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SCIENTIFIC ARTICLE

Normal Pacinian corpuscles in the hand: radiology–pathology correlation in a cadaver study

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Abstract

Objective To provide microdissection and histological confirmation of normal Pacinian corpuscles prospectively identified using MRI in a cadaver model.

Methods 3-T MRI of a cadaveric hand specimen was performed with fiduciary markers on the skin. Based on previous descriptions, subcutaneous nodules representing presumed Pacinian corpuscles were localized with respect to the skin markers, and their sizes and depths were recorded. Focused ultrasound was performed to attempt to visualize the corpuscles. Subsequent microdissection was then performed and the presence and location of Pacinian corpuscles were recorded and compared with the findings on MRI. Histological evaluation for each identified corpuscle was performed.

Results The MRI demonstrated 11 T2-hyperintense palmar subcutaneous nodules around the second through fifth metacarpophalangeal joints. None was visible sonographically. The first eight were dissected and proved to be normal Pacinian corpuscles histologically. In sites devoid of subcutaneous nodules on MRI, subsequent dissection failed to reveal any corpuscles.

Conclusion On MRI, normal Pacinian corpuscles appear as round or oval, T2-hyperintense subcutaneous nodules in the palms, clustered around the metacarpophalangeal joints, and should not be mistaken for pathological conditions.

Keywords Pacinian corpuscle · Vater–Pacini · Lamellar corpuscle · Touch receptor · Dermal anatomy · Hypodermal anatomy · Mechanoreceptor · MRI · Hand

Introduction

The Pacinian corpuscle is the main sensory receptor for vibration and deep pressure. They are found throughout the body, but are most numerous and most tightly grouped in the palms of the hands and the soles of the feet [1]. A recent article [2] posited that 1- to 5-mm, non-enhancing, T2-hyperintense, subcutaneous nodules frequently seen as incidental findings on magnetic resonance imaging (MRI) of the hands represent these structures. However, a presumptive argument was made by those authors based on the recognized distribution and histological features of the corpuscles reported in the pathology and dermatology literature, together with findings in two patients who underwent surgery where the nodules were serendipitously recognized histologically and then retrospectively identified on pre-operative MRI studies. No previous study has described the MRI appearance of the normal Pacinian corpuscle and provided pathological confirmation of these structures.

We designed the current study to prospectively localize these structures in a cadaver using MRI, and then definitively confirm that they do indeed represent normal Pacinian corpuscles by subsequent microdissection and histological analysis. A secondary aim was to determine whether ultrasound could identify these normal structures.

Materials and methods

The Biospecimen Subcommittee provided IRB approval for the study. One fresh cadaveric hand and wrist specimen was obtained via a request for any hand that was "intact, with no

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significant traumatic injury or evidence of prior surgery." The resultant specimen was from a 67-year-old Caucasian man who had no known history of any previous trauma, disease, or surgery involving the extremity.

Magnetic resonance imaging examination was performed on a 3-T GE Discovery 750 scanner (GE Healthcare, Milwaukee, WI, USA), using a dedicated wrist coil. The cadaver hand and wrist was placed palm side down in the isocenter of the scanner. MRI-compatible markers were placed on the skin over the palmar aspect of the hand (Fig. 1).

Coronal T1-weighted images were obtained as: matrix 384 × 256; field of view: 140 mm; slice thickness: 2 mm; gap: 2 mm; repetition time (TR): 678 ms; echo time (TE): 10.16 ms; flip angle: 142º. Coronal fat-suppressed T2-weighted images were obtained as: matrix 384 × 256; field of view: 140 mm; slice thickness: 2 mm; gap: 2 mm; TR/TE 415/49.6 ms; flip angle: 142°. Axial T1-weighted images were obtained as: matrix 384 × 256; field of view: 120 mm; slice thickness: 3 mm; gap: 3 mm; TR/TE 600/10.632 ms; flip angle: 142°. Axial fat-suppressed T2-weighted images were obtained as: matrix 384 × 256; field of view: 120 mm; slice thickness: 3 mm; gap: 3 mm; TR/TE 4,000/45.48 ms; flip angle: 142°.

One radiologist (NGR) with 6 years of musculoskeletal imaging experience prospectively identified presumed Pacinian corpuscles based on previous descriptions, namely, ovoid, hyperintense nodules on fluid-sensitive imaging, measuring 1–2 mm in length, that lie within the palmar soft tissues and are distinct from neighboring vessels [1]. For this study, we selected only those that could be clearly resolved on both the axial and the coronal imaging planes. Because Pacinian corpuscles are concentrated about the metacarpophalangeal (MCP) joints [3], the region of interest was limited to within 2 cm from the nearest MCP joint line. The signal characteristics of the identified nodules were noted and their locations were documented relative to the nearest marker by noting the clock face direction from the marker, the distance from the margin of the marker, the distance from the nearest MCP joint line, and the depth from the superficial margin of the skin. The radiologist also prospectively identified regions around the MCP joints that were devoid of any nodules that could represent Pacinian corpuscles. These locations were recorded.

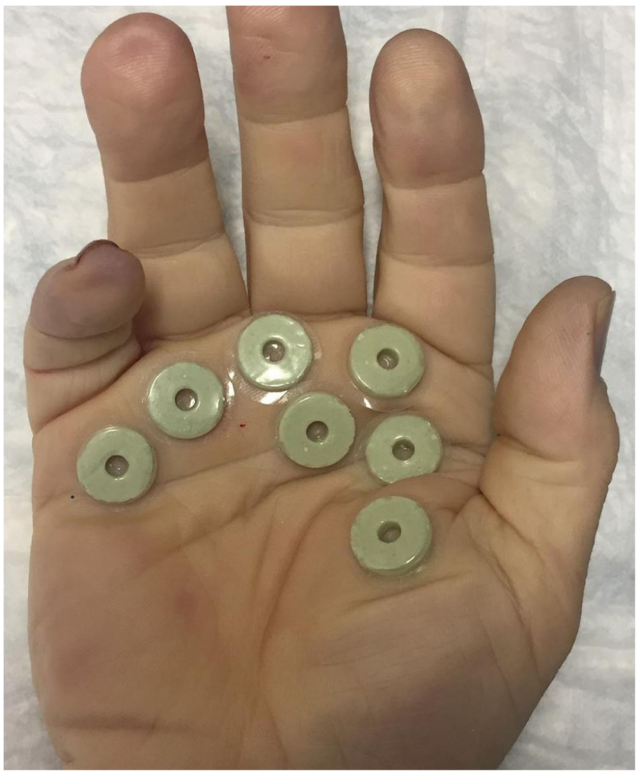

Fig. 1 Cadaveric hand and wrist specimen with MRI-compatible markers arranged along the palmar aspect of the distal hand about the metacarpophalangeal joints

The rim of the skin markers was circumscribed by indelible ink and the markers were removed. Ultrasound of the palmar soft tissues was performed immediately following the MRI in a blinded fashion by one radiologist (NSM) with 12 years of musculoskeletal imaging experience using a SonoSite M-Turbo system (FUJIFILM SonoSite, Bothell, WA, USA), with an L25x 13-6 MHz probe. The presence, echogenicity, size, and location of any identified subcutaneous nodules was recorded. Both radiologists (NSM and NGR) then repeated the ultrasound using the MRI to target the presumed corpuscles in an unblinded fashion. These findings were also recorded.

The anatomist (NL) then dissected in the region about the MCP joints. Incision was extended several centimeters proximal to the sites of interest, generally following the course of the digital nerves. Staged layered dissection was conducted with careful reflection of the soft tissue from skin to subcutaneous mass on the palmar aspect of the hand. Dissection was extended toward the MCP joints, taking care not to disrupt any nodular/vesicular connections to the digital nerves. All presumed Pacinian corpuscles were referenced to the skin marker ink reliefs on the skin by noting their relative clock face direction, distance, and tissue layer. Depth was noted as "1 mm" if found in the subcutaneous fat, just deep to the skin. The nodules were harvested and prepared for histological evaluation using standard hematoxylin and eosin staining. After dissection of the first eight MRI-localized nodules returned gross nodules in keeping with Pacinian corpuscles, the remaining three nodules observed on MRI were not targeted for dissection. This selection was at the discretion of the anatomist, who was blinded to the specific MRI appearance of any given nodule. The anatomist also dissected three superficial areas identified by the radiologist that did not contain imaging evidence of Pacinian corpuscles. The locations and sizes of the Pacinian corpuscles identified during the anatomical dissection correlated with the MRI.

Results

On MRI, 11 nodules corresponding to the reported size and appearance of Pacinian corpuscles in the pathology literature [1] were identified (Fig. 2). Nodules were hyperintense compared with the suppressed subcutaneous fat on the T2-weighted images. On the T1-weighted images the nodules were hypointense compared with the surrounding non-fat-suppressed fat and were approximately isointense compared with skeletal muscle. All were surrounded by fat.

Table 1 lists the sizes, locations, and anatomical relationships for the 11 nodules identified on the MRI. Nodules ranged in size from 2 × 2 × 1 mm to 5 × 4 × 4 mm, at a depth of 2 to 9 mm from the skin surface. All were located between 4 and 20 mm from the nearest MCP joint. A thin slip extending toward the closest digital nerve was visible in 7 of the 11 nodules.

At ultrasound, we were unable to confidently identify any subcutaneous nodules or other correlates for the corpuscles observed on MRI (Fig. 3).

Eight Pacinian corpuscles were targeted and were surgically identified by the anatomist, corresponding in location and size to eight nodules identified prospectively on MRI (Fig. 4). Nodule sizes, locations, and anatomical relationships for the dissected nodules are included in Table 1. Sizes ranged between 2 × 1 mm and 5 × 5 mm, at a depth of 1 mm (directly subcutaneous) to 5–10 mm from the skin surface. All were located 5–20 mm from the nearest MCP joint. All demonstrated a thin nerve connection to the neighboring digital nerve. All eight were removed and were confirmed as Pacinian corpuscles under microscopic evaluation, demonstrating the typical numerous, circumferential fibroblast layers surrounded by fluid, mimicking the appearance of a sliced onion (Fig. 5). No

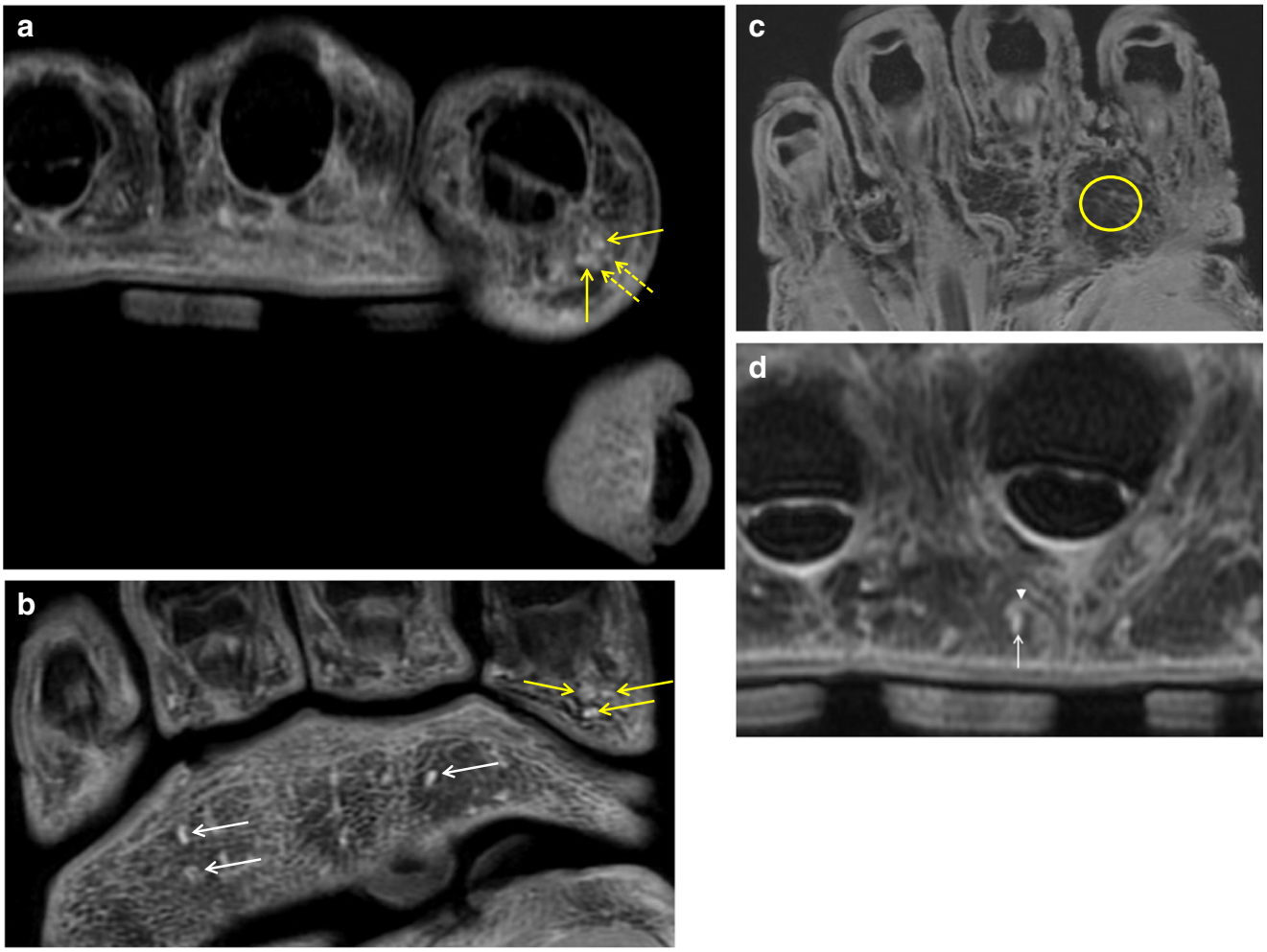

Fig. 2 T2-weighted images from the cadaver. **a** Axial image demonstrates the MRI markers along the superficial aspect of the palm. Two Pacinian corpuscles near the base of the proximal phalanx of the index finger are marked with *yellow arrows*. A third neighboring corpuscle is not included on this slice. *Dashed arrows* highlight small neighboring vessels passing radial to the corpuscles. **b** Coronal image demonstrates the three Pacinian corpuscles (*yellow arrows*). *White arrows* highlight three other Pacinian corpuscles that were proven on dissection. **c** Coronal image is centered 1 cm proximal to the Pacinian corpuscles near the second metacarpophalangeal joint and is devoid of corpuscles (*yellow circle*). **d** Axial image demonstrates the thin, thread-like connection (*arrowhead*) running to the corpuscle margin (*white arrow*) from the region of the digital nerve (not included)

Table 1 Size, location, and anatomical relationship for the nodules identified on MRI and at dissection

Nodule	1	2	3	4	5	6	7	8	9	10	11
Size on MRI, mm	3 × 2 × 1	3 × 2 × 1	2 × 2 × 1	5 × 4 × 4	3 × 2 × 1	3 × 2 × 2	3 × 2 × 2	3 × 2 × 2	2 × 2 × 1	3 × 2 × 2	2 × 2 × 1
Depth from skin on MRI, mm	2	2	9	9	2	3–4	3–4	3–4	5	8	6
Distance from nearest MCP joint on MRI, mm (joint)	10 (5th)	4 (5th)	5 (5th)	8 (3rd)	14 (3rd)	20 (2nd)	20 (2nd)	20 (2nd)	7.5 (2nd)	8 (4th)	14 (3rd)
Clock position relative to (marker)	9′ (2)	7:30′ (2)	5:30′ (5)	9′ (5)	8:30′ (5)	2′ (5)	2′ (5)	2′ (5)	5:30′ (5)	8:30′ (3)	1:30′ (3)
Thin slip extending toward digital nerve on MRI	Yes	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes
Targeted for dissection	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Pathological confirmation of Pacinian corpuscle	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	N/A
Size at dissection, mm	3 × 2	3 × 2	2 × 1	5 × 5	2 × 2	3 × 2	3 × 2	3 × 2	N/A	N/A	N/A
Depth from skin at dissection, mm	1	1	5–10	5–10	1	1	1	1	N/A	N/A	N/A
Distance from MCP joint at dissection, mm (joint)	10 (5th)	5 (5th)	5 (5th)	10 (3rd)	15 (3rd)	20 (2nd)	20 (2nd)	20 (2nd)	N/A	N/A	N/A

MCP metacarpophalangeal

attempt was made to dissect the remaining three nodules identified on MRI given the time constraints of the anatomist.

No corpuscles were found at dissection that had not been identified prospectively by MRI. Specifically, no additional corpuscles were found in the vicinity of the dissected corpuscles. In the three regions devoid of subcutaneous nodules on MRI, no Pacinian corpuscles were identified at dissection.

Discussion

We have commonly observed incidental, hyperintense palmar nodules on routine fluid-sensitive sequences during MRI. In clinical examinations where intravenous contrast medium had been injected, these nodules did not enhance. A previous publication presented an argument hypothesizing that these nodules are Pacinian corpuscles [2]. That argument, however, relied on two surgically and pathologically proven cases, with retrospective review of the preoperative MRI. One of those cases came to clinical attention because of flexor tenosynovitis, although the somewhat enlarged Pacinian corpuscles may have contributed to the clinical symptoms. The additional patient presented with a larger, neighboring neurofibroma. The observed Pacinian corpuscles in that case were almost certainly an incidental finding, although they were more numerous and some were enlarged beyond the reported normal in the anatomy and pathology literature. We know of no case reports discussing the prospective MRI diagnosis of the normal Pacinian corpuscle with subsequent surgical and pathological confirmation.

Our careful MRI–dissection–histological study in this cadaver confirmed that the nodules we have previously seen in patients' MRI studies do indeed represent normal Pacinian corpuscles. Eight discrete subcutaneous nodules were each proven to represent a single corpuscle. The 1- to 5-mm diameter of Pacinian corpuscles observed in this specimen matches that reported in the anatomical and pathological literature [1]. Importantly, areas devoid of nodules on the MRI showed no corpuscles at subsequent dissection.

In our prospectively observed Pacinian corpuscles, all were T2-hyperintense and T1-isointense compared with skeletal muscle. They were punctate structures separate from the more linear and tubular-shaped, neighboring vessels and nerves that crossed multiple axial and/or coronal images. The corpuscles were most numerous and most prominently grouped at the level of the MCP joints. Four of the eight dissected nodules had a definable thin, thread-like connection to the neighboring digital nerve on MRI and at dissection. This is most consistent with a thin peripheral nerve axon, and was commonly observed during our study. It was observed in all three of the nodules that were not dissected.

We were unable to identify any of the normal Pacinian corpuscles by ultrasound, despite the use of a high-frequency transducer, which should have provided high

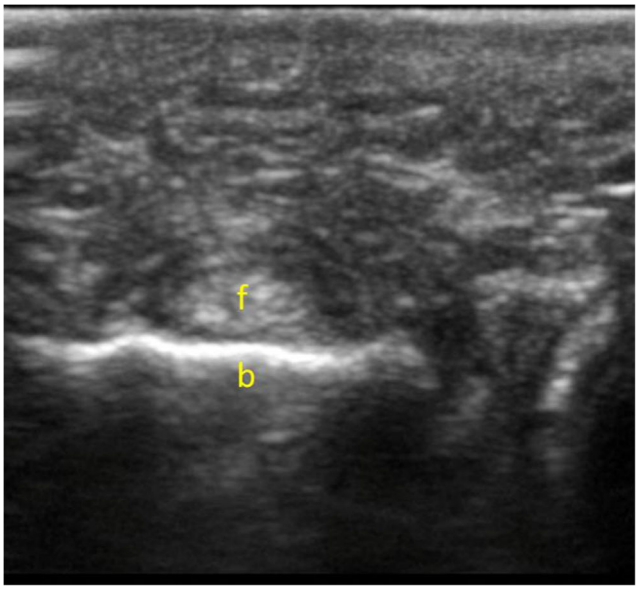

Fig. 3 Single ultrasound image obtained along the palmar aspect of the fourth metacarpophalangeal joint demonstrates the soft tissues about the flexor tendon (*f*). Cortical margin of the volar base ring finger proximal phalanx (*b*) is noted. No definite Pacinian corpuscle could be identified. The two confirmed Pacinian corpuscles (numbered 1 and 2 in Table 1) observed on MRI and dissection could not be resolved in the subcutaneous fat ulnar to the flexor tendon

spatial resolution images of the superficial subcutaneous fat. Likely, the corpuscles are occult on ultrasound because they are isoechoic compared with the background tissues and only have thin connective tissue capsules surrounding them [1].

One limitation of a cadaver study is that intravenous contrast medium cannot be given. Previous observations suggest that Pacinian corpuscles do not enhance, likely because they have a tight blood–nerve barrier [4, 5]. In our clinical experience, lack of enhancement helps distinguish these nodules from the normally enhancing, small subcutaneous vessels. It is possible that hyperintense structures in the subcutaneous fat of the cadaver were incorrectly discounted as being vessels when they were actually corpuscles and intravenous contrast medium could have helped to positively identify more corpuscles. Use of contrast medium may have allowed better characterization of the observed thin slips extending from the corpuscles toward the nearest digital nerve. It is our belief that these represent the thin extension of the nerve axon from the digital nerve, although they may represent tiny neighboring vessels that would be expected to enhance. Additionally, desiccation of the specimen may have altered the size and MRI signal characteristics in our specimen compared with in a living being.

A second limitation is that we dissected only 8 of the 11 nodules identified on MRI. All 8 returned gross and histological confirmation of Pacinian corpuscles. It was our belief that further dissection was not necessary, given time constraints. Our anatomist was blinded to the specific MRI appearance of any given nodule in an attempt to reduce selection bias and to avoid targeting larger or better defined nodules for dissection.

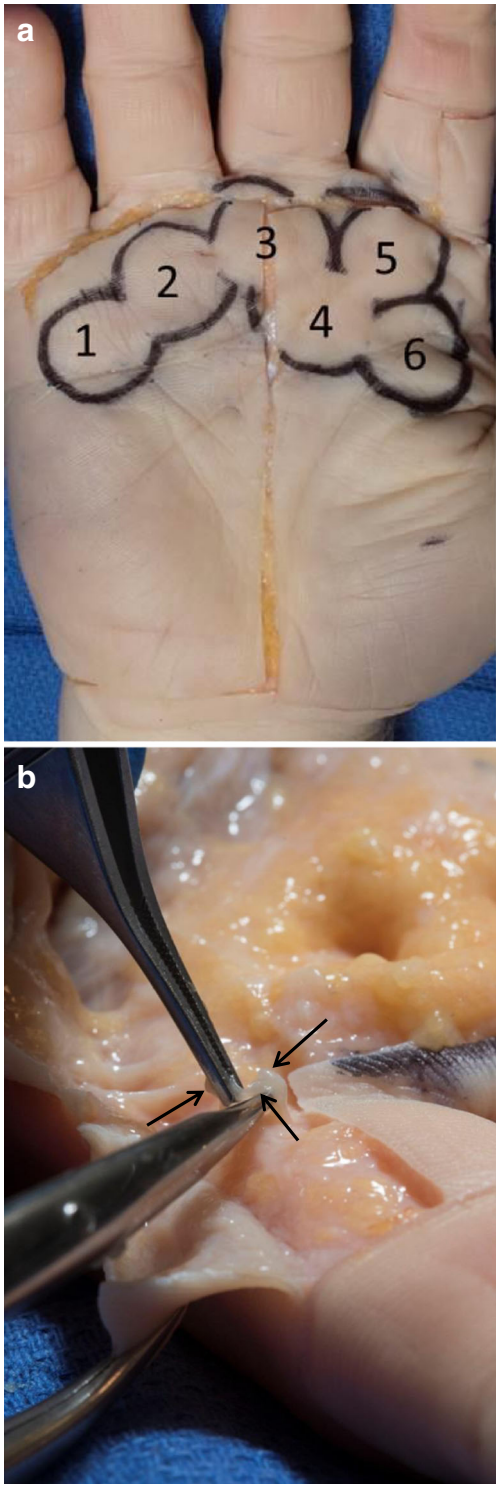

Fig. 4 **a** Dissection images demonstrating the superficial dermal dissection. The sites of MRI skin markers (removed) are labeled *1–6*. **b** Identification of small, glistening, nodular, presumed Pacinian corpuscles, along the course of the digital nerve at the radial base of the index finger proximal phalanx. Two are displayed atop the closed scissors tip. The third Pacinian corpuscle in this region is seen to the left of the closed clamp. These corpuscles are marked with *black arrows*

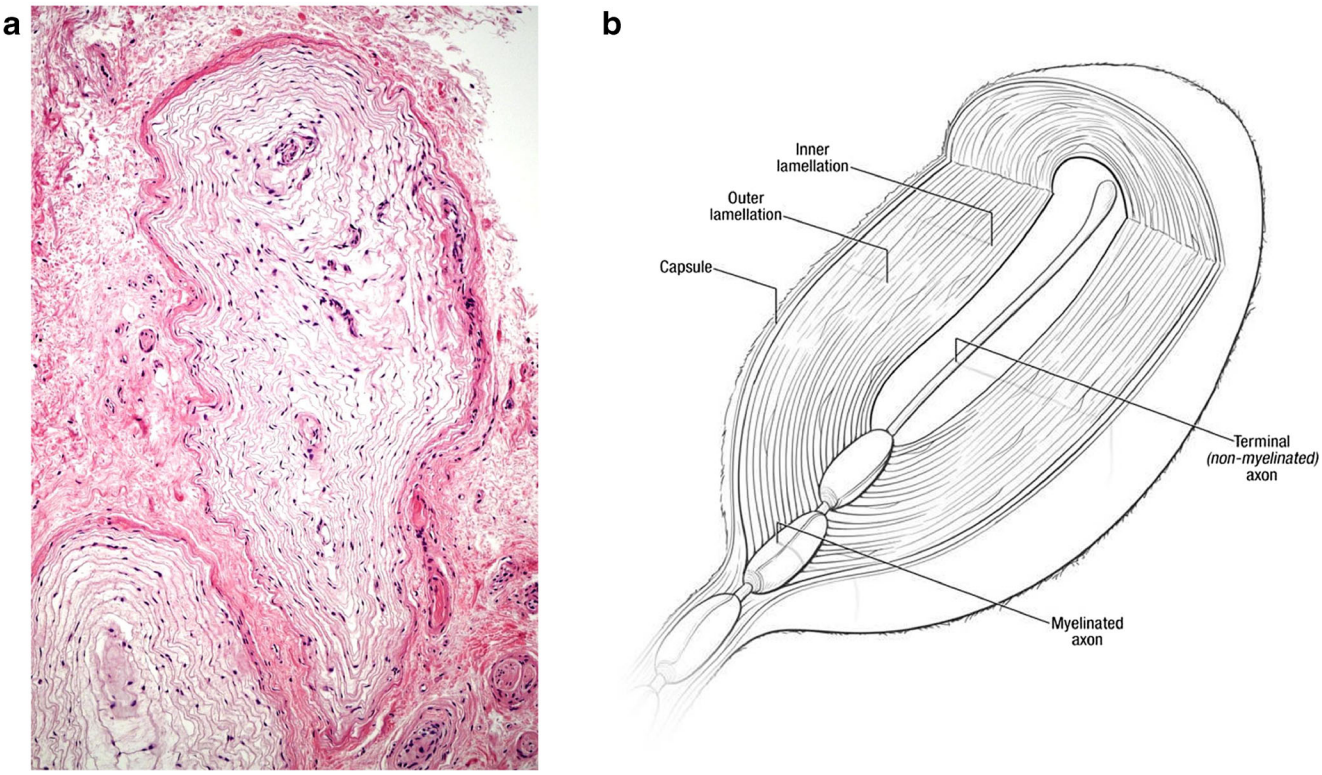

Fig. 5 **a** Pictomicrograph (hematoxylin and eosin stain; original magnification ×4) demonstrates two of the three Pacinian corpuscles dissected from the radial aspect of the proximal phalangeal base of the index finger. These corpuscles (one partially included) correlated with the presumed Pacinian corpuscles on MRI. **b** They demonstrate the expected lamellated appearance, as seen in the schematic. The crenulated appearance of the dissected corpuscle is due to freezing of the specimen after MRI and before dissection. Used with permission of Mayo Foundation for Medical Education and Research

In our past clinical experience, we have seen patients with more numerous and larger nodules (Fig. 6) than we identified in the cadaver, with individual nodules measuring up to 6 × 5 mm. These can be prominent and numerous within the hands, and as such, our hand and wrist surgeons occasionally note the incidental presence of Pacinian corpuscles in their dissections. We have observed cases where normal corpuscles were so obtrusive that the reading radiologist had to comment on them as "salient nodules of unknown etiology" or even suggest that these could represent a sort of inflammatory though non-enhancing nodule. Understanding the normal appearance of these corpuscles (Table 2) will aid radiologists in the identification of these normal structures, especially when prominent and numerous, and prevent them from being incorrectly attributed to pathology. There are case reports describing symptomatic Pacinian corpuscles in the dermatology and pathology literature [6], although none included MRI. Awareness of the normal Pacinian corpuscle on MRI should help the radiologist to consider and distinguish a potentially pathological one when encountered.

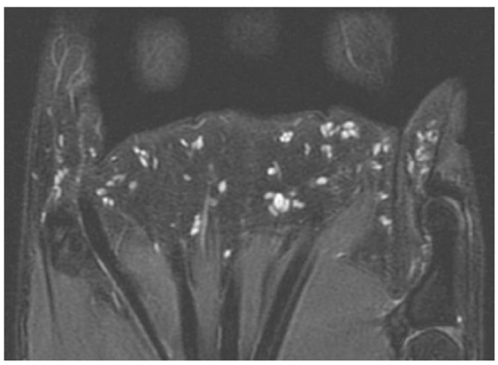

Fig. 6 Coronal T2-weighted image demonstrates a clinical patient with the often observed, more prominent and numerous, presumed corpuscles. This clinical patient was a 38-year-old woman with celiac disease and clinical concern for rheumatoid arthritis. Subsequent workup and MRI were negative for inflammatory arthropathy

Table 2 MRI characteristics of normal Pacinian corpuscles

T2 hyperintense subcutaneous nodules separate from vessels
Round or oval, 1-5 mm in diameter
Nonenhancing (based on prior observations in clinical studies)
Concentrated in subcutaneous fat of palms around the metacarpophalangeal joints
Thin nerve extension to the digital nerve may be observed

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interest.

Informed consent This study was approved by the institutional review board of our institution and by the Biospecimen Subcommittee.

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