carpus facing up. The middle carpal joint was distended with fluid administered through an 18-gauge needle via a dorsal lateral approach as described above, and pressure within the joint was maintained using a nitrogen-powered pump system‡. The arthroscopic portal was made in the center of the distal half of the palmarolateral outpouching of the middle carpal joint, which was distinctly seen after the middle carpal joint was distended with fluid. This was accomplished by first making a 6-mm-skin incision at that site using a number 11 scalpel blade. The arthroscopic cannula was then inserted into the joint using a sharp trochar. After the cannula was securely seated within the joint, the trochar was removed, the arthroscope was inserted, and the joint was evaluated. An instrument portal was created in the center of the proximal half of the palmarolateral outpouching of the middle carpal joint by first using an 18-gauge needle to identify the ideal location for the portal and then by making a stab incision into the joint at that location with a number 11 scalpel blade. This portal was used to allow entry of an arthroscopic probe or a motorized arthroscopic blade (Linvatec Apex Arthroscopy Shaver System with a 4.2 mm§). The motorized arthroscopic blade was used to carefully remove excess synovial tissue within the palmar lateral outpouching of the middle carpal joint to facilitate identification of underlying structures. All arthroscopic examinations were recorded on video tape. Data obtained included: (1) the bony surfaces located within the palmar lateral outpouching of the middle carpal joint, and (2) the ligamentous structures located within the palmar lateral outpouching of the middle carpal joint.

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*Esaote Vet MR Grande, Genova, Italy.
†Storz Arthroscope; Karl Storz, Tuttlingen, Germany.
‡Arthro-Flo Irrigator; Davol, Cranston, RI.
§Full-Radius Resector; Linvatec, Largo, FL.
These structures were verified by comparison with the MR images and gross dissection of the limbs following arthroscopic evaluation.

Results

The MRI arthrography protocol used in this study resulted in images with excellent definition of the palmar lateral outpouching of the middle carpal joint. Both bony and ligamentous structures were easily identifiable. The 0.7-mm-slice thickness allowed for the definition of thin, hypointense (gray and black) soft tissue strands contrasted against hyperintense (white) joint fluid and contrast medium mixture. The finely reticulated web-like nature of the intra-articular synovial tissues resembled that seen on arthroscopy (Fig. 1). The larger, discrete hypointense tendons and ligaments within the palmar lateral outpouching of the middle carpal joint were likewise well visualized. The mean dimensions of the palmar lateral outpouching of the middle carpal joint were: depth 2.8 cm (median 2.8, range 2.5–3.2); width 1.8 cm (1.8, 1.6–2.0); height 2.6 cm (2.7, 2.2–2.9). The tendon of the ulnaris lateralis muscle appeared to provide the lateral boundary of the palmar lateral outpouching of the middle carpal joint.

In all limbs portions of the following bones appeared to be within the palmar lateral outpouching of the middle carpal joint: the entire distal palmar surface of the ulnar carpal bone, the entire proximal palmar surface of the fourth carpal bone, and the proximal palmar tip of the fourth metacarpal bone. The ulnar carpal bone and fourth carpal bone appeared to be in close apposition at the dorsal aspect of the palmar lateral outpouching of the middle carpal joint, but were further apart palmarly and laterally. Within the palmar lateral outpouching of the middle carpal joint several distinguishing features of the bones were noted; the fourth metacarpal bone was found to have a proximal lateral projection that directly apposed the lateral aspect of the fourth carpal bone, the most palmar aspect of the ulnar carpal bone had a distinct hooked-shaped tip (Fig. 1), and the most palmar aspect of the fourth carpal bone had a distinct triangular projection (Fig. 2B). These appearances were a consistent finding in all limbs. It appeared in some limbs that portions of the distal palmar medial intermediate carpal bone and the proximal palmar medial third carpal bone may be within the palmar lateral outpouching of the middle carpal joint; however, this was hard to definitively determine as all areas of the middle carpal joint, not just the palmarolateral pouch, were surrounded by the joint fluid and contrast medium mixture that had a hyperintense signal.

There were two distinct hypointense ligaments seen within the palmar lateral outpouching of the middle carpal joint of all limbs. The first was a structure consistent with descriptions of the lateral palmar intercarpal ligament, originating on the distal palmar medial aspect of the ulnar carpal bone and inserting on the proximal palmar medial aspect of the fourth carpal bone (Fig. 3). The location and appearance of this ligament was similar in all limbs. The second structure had a signal intensity similar to that of the first. It originated on the palmar distal lateral aspect of the ulnar carpal bone and inserted on the palmar lateral surface of the fourth carpal bone (Fig. 3). This ligament
had a more variable appearance with respect to its width and the number of sequential images from each carpus on which it was seen. In some images it appeared to be a continuation of the lateral collateral ligament of the carpus. This finding is consistent with previous descriptions of a deep branch of the lateral collateral ligament.20

The palmar lateral outpouching of the middle carpal joint was readily identifiable after distention of the middle carpal joint and placement of the arthroscope was easily accomplished in all limbs. There was ample room to maneuver both the arthroscope and an instrument in most areas of the pouch. Upon initial entry into the joint, the ulnar carpal bone and fourth carpal bone were apparent in six out of seven limbs (Fig. 4A and 4B); in the other limb the arthroscope portal was slightly more distal than described and the only bony structures visible were the fourth carpal bone and fourth metacarpal bone (Fig. 2B). After evaluation of the joint, but before the motorized arthroscopic blade was used to remove excess synovial tissue, the structures visible within the palmar lateral outpouching of the middle carpal joint of all limbs (except the limb mentioned above) included the distal palmar surface of the ulnar carpal bone, the proximal palmar surface of the fourth carpal bone, and the deep branch of the lateral collateral ligament (Figs. 4A–D). This ligament was seen in all limbs as the most lateral structure within the palmar lateral outpouching of the middle carpal joint coursing between the ulnar carpal bone and fourth carpal bone; however, its thickness and prominence varied. In some limbs a portion of the lateral palmar intercarpal ligament could be seen by driving medially between the ulnar carpal bone and fourth carpal bone, but in all limbs the ligament was covered by a large amount of synovial tissue and although it could be felt with an arthroscopic probe it was not seen as a discrete structure (Figs. 4C and 5). Both the ulnar carpal bone and fourth carpal bone were completely covered with cartilage at this location. The distal lateral edge of the ulnar carpal bone was rounded and could be probed underneath the deep branch of the lateral collateral ligament. By driving the arthroscope laterally and proximally the palmar surface of the ulnar carpal bone could be examined; it was covered by a large amount of soft tissue, some of which appeared to be ligamentous. This soft tissue originated from an irregular ridge extending laterally to medially on the palmar aspect of the ulnar carpal bone, which corresponded with the “hook” seen on the MR images. Palmar to the ulnar carpal bone there was a large cul-de-sac, also seen on the MR images. The fourth carpal bone was covered by a large amount of synovial tissue distally except in one limb, where the fourth metacarpal bone was readily apparent distal to the fourth carpal bone without the use of the arthroscopic blade.

After the above structures were identified, the arthroscopic blade was inserted through the instrument portal and carefully used to remove some of the synovial tissue covering underlying structures. Specifically, tissue was removed distal to the fourth carpal bone to reveal the articulation between the fourth carpal bone and fourth metacarpal bone (Figs. 2B and 4E). This took little time and did not require extensive dissection. At this location, the fourth carpal bone and fourth metacarpal bone had only a thin rim of cartilage apparent over an area of exposed subchondral bone. These bones were in closer apposition than the fourth carpal bone and the ulnar carpal bone, and at this location the triangular shape of the palmar aspect of the fourth carpal bone seen on the MR images could be viewed. This gave the appearance of three separate bones at this location; however, upon comparison with the MR and gross images it was confirmed that this was due to the irregular shape of the fourth carpal bone (Figs. 2B and 4). In the limb that was entered distally (i.e., at this location), the arthroscopic blade was used to access the area of the ulnar carpal bone and fourth carpal bone.

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**Fig. 3.** Dorsal (A, B) and sagittal (C) magnetic resonance images of the carpus illustrating the origin and insertion of the lateral palmar intercarpal ligament and the deep branch of the lateral collateral ligament; (A) more dorsal and (B) more palmar images. (C) Corresponding sagittal MR image illustrating the plane of image A (straight line) and image B (dotted line). (a) intermediate carpal bone, (b) ulnar carpal bone, (c) third carpal bone, (d) fourth carpal bone, (e) fourth metacarpal bone; star, lateral palmar intercarpal ligament; arrow, lateral collateral ligament.
Once the articulation between the fourth metacarpal bone and fourth carpal bone was evaluated, the arthroscopic blade was used to resect portions of the synovial tissue covering the ulnar carpal bone and lateral palmar intercarpal ligament. This took more time due to the extensive amount of synovial tissue present at that location. In some limbs this revealed thin, web-like ligamentous tissue between the ulnar carpal bone and fourth carpal bone of variable course. These structures were not seen as a distinct entity on any of the MR images but upon gross dissection were found to be part of the palmar carpal ligament. In all limbs, a clearer view of the lateral palmar intercarpal ligament was obtained after removal of some of the overlying synovial tissue; it was more taught than the surrounding soft tissue and coursed diagonally, originating at the palmar medial surface of the ulnar carpal bone and inserting on the palmar lateral surface of the third carpal bone (Figs. 3 and 5). In three limbs, once the synovial tissue around the lateral palmar intercarpal ligament was resected the arthroscope could be guided palmarly and medially to view the palmar medial aspects of the third carpal bone and the intermediate carpal bone; however, there was little room to maneuver at this location (Fig. 5). This approach was attempted in the other limbs, but the third carpal bone and the intermediate carpal bone could not be seen due to the variability in the amount of synovial tissue covering and extent of the palmar lateral outpouching of the middle carpal joint in these limbs. When seen, the third carpal bone and the intermediate carpal bone had a lesser amount...
of cartilage covering with exposed subchondral bone apparent, similar to that seen at the fourth carpal bone–fourth metacarpal bone articulation.

Gross dissection of the limbs compared well with the MR images of the palmar lateral outpouching of the middle carpal joint. All structures identified in the palmar lateral outpouching of the middle carpal joint arthroscopically were verified. The second ligament seen on the MR images was found to be a deep branch of the lateral collateral ligament of the carpus, and the thin ligamentous structures within the palmar lateral outpouching of the middle carpal joint in some of the limbs were confirmed to be part of the palmar carpal ligament.

Discussion

The protocol used to perform MR contrast arthrography on cadaveric limbs did help define the anatomy of the palmar lateral outpouching of the middle carpal joint. We chose to perform MR contrast arthrography over plain MR in order to evaluate the limits of the palmar lateral outpouching while the joint was distended, therefore approximating what would be seen clinically during arthroscopy. Additionally, contrast arthrography was ideal because it allowed hypointense structures (such as ligaments and bones) to stand out easily against the hyperintense background that the joint fluid and contrast medium mixture provided. One disadvantage of this technique is that it did not allow for the distinct visualization of cartilage, as both cartilage and the joint fluid and contrast media mixture had a similar signal intensity in the protocol used here. However, the resultant MR images of bony and soft tissue structures corresponded well with what was seen both arthroscopically and on gross dissection. The images were instrumental in helping to identify these structures during arthroscopy of the palmar lateral outpouching of the middle carpal joint. This was important because as we hypothesized, although the approach to the palmar lateral outpouching of the middle carpal joint is technically easy, once inside of the joint the anatomy can be confusing due to the extensive amount of synovial tissue covering the underlying structures and the unusual shapes of parts of the bones at this location. There was ample room to maneuver within the palmar lateral outpouching of the middle carpal joint; therefore, the images generated from this study may aid in intra-articular orientation and facilitate osteochondral fragment removal from this location in clinical cases.

Although we verified the hypothesis that portions of the ulnar carpal bone, fourth carpal bone, and lateral palmar intercarpal ligament were accessible arthroscopically within the palmar lateral outpouching of the middle carpal joint, we found that several other structures were accessible via this approach as well. Upon entry into the joint we were immediately able to view the distal palmar surface of the ulnar carpal bone, the palmar surface of the fourth carpal bone, and the deep branch of the lateral collateral ligament in all limbs except one in which the joint was entered more distally. However, after the use of a motorized arthroscopic blade we were able to access the lateral palmar intercarpal ligament and the proximal palmar aspect of the fourth metacarpal bone in all limbs, and the palmar medial aspects of the third carpal bone and intermediate carpal bone in three out of seven limbs. These findings differ from that of a recent study, in which only the fourth carpal bone and ulnar carpal bone were visualized within the palmar lateral outpouching of the middle carpal joint. This could be due to a difference in arthroscopic technique, as the approach in the previous report was made with the horses in dorsal recumbency and the carpi in 20°–30° of flexion. In our study the limbs were positioned in lateral recumbency with minimal flexion of the carpus; this may have opened up the palmar lateral outpouching of the middle carpal joint and allowed for more medial areas of the joint to be observed. Additionally, many of the structures identified in the present study were only visualized after a motorized arthroscopic blade was used to remove portions of the overlying synovial tissue, and it is unclear if this was done in the previous study. It should be emphasized that this must be done with care in patients to avoid causing damage to underlying structures. We have used this technique to remove osteochondral fragments from the palmar lateral outpouching of the middle carpal joint in numerous patients without adverse effects from the synovial resection. It is also important to note that the third carpal bone and the intermediate carpal bone were only visualized in three out of seven limbs in this study, indicating that variability exists in the boundaries of the palmar lateral outpouching of the middle carpal joint as well as the amount of synovial tissue covering these areas among horses. Unfortunately, it was difficult to predict from the MR images which limbs these bones would be accessible in, due to the fact that the entire middle carpal joint had a hyperintense signal so there was no clear distinction of where the palmar lateral outpouching of the middle carpal joint boundaries were. An attempt was made to enter this area in all limbs using the motorized arthroscopic blade. In those limbs where the third carpal bone and the intermediate carpal bone could be seen, there was little room to maneuver due to the sharp tapering of the joint pouch at this location.

Analysis of the MR images allowed us to predict that some of the above structures which were previously thought to be inaccessible would have portions located within the palmar lateral outpouching of the middle carpal joint. We were able to predict that the proximal palmar tip of the fourth metacarpal bone would be visible arthroscopically from the MR images, and although it was only immediately apparent in one limb, there was minimal synovial tissue covering it in all other limbs. This tissue was easily removed with the motor-
ized arthroscopic blade to allow access to the fourth metacarpal bone–fourth carpal bone articulation. The deep branch of the lateral collateral ligament of the carpus could also be predicted to be intra-articular from evaluation of the MR images, but to our knowledge this has not been previously described. However, the course of the ligament on both the MR images and on gross dissection matches previous descriptions of the origin, insertion, and course of a deep branch of the lateral collateral ligament. This ligament could always be seen, but its thickness and prominence within the joint were variable; however, it was a useful landmark to identify the most lateral aspect of the joint.

There was a definite learning curve associated with the arthroscopic exploration of the palmar lateral outpouching of the middle carpal joint, but several key factors helped maintain orientation within the pouch. Upon initial entry of the pouch, the cartilage-covered portions of the fourth carpal bone and the ulnar carpal bone are typically the first structures identified. The appearance of this area is distinct because both bones are completely covered with cartilage, and they are spaced further apart laterally than medially. If the arthroscope portal is placed too distally, as in one limb in this report, the bones seen (the fourth carpal bone and fourth metacarpal bone) will not be completely cartilage covered and will be closer together, and no discrete ligaments will be seen. If this occurs, the motorized arthroscopic blade can be used to remove tissue proximally and enter the larger area of the pouch. Once the articulation between the fourth carpal bone and the ulnar carpal bone is located, the curve of the distal lateral ulnar carpal bone is palpable, and the deep branch of the lateral collateral ligament can always be used as the lateral-most landmark. A large amount of synovial tissue will be seen to originate from the palmar ridge of the ulnar carpal bone, giving the appearance of a pillar of tissue, and beneath this tissue is the lateral palmar intercarpal ligament. It is easy to mistake this excess synovial tissue for the lateral palmar intercarpal ligament itself, but the latter structure is more taught and courses between the medial and dorsal most extent of the ulnar carpal bone and fourth carpal bone, whereas the excess synovial tissue is more palmar and can be moved easily when probed. The lateral palmar intercarpal ligament will not be distinctly seen until this tissue is removed. The large cul-de-sac palmar to the ulnar carpal bone can be examined by moving palmar to the ulnar carpal bone and directing the arthroscope proximally.

Use of a motorized arthroscopic blade was essential for identifying many of the structures within the palmar lateral outpouching of the middle carpal joint. Subjectively, a 4.2 mm full-radius resector could be more accurately guided within the joint to avoid damaging underlying structures than a larger (5.5 mm) blade. With the 4.2 mm blade, excess soft tissue was easily removed, while inadvertent damage to ligaments was usually minimal because greater effort is needed to debride thicker tissue using this method. Although not addressed specifically in this study, the motorized arthroscopic blade would appear to be an extremely valuable tool to use when trying to remove osteochondral fragments from the palmar lateral outpouching of the middle carpal joint. Clinically we have removed loose fragments from the cul-de-sac palmar to the ulnar carpal bone as well as fragments adhered to the excess synovial tissue in other areas of the pouch using this technique.

In conclusion, MR arthrography was a useful tool for helping to define the anatomy of the palmar lateral outpouching of the middle carpal joint; images obtained using the protocol developed in this study compared well with both the arthroscopic and gross appearance of structures located within the pouch and were helpful in establishing orientation during arthroscopic examination of the joint. The arthroscopic approach to the palmar lateral outpouching of the middle carpal joint is technically easy, although visualization of all of the structures located within the pouch requires use of a motorized arthroscopic blade. Portions of the ulnar carpal bone, fourth carpal bone, fourth metacarpal bone, lateral palmar intercarpal ligament and a deep branch of the lateral collateral ligament of the carpus can always be identified, and in some limbs the medial aspects of the third carpal bone and the intermediate carpal bone may also be seen. Knowledge of the extent of the palmar lateral outpouching of the middle carpal joint and its arthroscopically accessible structures could help predict which palmar carpal osteochondral fragments can be removed via this approach. Owing to the ease of manipulation within the pouch and the reportedly improved outcome obtained after removal of palmar carpal osteochondral fragments, arthroscopic removal of fragments in the palmar lateral outpouching of the middle carpal joint should be considered in patients.

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