



## "Haleem's Hen"; A mnemonic for the anatomy of hindfoot structures at the level of sustentaculum tali on coronal T1-weighted magnetic resonance images

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### ABSTRACT

Magnetic resonance anatomy of the hindfoot as seen at the level of the sustentaculum tali is intricate due to surrounding muscles, tendons, aponeurosis and ligaments. The objective of this work is to provide a mnemonic with illustrative figures to simplify this complex anatomical region on coronal T1-weighted MR images (T1-MRIs).

One hundred and twenty-four patients referred for foot and ankle complaints were scanned utilizing standard MRI imaging protocols for depiction of the hindfoot. Only coronal T1-MRIs of the calcaneus at the level of sustentaculum tali of unremarkably reported patients were selected for this work.

Upon viewing the calcaneus with the adjacent anatomical structures on coronal T1-MRIs, the overall appearance resembles a "Hen in the Nest with Four Eggs". The calcaneus represents the body of the hen, while the sustentaculum tali forms the head and neck. The posterior tibial tendon represents the crest of the hen, and the flexor digitorum longus and flexor hallucis longus tendons represent its beak and wattle, respectively. The peroneus brevis and peroneus longus tendons represent the tail, and the long plantar ligament represents the flexed legs of Haleem's hen. The plantar aponeurosis represents the hen's nest. Whereas the abductor hallucis, flexor digitorum brevis, abductor digiti minimi and quadratus plantae muscles are the four eggs.

The mnemonic, "Haleem's Hen in the Nest with Four Eggs", serves as a simplified phrase for radiologists and orthopedic surgeons to easily recall the anatomy of the hindfoot when viewing it at the level of the sustentaculum tali on coronal T1-MRIs.

### 1. Introduction

The foot and ankle are among the most injured parts of the musculo-skeletal system, which involves both amateur and professional athletes of all ages [1,2]. Proper management often requires advanced imaging, where orthopedic surgeons resort to magnetic resonance imaging (MRI) as it is an integral imaging modality for musculo-skeletal diagnosis [3].

Magnetic resonance anatomy of the hindfoot as seen on magnetic resonance images (MRIs) at the level of the sustentaculum tali is intricate due to surrounding muscles, tendons, aponeurosis and ligaments. This can be confusing for both junior radiologists and orthopedic surgeons, making it challenging to accurately identify anatomical structures and diagnose various pathologies in this region. The objective of this work is to provide a mnemonic with illustrative figures to simplify

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this complex anatomical region on coronal T1-weighted MR images (T1-MRIs).

## 2. Materials and methods

A retrospective review of MRIs of 124 patients were selected for this study. Patients were scanned with a 1.5 Tesla superconducting magnet (Signa; G.E. Medical System, Madison, WI) or 1.5 Tesla superconducting magnet (Avanto, Siemens, Germany). Standard positioning was utilized in multiple planes with a slice thickness of 2–3 mm and an interslice gap of 0.5–1 mm. While a complete study was performed for all patients, only coronal T1-weighted (TR 500/TE 20) spin-echo MR images of the calcaneus at the level of the sustentaculum tali were selected for this study. The field of view for the images (FOV) ranged from 10 cm to 18 cm, and the matrix size was 512 × 256. All selected MRI studies were conducted for suspected foot and ankle pathologies that did not involve the hindfoot at the level of the sustentaculum tali. These were interpreted by the most senior author radiologist. The examined T1-weighted coronal images were selected by identifying the sustentaculum tali proximally and progressing distally to the level of the calcaneocuboid and talonavicular joints. In addition to T1-weighted images, other MR sequences were utilized, namely proton density with fat suppression (PD-FS) as well as bone density reformatted coronal computed tomography (CT) images of the calcaneus to clarify a few anatomical structures in this work.

## 3. Results

The mnemonic “Haleem’s Hen in the Nest with Four Eggs,” serves as a simplified phrase for radiologists and orthopedic surgeons to easily recall the anatomy of the hindfoot. The mnemonic, which illustratively represents bony and soft tissues in the hindfoot, can be divided into five parts:

1. The “body” of the hen.
2. The “head and neck” of the hen.
3. The “tail” of the hen.
4. The “flexed legs” of the hen.
5. The “nest” of the hen and the “4 eggs” on which the hen sits.

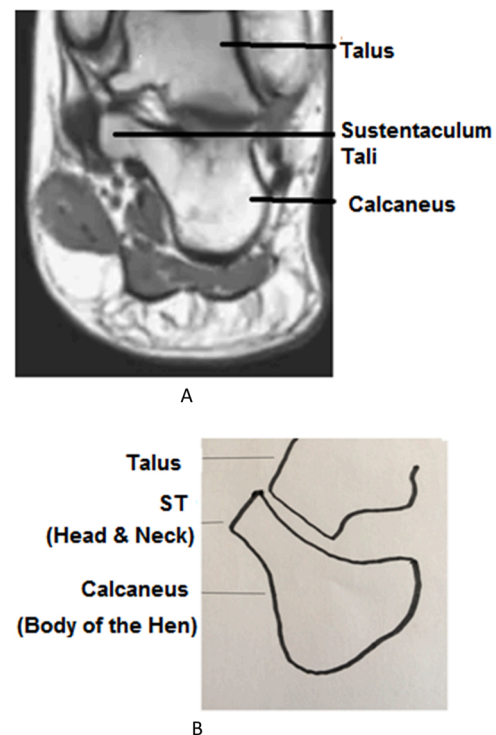
In the following order, as aforementioned, several considerations for these anatomical structures as viewed on coronal T1-weighted MRIs at the level of sustentaculum tali will be detailed below.

The “body” of Haleem’s hen represents the calcaneus bone, with the body of the calcaneus including the most anterior part of the posterior facet (Fig. 1A).

The “head and neck” of Haleem’s hen is represented by the sustentaculum tali (Fig. 1B). The sustentaculum tali is a bony projection that arises from the supero-medial aspect of the calcaneus and mimics a shelf that supports the posterior portion of the talus [4]. The tendon of flexor hallucis longus (FHL) passes into the sole of the foot through the groove beneath the sustentaculum tali, giving the appearance of the “wattle” of the postulated Hen (Fig. 2A).

The well-known mnemonic “Tom, Dick and Harry” describes the medial to lateral relationship of the posterior tibial tendon (PTT), flexor digitorum longus (FDL), and flexor hallucis longus (FHL) tendons seen on axial MR images of an anatomical specimen of the human body at the level of medial malleolus [4,5]. We observed that the same mnemonic (i.e. “Tom, Dick and Harry”) can be applied to the coronal MR images of this work to describe the superior to inferior relationship of these tendons in the hindfoot at the level of sustentaculum tali. The PTT, FDL and FHL are also seen superior, medial and inferior in relation to the sustentaculum tali, respectively. The PTT represents the crest, while the FDL and FHL tendons represent the beak and wattle of Haleem’s hen, respectively (Fig. 2B).

The “tail” of Haleem’s hen is represented by the peroneus brevis (PB)



**Fig. 1.** A – Coronal T1-weighted MR image shows calcaneus (body of the hen) at the level of the sustentaculum tali (head and neck of the hen). B – Illustrative figure shows the calcaneus (body of the hen) and sustentaculum tali (head and neck of the hen).

and peroneus longus (PL) tendons adjacent to the proximal lateral aspect of the lateral wall of the calcaneus (Fig. 3A).

The “flexed legs” of Haleem’s hen are represented by the long plantar ligament, as seen in relation to the close proximity of the plantar aspect of the calcaneus (Fig. 3B).

The long plantar ligament is a long ligament on the underside of the foot that connects the calcaneus with the cuboid bone and extends to the second, third, fourth and fifth metatarsals [4]. However, it is noteworthy that all MRI sequences show that the long plantar ligament merges imperceptibly with the plantar aspect of the calcaneus, as both have low signal intensity on all MRI sequences, including T1-weighted images, and proton density with fat suppression (Figs. 3A and 4).

It is easy to differentiate between the bony cortex of the plantar aspect of the calcaneus and the long plantar ligament by using computed tomography, which provides reformatted coronal images of the calcaneus as delivered by thin CT cuts. The bony cortex of the calcaneus exhibits high density whereas the long plantar ligament exhibits low density on CT (Fig. 5).

The “nest” is represented by the plantar aponeurosis (PA). The lateral portion of the plantar aponeurosis (lateral cord) is directly inferior to the abductor digiti minimi (ABDM) muscle. The medial portion (medial cord) of the PA is directly inferior to the abductor hallucis muscle (ABH) [2] (Figs. 6A, 6B and 7). The flexor digitorum brevis (FDB) muscle is directly inferior to the central portion of the PA (central cord). When visualized on the coronal MR image at the level of sustentaculum tali, these three muscles (ABH, FDB and ABDM) are close in proximity to the dorsal aspect of the medial, central and lateral cords of the plantar aponeurosis, respectively. These muscles represent three out of the four eggs in the nest (Fig. 8A). The fourth egg is represented by the quadratus plantae (QP) muscle. The QP has two origins. The medial, muscular and larger head originates from the medial concave surface of the calcaneus, and the lateral, tendinous and flat head originates from the lateral border of the inferior aspect of the calcaneus [2,6]. Therefore, the muscular component (i.e. the medial, larger head) of the quadratus

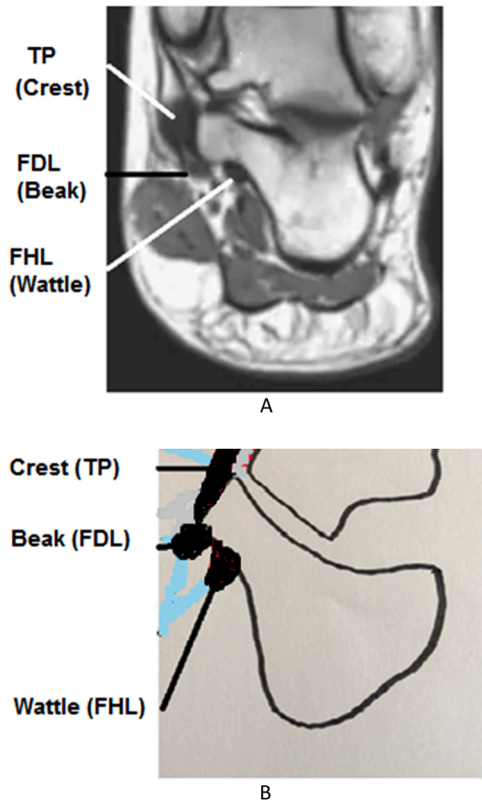


Fig. 2. A – Coronal T1-weighted MR image shows the calcaneus at the level of the sustentaculum tali with the tibialis posterior, flexor digitorum longus and flexor hallucis longus muscles representing the crest, beak and wattle of the hen, respectively. B – Illustrative figure shows the crest (tibialis posterior), beak (flexor digitorum longus) and wattle (flexor hallucis longus) of the hen.

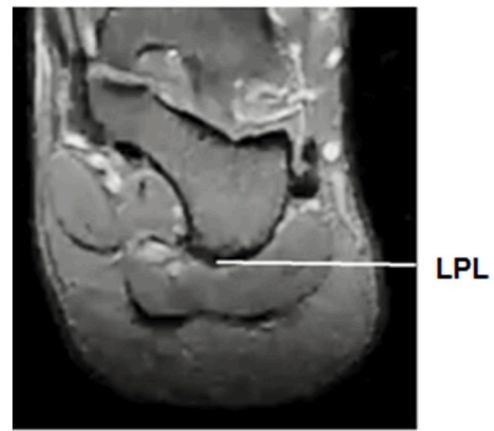


Fig. 4. Coronal PD MR image with fat suppression shows the long plantar ligament merging with the cortex of the plantar aspect of the calcaneus.

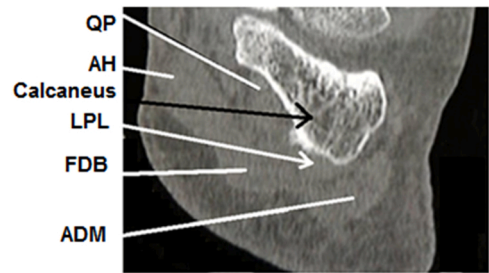


Fig. 5. A bony density reformatted coronal CT image shows the calcaneus and the long plantar ligament, which is seen adjacent to the cortex of the plantar aspect of the calcaneus.

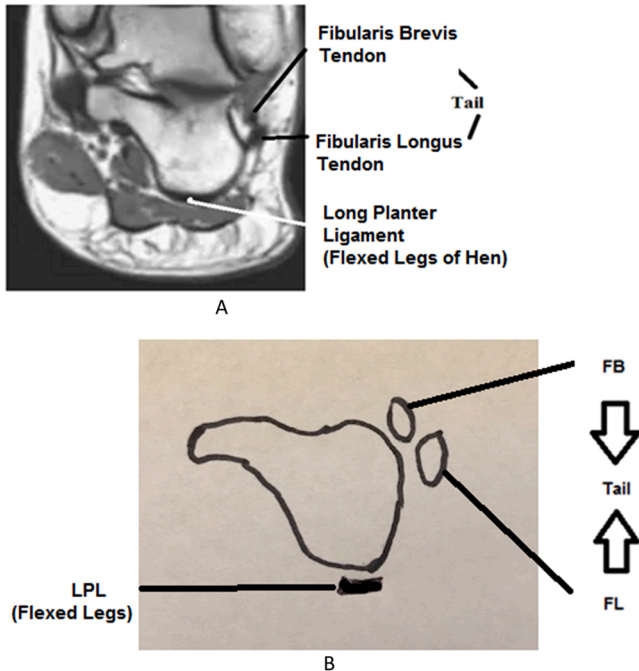


Fig. 3. A – Coronal T1-weighted image shows the peroneus brevis and peroneus longus tendons as the tail of the hen and the long plantar ligament as the flexed legs of the hen. B – Illustrative figure shows the tail made up of the peroneus brevis and peroneus longus tendons and the flexed legs made up of the long plantar ligament.

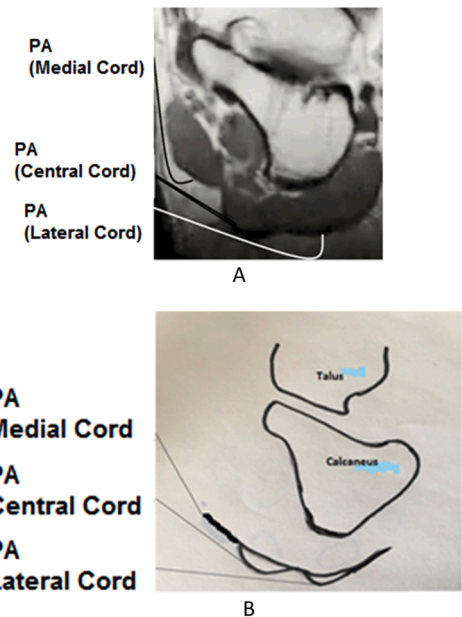


Fig. 6. A – Coronal T1-weighted MR image shows the three components of the plantar aponeurosis (i.e. medial, central and lateral cords), which represent the nest. B – Illustrative figure shows the medial, central and lateral cords of the plantar aponeurosis which comprise the nest.

plantae muscle represents the fourth egg in the mnemonic and is seen near the medial aspect of the calcaneus on the coronal T1-MRI (Fig. 8A). These four muscles, the abductor hallucis (ABH), flexor digitorum brevis

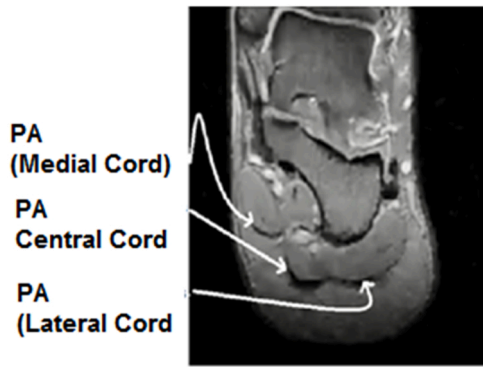


Fig. 7. Coronal PD MR image with fat suppression shows the nest made up of the medial, central and lateral cords of the plantar aponeurosis.

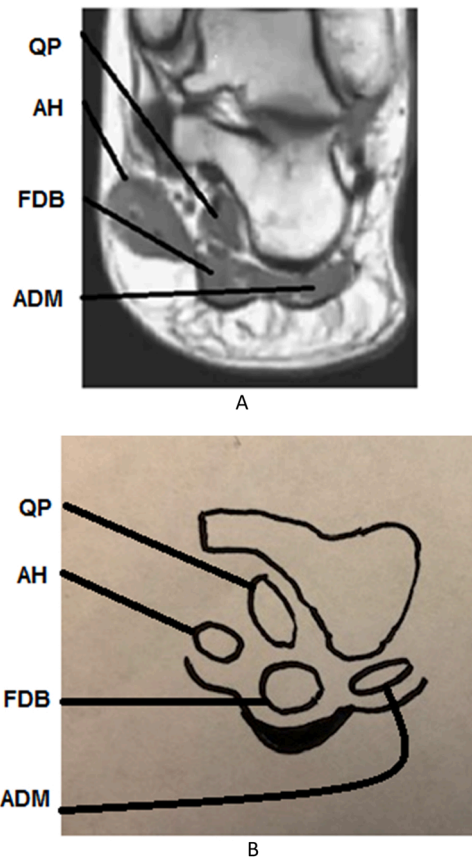


Fig. 8. A – Coronal T1-weighted MR image shows the four eggs made up of the abductor hallucis, flexor digitorum brevis, abductor digiti minimi and quadratus plantae muscles. B – Illustrative figure shows the four eggs represented by the abductor hallucis, flexor digitorum brevis, abductor digiti minimi and quadratus plantae muscles.

(FDB), abductor digiti minimi (ABDM) and quadratus plantae (QP), represent the four eggs in the nest (Fig. 8B and Fig. 9).

4. Discussion

During medical training, medical students and residents are equipped with mnemonics and other memorization strategies to learn and recognize normal and abnormal anatomy and physiology. After completing medical school and residency, physicians continue to accurately recall clinically relevant anatomical features and pathologies due to memorizing noteworthy mnemonics.

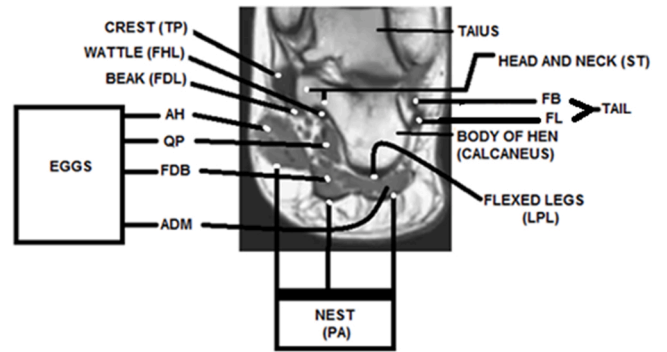


Fig. 9. When viewing the calcaneus with a coronal T1-weighted MR image as the level of the sustentaculum tali, the resulting image resembles “Haleem’s Hen in the Nest with Four Eggs.” This image shows the relevant anatomical structures and their corresponding parts in the mnemonic.

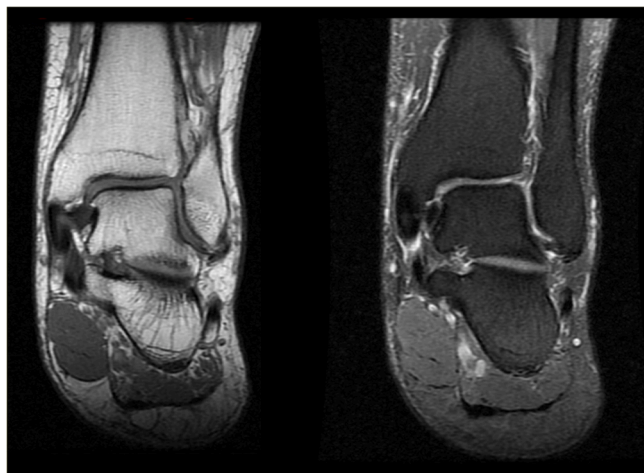
The magnetic resonance anatomy of the hindfoot as seen on coronal T1-weighted magnetic resonance images at the level of the sustentaculum tali is intricate due to surrounding muscles, tendons, aponeurosis and ligaments. This can be confusing for both junior radiologists and orthopedic surgeons, making it challenging to accurately identify anatomical structures and diagnose pathology in this area. The objective of this work is to provide a mnemonic with illustrative figures to simplify this complex anatomical region on coronal T1-weighted MR images (T1-MRIs).

One mnemonic of relevance that is frequently used by physicians is the “Scotty Dog” sign. The “Scotty Dog” was first referenced in the literature almost 50 years ago and is still used in medical education today [7]. The “Scotty Dog” sign is used to depict and understand the bony features of the posterior elements of the lumbar vertebra on the oblique radiograph. The nose of the dog represents the transverse process, the ear is the superior facet, the front leg is the inferior facet, the neck or collar is the pars interarticularis, and the eye is the pedicle [7].

The “Scotty Dog” is not only useful for recalling normal human anatomy, but also is useful in remembering and identifying different pathologies. One of the most well known is the broken neck of the “Scotty Dog”. The gap in the dog’s neck seen on radiographs indicates a fractured pars interarticularis or congenital pars defect [8]. Similarly, “Haleem’s Hen in the Nest with Four Eggs,” is not only a useful tool for medical education, but also is a useful mnemonic for identifying different pathologies identified with a coronal T1-weighted magnetic resonance image of the calcaneus at the level of the sustentaculum tali.

Pes planus, flexor digitorum brevis hemangioma, Baxter’s neuropathy associated with chronic denervation abductor digiti minimi atrophy and peroneal tendinitis are all examples of pathologies that can be identified by utilizing the mnemonic to differentiate them from normal physiology on a coronal T1- and T2-weighted MRI. Representative images of all aforementioned examples are shown in Figs. 10–13.

While MRI studies have described the magnetic resonance anatomy of this region of the foot before, none have developed a simple mnemonic that will allow for easy recall of these structures. With the body and head/neck of the hen representing prominent bony features of the hindfoot, the calcaneus and sustentaculum tali, respectively, the remaining parts of the mnemonic represent muscle, tendons, ligaments, and aponeurosis. The crest, beak, and wattle of the hen represent tendons of the deep posterior compartment muscles of the leg, the PTT, FDL, and FHL, respectively. The tail of the hen represents the tendons of the lateral compartment muscles of the leg, the PB and PL. The flexed legs of the hen represent the only ligament in the mnemonic, the long plantar ligament. The nest of the hen represents the only aponeurosis of the mnemonic, the plantar aponeurosis. Finally, the four eggs in the nest represent four intrinsic muscles of the foot. The first three eggs represent three intrinsic muscles in the first, most superficial layer of the foot, the



**Fig. 10.** Pes planus can present with posterior tibial tendinopathy and atrophy of the quadratus plantae muscle component, which is associated with signs of inflammation around the crest of the hen and a small fourth egg, respectively, as shown above in the coronal T1 (left) and PDFS (right) MRIs.

ABH, FDB, and ABDM. The last egg represents the fourth muscle, the QP, which is found in the second, deeper layer of intrinsic muscles of the foot. These simple groupings further complement the illustrative mnemonic in being a helpful and clinically relevant tool for students and physicians.

In conclusion, “Haleem’s Hen in the Nest with Four Eggs”, descriptively illustrates the normal anatomical structures of the hindfoot as seen at coronal T1-weighted MR images at the level of sustentaculum tali. The first and corresponding authors were first among the group of five authors to observe the structure of the hindfoot and create a very useful mnemonic incorporating their shared surname. This mnemonic could prove to be a learning tool for medical students and useful reminder for practicing radiologists, orthopedists, general surgeons, physicians and anatomists to recall and visualize the positioning and spatial relationships of bony and soft tissue structures in the hindfoot.

#### Ethical statement

All the authors mentioned in the manuscript have agreed for authorship, read and approved the manuscript, and given consent for

submission and subsequent publication of the manuscript.

Dr. Amgad Mohammed Haleem, MD, Ph.D. accepts responsibility for maintaining the integrity of the manuscript.

A patient’s right to privacy was maintained throughout this study and no identifying information was used in the manuscript.

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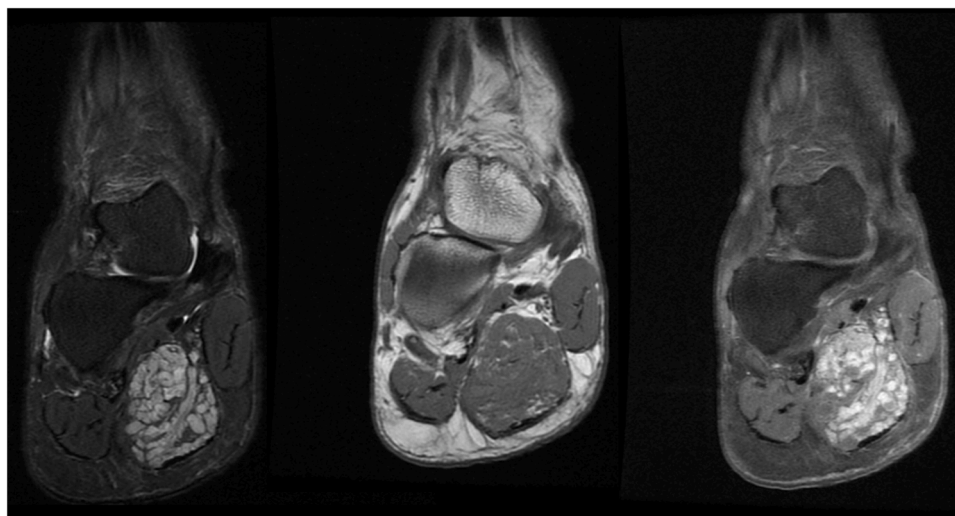
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#### CRediT authorship contribution statement

**Amgad Mohammed Haleem MD, Ph.D.:** Supervision, Data curation, Validation, Visualization, Writing – original draft, Writing – review & editing. **Ahmed Haleem MD:** Conceptualization, Data curation, Formal analysis. **Brandon William Moritz, BS:** Data curation, Validation, Visualization, Writing – original draft, Writing – review & editing. **Sohair Abdel Atti A Hindawi, MD, FRCR:** Conceptualization, Data curation, Formal analysis. **Hoda A Amin El-Deeb, MD:**



**Fig. 12.** Baxter’s neuropathy and chronic denervation presents with abductor digiti minimi atrophy on coronal T1 MRI, and this pathology is associated with a small third egg.



**Fig. 11.** On coronal T2 fast spin (left), T1 (middle) and T1 FS post-contrast (right), a hemangioma of the flexor digitorum brevis can be visualized as an abnormal, hyperintense mass within the second egg of the hen.



**Fig. 13.** Abnormal inflammation/thickening of the peroneus brevis and longus is typical of peroneal tendonitis, which would relate to enlargement of the tail of the hen. On this coronal PDFS (left) and T1 (right), peroneus brevis inflammation and enlargement can be visualized.

Conceptualization, Data curation, Formal analysis. **Alaa El-Sherif, MD, FAFR:** Conceptualization, Data curation, Formal analysis. **Mohammed Alberawi MD:** Writing – review & editing.

### Conflict of interest

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article. No funds were received in support of this study.

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