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IMAGE & SIGNAL PROCESSING

Application of MRI and CT Energy Spectrum Imaging in Hand and Foot Tendon Lesions

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Abstract

To deeply analyze the tendon lesions of hands and feet, the application of Computed Tomography (CT) energy spectrum imaging and magnetic resonance imaging (MRI) in anatomy and lesions is mainly studied. Firstly, the related information of the subjects is introduced in turn. Secondly, Gemstone Spectral Imaging (GSI) and MRI examinations are performed respectively. Through energy spectrum analysis software, suitable single energy value (KeV) is selected, the mixed energy image is converted into the single energy image, and a variety of image recombination methods are used to observe the energy spectrum CT image and compare the results with MRI. The results of the study show that GSI could display the morphology, continuous walking and dead point of the tendon, especially the three-dimensional spatial relationship of the tendon, bone and muscle, which is superior to MRI. There is no statistically significant difference between GSI and MRI in the display of tendon rupture, thickening, deletion and compression. And GSI is not as clear as MRI in the display of tendon adhesion, degeneration and tendon sheath lesions, and the difference is statistically significant. Therefore, MRI is still the first choice in hand and foot tendon lesions, especially in the display of early pathological changes of the tendon and tendon sheath diseases, as well as the evaluation of postoperative functional rehabilitation of the tendon. And CT energy spectrum imaging, as a new imaging mode, can clearly show the anatomy of normal tendon of hand and foot and most tendon lesions, especially in the observation of tendon morphology, which has a high diagnostic value.

Keywords Energy spectrum imaging · Magnetic resonance imaging · Tendon · X-ray computer · CT

Introduction

Hands and feet are important motor organs of the human body. They can complete various fine movements and have very important functions. As hands and feet are in direct contact with the outside world most frequently in life, work and activities, they are easily damaged by external forces. In addition, some systemic diseases often accumulate to the hands and feet, among which tendon and ligament lesions account for a large part, which is very common clinically. Tendons are carriers of hands and feet movements. They attach to the bone, connect to the muscles, and transmit the tensile load from the muscles to the bones, ultimately producing a variety of motor functions and fine movements [1, 2]. Tendon lesions are clinically divided into open and closed lesions. Open tendon lesions often involve more severe fractures. In the treatment of fractures, the treatment of tendons is also considered. In daily work, closed lesions are often observed, only relying on clinical examination and experience, sometimes it is difficult to make a correct judgment, and early diagnosis and early surgical treatment are critical for tendon healing and functional recovery. Therefore, imageological examination plays an important role in the diagnosis of hands and feet tendon lesions. The first clinical application is ordinary X-ray, which has a high diagnostic value for bone lesions such as fractures and bone tumors. However, it is difficult to show most tendon lesions due to the lack of density comparison of soft tissue. And soft tissue X-ray is mostly used to observe the changes of soft tissue in the achilles tendon region, because low tube voltage and high tube current can improve the contrast ratio of image density [3, 4].

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Due to its high resolution of soft tissue, MRI is often used as the first choice for examination of hand tendon and paratenon injury. However, MRI also has its own limitations, including many contraindications, complex imaging, long examination time and easy to appear artifacts. Ultrasound can be timely and dynamically observed, and has a high diagnostic value for tendon lesions, but it relies too much on the operator's experience, proficiency, and so on, and there is no objective evaluation standard [5]. Conventional CT has a lower resolution than MRI in soft tissue imaging due to the small difference in density [6]. In recent years, with the continuous development of CT energy imaging technology, the application of CT has been pushed to a new era [7]. In this study, it aims to preliminarily explore the application value of dual-energy CT energy spectrum imaging mode and MRI in the diagnosis of tendon anatomy and lesions, and to compare and analyze the two imaging methods, so as to provide the best imaging support for clinical practice.

Analysis methods and materials

The participants information

A total of 60 hand and foot patients who underwent concurrent CT energy spectrum imaging and MRI from October 2015 to December 2017 were enrolled in Affiliated Hospital of Inner Mongolia Medical University. There were 32 males and 28 females, aged 15 to 80 years, with an average age of 42 years. Basic clinical history: hand and foot trauma; functional disorder, pain and deformity caused by the operation of hand and foot tendon; hand and foot pain and discomfort, limited movement; hand and foot infection and soft tissue inflammation; history of autoimmune diseases, such as rheumatoid arthritis, systemic lupus erythematosus, tuberculosis, diabetes and hormone use for a long time. After surgery, pathology or combined with medical history, signs, follow-up and other data, 52 patients were diagnosed with hand and foot tendon lesions. Specific types and number of cases: 21 cases of tendon rupture; 26 cases of adhesion infection after tendon transplantation and fracture; 10 cases of injury and postoperative tendon loss; 15 cases of tendon compression; 8 cases of tendon degenerative changes; 30 cases of tendon sheath lesion. 8 patients with normal hands and feet were treated as normal tendon control group (4 cases of hand tendon and 4 cases of foot tendon). Informed consent was signed by all patients or their families and this study was approved by the Ethics Committee of Affiliated Hospital of Inner Mongolia Medical University, and the informed consent was signed by all participants. Exclusion criteria: pregnant women, infants and children, and patients with contraindications to MRI examination (other examination methods are recommended).

MRI image post-processing

The 3D FSPGR T_1WI image is transmitted to the AW 4.3 workstation. In the clarview option, the image is filtered with Filter A mode to increase contrast and sharpness, multiple planner reconstruction (MPR), curved planner reconstruction (CPR) and other image processing methods are performed on the tendon. From multiple angles and levels, the walking, morphological and signal of the tendon are continuously observed, and the main tendon of the hands and feet is marked to maximum display the full length at one level.

GSI image post-processing

The images obtained after GSI scanning are mixed energy images of 140 and 80KvP, and the optimal contrast to noise ratio (Optimal CNR) option is selected with GSI energy spectrum analysis software. Two regions of interest (ROIs) with basically the same size range are selected and respectively placed on the tendon to be observed and the surrounding soft tissue. KeV with the optimal contrast ratio between the tendon and the surrounding soft tissue, such as muscles, is obtained by the single energy value (KeV) test. The image is reconstructed to a layer thickness of 0.625 mm and a space of 0.625 mm. Reconstruction mode: the single-energy image of the optimal KeV for soft tissue is transmitted to the workstation, and the tendon and tissues surrounding them are observed with image processing modes such as Volume rendering (VR), Multiple Planar Reconstruction (MPR), and Curve Planar Reconstruction (CPR).

MRI and GSI imaging features of hand and foot tendon lesions

Key points of MRI diagnosis of tendon lesions: first, signal changes. First, signal changes. Changes in signals of different sequences can clearly show the condition of tendon lesions, which is helpful to analyze the nature of lesions and locate the lesions. Second, morphological changes, including loss, compression, tortuosity, contracture and other changes. Third, tendon sheath changes. In T_2WI and PDWI fat suppression imaging, changes in tendon sheath signals can be clearly observed. According to the degree of synovial fluid accumulation around the tendon, tendon sheath lesions can be divided into three grades: grade 1: the maximum radius of the liquid surface is less than the tendon diameter × 0.25; grade 2: the maximum radius of the liquid surface is between the tendon diameter × 0.25 and × 1; grade 3: the maximum radius of the liquid surface is greater than the tendon diameter × 1. Fourth, tendon tear. Based on the studies of Pomeranz et al., tendon tear is divided into three grades according to the degree of lesion: grade 1: small amount of tear inside the tendon, which doesn't involve the tendon edge; grade 2: about 50% tendon tear, part of tendon fiber continuously exists, tendon edge is affected, and accompanied by peritendinous tissue lesion; grade 3: complete tearing, tendon fibers are continuously interrupted, and the peritendinous tissue is severely affected. Fifth, the surrounding soft tissue and bone lesions. Diagnosis of tendon lesions by GSI: changes in tendon density; changes in contour, MPR and other image processing modes are used to observe whether the tendon is thickened, stressed, twisted, etc.; abnormal changes of tendon sheath and surrounding soft tissue; changes in the shape and density of tendon after tear, and lesions are graded according to the above MRI tendon tear criteria; merge fracture [8, 9].

Comparison and statistical treatment of MRI and GSI in the detection of tendon lesions

The comparison between the two methods for detecting tendon lesions is analyzed, and the application in clinical practice is preliminarily discussed. SAS 9.0 statistical software is used for statistical analysis. GSI and MRI are used for comparison of tendon lesions detection with χ^2 test of matched fourfold table, and $P < 0.05$ indicates that the difference is statistically significant.

Results and discussion

MRI and GSI display of hand and foot tendon anatomy

Normal tendons are extremely low-signal (black) in all MRI sequences, which are significantly contrasted with surrounding muscles, bones, and fat. Normal tendons sometimes show false appearances in imaging, showing higher signals, sometimes due to the accumulation of fat around the tendon, the effect of the dead point (the joint with the bone), the increased signal intensity, and more importantly, the "magic angle phenomenon". When the angle between the tendon and the imaging direction of the main magnetic field is 45–65 degrees, affected by the direction of the main magnetic field, the T_2 relaxation time of the tendon fiber is prolonged, which is manifested as a high-signal shadow of thin strips inside the tendon. When the angle is 55 degree, the signal is the strongest, and the signal is the most obvious in T_1WI and PDWI sequences. After changing the scanning position and increasing TE time to scan again, the artifact disappears or decreases, as shown in Fig. 1. Because of its high tissue resolution, MRI can clearly show the vast majority of hand and foot tendons. The 3D FSPGR T_1WI sequence and the oblique sagittal position sequence of T_1WI as consistent as possible with tendon walking are the best imaging methods to observe tendon anatomy, it uses Field of View (FOV), thin layer continuous scanning, MPR, CPR, and other image post-processing methods.

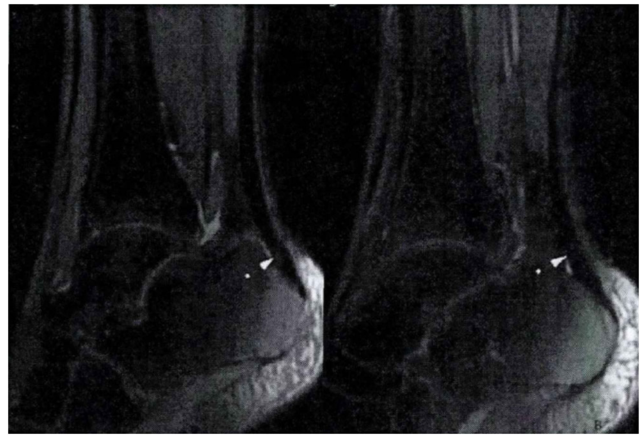

Fig. 1 Magic angle artifact of a normal Achilles tendon

The 3D FSPGR T_1WI sequence can be used to observe the tendon at any angle, so that each tendon can be displayed at one level to the maximum extent. Hand and foot tendons are composed of flexor tendon and dorsal extensor tendon. For flexor tendon and foot extensor tendon, MRI can clearly show the normal signal, stop point, walk, morphology of the tendon, and the reasons due to limited coil resolution and examination time. For the distal medial segment of the middle phalanx, the posterior aponeurosis branch and the terminal sputum shows a lack of clearance, with a score of 0.5. The remaining hand and foot tendons show an average score of more than 4, as shown in Tables 1 and 2, Figs. 2, and 3. Compared with surrounding soft tissue, GSI images of normal tendons show slightly higher density, smooth and neat edges, and natural walking. Through VR, MPR, CPR and other image reconstruction methods, GSI can intuitively display the three-dimensional spatial relationship among muscles, tendons and bones, and show the entire tendon movement on one level. In the case of hand and foot malformation, it can better reflect the overall anatomical relationship between tendon, deformed bone, and muscle. GSI can show most of the tendon of the hand and foot, the flexor tendon is larger, it shows better than the extensor tendon. For the extensor finger tendon and branches at the distal end of the proximal phalanx, the results are not clear, with a score of 0. The average scores of other tendons are all greater than 4, as shown in Tables 3 and 4, Figs. 4, and 5.

Tendon lesion of hand and foot on MRI

MRI can clearly show most abnormal tendon lesions, as shown in Table 5. For the contour changes of the tendon, such as compression, thickening, contracture, etc., MRI T_1WI images can clearly display them, and at the same time, it can observe changes of the signal and periorbital tissue lesions. When the tendon is torn, the signal on the fat suppression image of T_2WI and PDWI is obviously increased, the tendon is continuously changed, the broken end is tortuous, the signal of tendon is increased, and the soft tissue around the tendon is

Table 1 The normal tendon of the hand on MRI (4 people, 4 hands)

Tendon	Signal	Morphology	Attachment point	Average score
Tendon of long radial extensor carpal muscle/Tendon of musculus extensor carpi radialis brevis	8	8	8	6
Ulnar wrist long extensor tendon	8	8	8	6
Tendon of extensor digitorum (to the bottom of the middle phalanx)	6	8	4	4.5
Tendon of extensor digitorum (to the distal end of the middle phalanx)	2	0	0	0.5
Tendon of flexor carpi ulnaris	8	8	8	6
Tendon of flexor carpi radialis	8	8	8	6
Flexor pollicis longus muscle tendon	8	8	8	6

affected, showing a high signal intensity. Sagittal and transverse T_1WI images can be used to observe the continuity of tendon fibers and determine whether the tendon fibers are completely or incompletely torn. In the case of tendon tear, complete Achilles tendon tear (grade 3): 7 cases; partial tear (grade 1–2): 4 cases; partial tibial tendon tear (grade 2): 4 cases; complete tibial tendon tear (grade 3): 3 cases; complete tear of the ulnar flexor carpal tendon: 1 case; complete tear of the tendon of extensor digitorum: 1 case; tear of the proximal interphalangeal joint horizontal extensor tendon: 1 case. In tendon adhesions, MRI clearly shows the extent of adhesion and the accompanying abnormal changes in periorbital soft tissue. The T_2WI and PDWI fat suppression images shows a high signal, T_1WI shows a slightly lower signal, the normal tendon signals disappear or blur, the periorbital soft swell, and the boundary between the tendon and the tendon is unclear. Synovial lesion of tendon sheath is the early stage of tendon lesion. Synovial fluid exudation presents obvious high signal on T_2WI and FSPDWI, and when multiple tendon sheaths are accumulated, T_1WI presents thickening change of peritendinous soft tissue. Tendon degeneration change is an early pathological change of the tendon, often accompanied by other systemic diseases. In this group, 5 patients showed slight thickening of the tendon compared with the contralateral side, and sometimes the longitudinal and slender high signal shadow could be observed in the tendon. Combined with clinical practice, it was considered to be a tiny tear of the tendon fiber bundle. Some cases were accompanied by increased signals of tendon sheath and peritendinous soft tissue, and 1 case failed to make a correct imaging diagnosis due to the lack of obvious signs. MRI can also fully evaluate tendon tear and rehabilitation effect after transplantation and make imaging tracking analysis of postoperative patients undergoing functional exercise, so as to evaluate the effect of rehabilitation training on tendon repair. Imaging tracking was performed on 5 patients with Achilles tendon tears. At the 7th month after surgery, the continuity of signal in Achilles tendon and tendon fiber were significantly improved compared with that at the 1st month after surgery. Postoperative standardized rehabilitation treatment and functional exercise can accelerate tendon healing, as shown in Fig. 6. MRI failed to find some lesions, mainly because of the severe image motion artifact, followed by imaging illusion, such as magic angle effect and vascular pulsation artefact. In addition to observing tendon lesions, MRI can also show abnormal changes in the peritendinous tissue and comprehensively evaluate the hand and foot lesions. In this study, there were 18 cases of limbs fracture, 4 cases of nervous lesion caused by hand deformity, 5 cases of hand cavernous hemangioma, 2 cases of wrist lipoma, 4 cases of phalanx enchondroma, 3 cases of osteochondroma, 4 cases of traumatic osteoarthritis, 8 cases of calcaneus and talus bone contusion, 6 cases of rheumatoid arthritis and interphalangeal joint fusion, 3 cases of soft tissue scar formation after burn, and 4 cases of plantar fasciitis.

Table 2 Normal foot tendon on MRI (4 people, 8 ft)

Tendon	Signal	Morphology	Attachment point	Average score
Tibialis posterior tendon	16	16	16	6
Tendon of the flexor digitorum longus	16	16	8	5
Tendon of the flexor digitorum longus	16	16	16	6
Achilles tendon	16	16	16	6
Tendon of extensor digitorum longus pedis	16	16	8	5
Tendon of peroneus longus	16	16	16	6
Peroneus brevis tendon	16	16	16	6

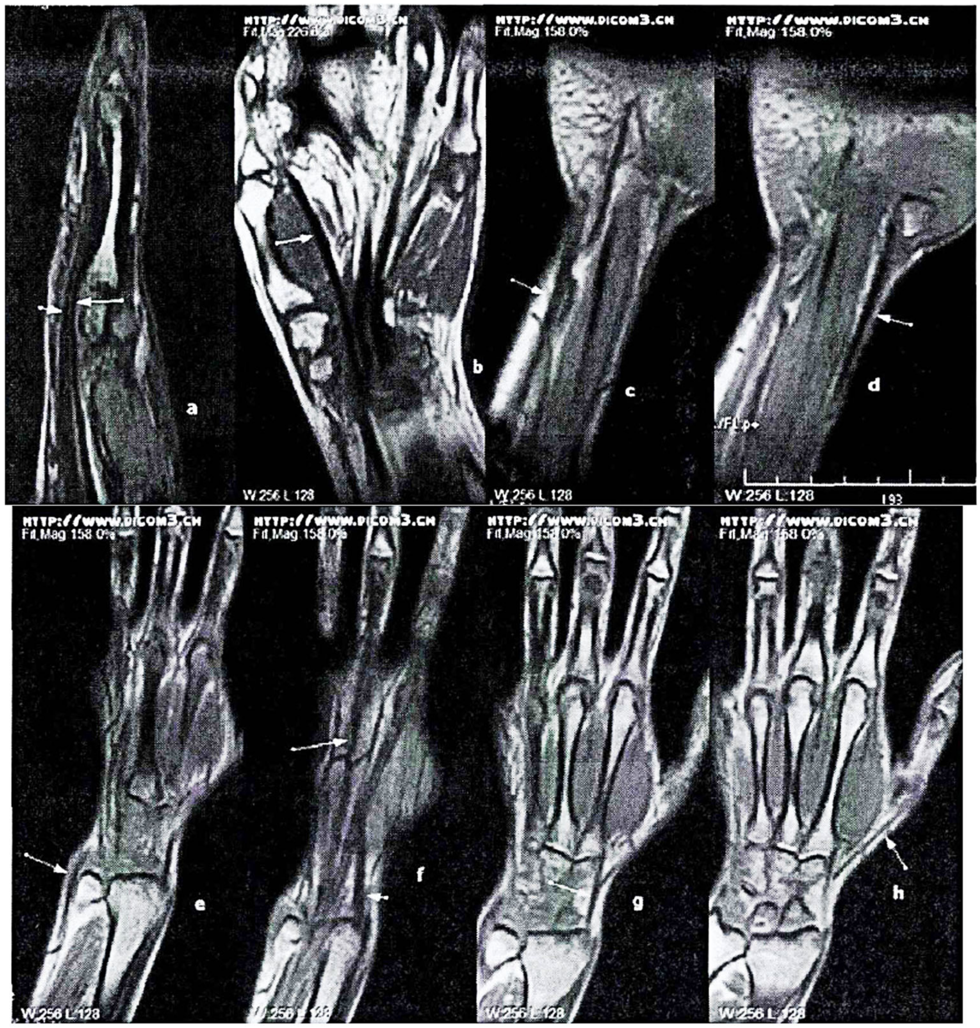

Fig. 2 Main tendons of normal hands. **a** flexor digitorum profundus tendon (long arrow) and superficial flexor tendon of finger (short arrow); **b** flexor pollicis longus muscle tendon; **c** ulnar wrist flexor tendon; **d** flexor carpal radialis tendon; **e** ulnar wrist extensor tendon; **f** tendon of extensor digitorum (long arrow) and tendon of musculus extensor carpi radialis brevis (short arrow); **g** tendon of long radial extensor carpal muscle; **h** tendon of extensor pollicis longus

Tendon lesion of hand and foot on GSI

According to tendon density, contour and walking changes, GSI can show most tendon and paratendon tissue lesions (Table 6). When a tendon is torn, the main manifestations are thickening of the tendon, tortuosity of the broken end tendon, contracture, and unsmooth edge of the tendon. GSI can correctly diagnose most tendon tears by comparing them with healthy side tendons. For small tear (grade 1) in the GSI imaging, sometimes it is only manifested as tendon thickening, slightly reduced density, lack of more signs, so it is easy to miss diagnosis. Adhesion in GSI is manifested as decreased tendon density, thickened, and unclear boundary with surrounding soft tissue. Adhesion is easy to be diagnosed by comparing with healthy side. For very small tendon adhesion, there is little change in tendon density and walking. It is difficult to be diagnosed only by imaging signs, so it needs to be combined with clinical practice. Tendon sheath inflammatory lesions with a wide range can be manifested on GSI as thickening of peritendinous soft tissue and disappearing of gap on peritendinous fat. However, for most of the abnormal changes of tendon sheath, there is a lack of strong imaging signs and no clear diagnosis can be made. Degenerative changes of tendon are early pathological changes of tendon. Tendon density and morphology are basically normal, so GSI diagnosis is difficult. Among them, 1 case only shows slight tendon thickening, which is considered as a degenerative change of tendon in combination with clinical practice. In this study, the cases that GSI fails to find are mainly early tendon lesions, inflammatory changes in a single tendon sheath, and minor tearing and adhesion of individual tendons. The main reason is that the density resolution of GSI is still limited, followed by the degradation of image quality caused by motion artifacts and metal artifacts. Like MRI, GSI can also show the lesions around the tendon while observing the tendon, especially for fractures, bone destruction, hand and foot deformities, and the relationship between tendons and bones. In addition, it can observe the overall situation of tendon and fracture in three-dimensional color mode, measure the angle and size of three-dimensional space, and provide accurate positioning

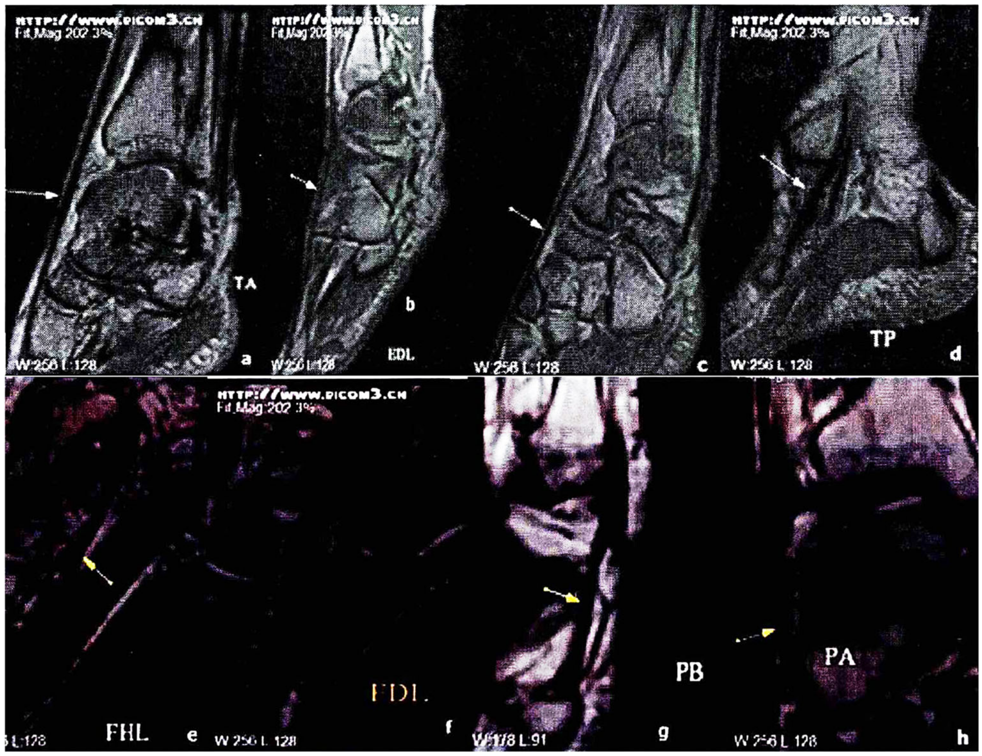

Fig. 3 Main tendon of the foot: **a** anterior tibial tendon (TA); **b** tendon of extensor digitorum longus pedis (EDL); **c** extensor hallucis longus tendon (EHL); **d** posterior tibial tendon (TP); **e** flexor hallucis longus tendon (FHL); **f** tendon of the flexor digitorum longus (FDL); **g** peroneus brevis tendon (PB); **h** tendon of peroneus longus (PL)

guidance for clinical surgery. However, it fails to well display the pathological changes such as edema and exudation of peritendinous soft tissue.

MRI imaging of hand and foot tendon lesions

MRI has a very high soft tissue resolution, so far, it is still the first choice to show tendon, ligament, muscle and other soft tissue lesions. It can provide more abundant image information according to the relaxation time and imaging sequence of tissue. MRI can show the vast majority of tendon and paratendon tissue lesions. For shape changes of tendon, through multi-directional imaging, it can clearly show the degree of tendon morphological changes and the relationship with other lesions. In addition to observing tendon, it can also evaluate the pathological changes of the periorbital tissue. It is a good choice for tendon rupture, ultrasound, and CT. MRI has irreplaceable advantages. Among the static images, it provides the most comprehensive image information. Achilles tendon is the most vulnerable tendon in human body, because it carries important sports functions and is closely related to human daily activities and physical exercise. Achilles tendon tears are often caused by sudden and indirect external forces, and severe degenerative changes in the achilles tendon can also lead to tears. Tendon degenerative changes are the early pathological changes of the tendon, and there are not many signs on MRI, which must be combined with clinical and follow-up before the final diagnosis. In addition to showing

Table 3 The normal tendon of the hand on GSI (4 people, 4 hands)

Tendon	Density	Morphology	Attachment point	Average score
Tendon of long radial extensor carpal muscle/Tendon of musculus extensor carpi radialis brevis	8	8	8	6
Ulnar wrist long extensor tendon	8	8	8	6
Tendon of extensor digitorum (to the bottom of the middle phalanx)	6	8	4	4.5
Tendon of extensor digitorum (to the distal end of the middle phalanx)	2	0	0	0
Tendon of flexor carpi ulnaris	8	8	8	6
Tendon of flexor carpi radialis	8	8	8	6
Flexor pollicis longus muscle tendon	8	8	8	6

Table 4 Normal foot tendon on GSI (4 people, 8 ft)

Tendon	Density	Morphology	Attachment point	Average score
Tibialis posterior tendon	16	16	16	6
Tendon of the flexor digitorum longus	16	16	8	5
Tendon of the flexor digitorum longus	16	16	16	6
Achilles tendon	16	16	16	6
Tendon of extensor digitorum longus pedis	16	16	8	5
Tendon of peroneus longus	16	16	16	6
Peroneus brevis tendon	16	16	16	6

tendon lesions, it is also possible to observe abnormal changes in peritendinous soft tissue and bone at the same time. For soft tissue diseases, in this study case, it clearly shows cavernous hemangioma, lipoma, etc. For bone contusion, MRI can clearly show the changes of early bone marrow edema signal and the abnormal condition of cartilage, which has a great advantage over CT. However, in the observation of fractures, especially small fractures, MRI is not as sensitive as CT, and the display of soft tissue softening is not as good as CT.

Comparative analysis and clinical application of MRI and GSI in tendon lesions

There is no significant difference between GSI and MRI in showing abnormal changes in tendon appearance, tear, and adhesion. Both of them can meet the requirements of clinical diagnosis. The three-dimensional imaging of GSI has a unique advantage in showing the contour of tendon. It can clearly show the thickening, compression and loss of tendon, and its image is straightforward. For clinicians, it is more conducive to preoperative positioning and postoperative effect evaluation. Tendon tear is first manifested as a change in the contour of the tendon, thickening of the tendon, continuous interruption of the walking, distortion of the broken end, abnormal density change, and high signal on MRI. Based on the above signs, most tendon tears can be diagnosed by both methods. However, for the micro-tear of tendon, GSI is not as informative as MRI. Through different sequences and signal changes, MRI can clearly show the lesion of tendon and peritendinous lesions, and there are more diagnostic methods than GSI, which are more reliable. For the evaluation criteria of tendon tear, MRI is more convincing than GSI and can be clinically recognized. For tendon adhesion, from the perspective of satisfying the diagnosis, most adhesion can be diagnosed by both examination methods, but MRI has a great advantage in small local adhesion. Although GSI is much better than conventional CT in terms of density resolution and image quality, compared with MRI, it is still subject to X-ray soft tissue density resolution for tendon sheath lesions and degenerative changes of tendon, which has no advantage, significant difference and statistical significance. In some cases, only peritendinous soft tissue thickening is observed. GSI can accurately measure the real CT value of tissue, eliminate the influences of beam hardening artifacts and

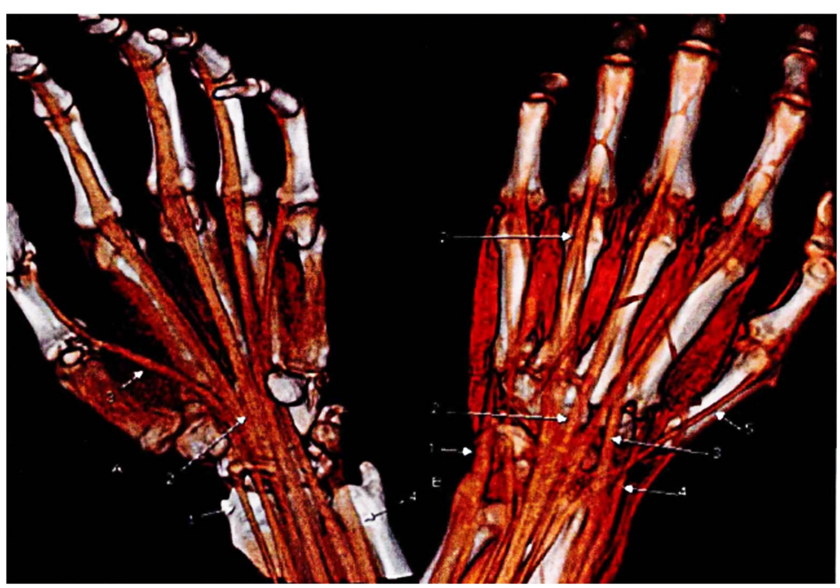

Fig. 4 The main tendon of the normal hand

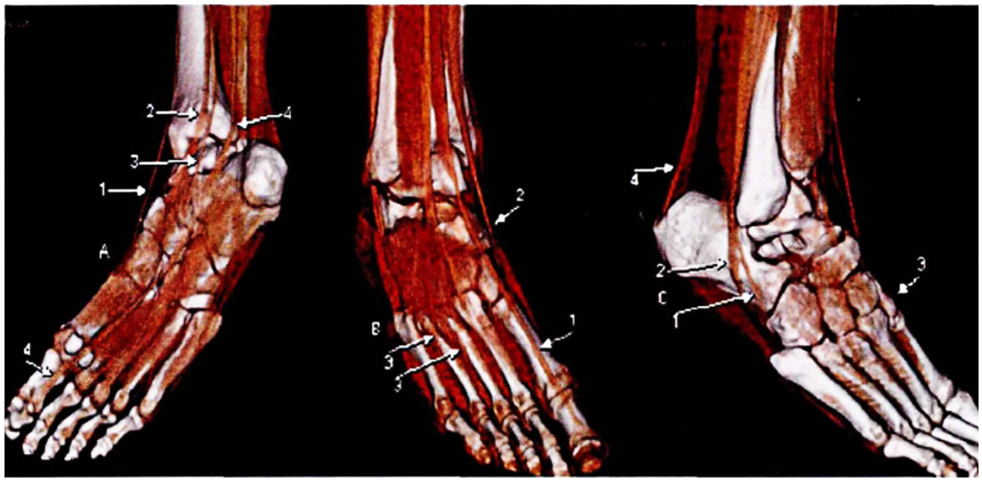

Fig. 5 The main tendon of the normal foot

partial volume effect. After obtaining CT values of tissues with different single energy values, GSI presents them in the form of curves and can perform material separation and analysis to achieve a preliminary leap from morphology to functional imaging, which is also the direction of future development of CT technology. Although MRI has great advantages in soft tissue imaging, MRI also has its disadvantages and limitations. Different from the simple principle of CT imaging, MRI is multi-parameter imaging. The uniformity of magnetic field, coil resolution, the design of scanning position and the application of sequence can all affect the image quality. The scan time of the hand and foot examination is long, the patient's position is uncomfortable, and various artifacts are prone to occur, including motion artifacts, "magic angle effect" of tendon, and vascular beat artifacts. There are many contraindications for MRI examination. Patients with metal stents, pacemakers, and rescue equipment such as ventilators and electrocardio monitors can't be inspected. Although some metal implant devices are not sensitive to magnetic field, there will be serious metal artifacts in the examination, which will also affect the diagnosis of diseases. Pregnant women within 3 months of pregnancy, patients with space claustrophobia, acute trauma and severe mental depression are not suitable for examination. The scanning speed of GSI is fast, and it is almost free from the interference of patient movement and organ peristalsis artifacts. The operation is simple and the cost is low. After scanning, a variety of image post-processing modes can be carried out. Disadvantages: the density resolution of soft tissue still needs to be further improved; the patient receives more radiation, which can be harmful to children and pregnant women. Both GSI and MRI examination methods have advantages and disadvantages in tendon lesions. In actual clinical work, a reasonable choice should be made according to the patient's different conditions.

Table 5 Manifestations of tendon lesions

Lesion	Manifestation of MBI	Number of cases
Press	Changed morphology and normal tendon signal	14
Adhesion	High signal on FS PDWI, low or equal signal on T_1WI, unclear boundary with surrounding soft tissue	25
Deletion	No normal tendon signal	9
Tear (complete or incomplete tear)	Increased signal on FS PDWI tendon, low or equal signal on T_1WI, contracted tendon tendon at the broken end, thickening, high signal in paratenon	20
Degenerative changes	T_2WI and FS PDWI showed an increase in the diameter of thin strip-shaped high-signal tendon, and the high signal of tendon sheath in some cases was changed.	7
Tendon sheath lesion	High signal on FS PDWI tendon, low or equal signal on T_1WI, and normal signal in tendon	28

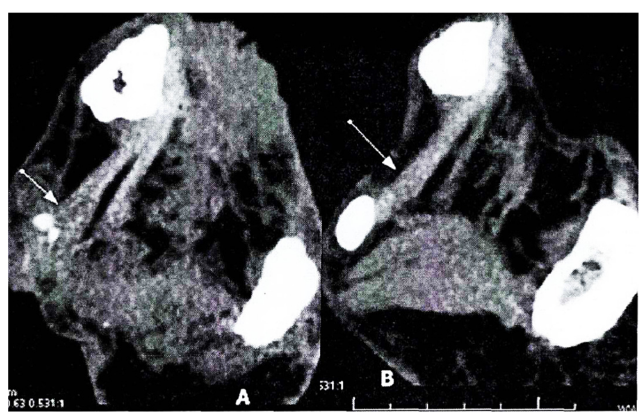

Fig. 6 **a**, **b** GSI multiplanar reconstruction image. After the right foot was injured, the posterior tibial tendon was torn. **a** the dead point of the posterior coelomic tendon was thickened and the density was decreased; **b** contralateral normal luminal posterior tendon

Table 6 Tendon lesion of hand and foot on GSI

Lesion	The manifestation of CT energy spectrum imaging	Number of cases
Press	Tendon morphological changes, diameter becomes smaller	14
Adhesion	The density of the tendon and adhesion area is reduced, the edge of the tendon is rough, and the boundary with surrounding soft tissue is unclear.	23
Deletion	Tendon is not shown, and VR image is more intuitive	10
Tear (complete or incomplete tear)	In complete tearing, the tendon continuity is interrupted, and the tendon tendon is thickened and contracted.	18
Degenerative changes	Tendon density and morphology show no abnormal changes	1
Tendon sheath lesion	Thickened soft tissue around the tendon, or no abnormalities	16

Conclusion

MRI and CT energy spectrum imaging are used to explore their application in hand and foot tendon lesions. Studies have found that GSI has advantages over MRI in showing tendon morphology, continuous walking, and stasis, especially in showing the three-dimensional spatial relationship between tendon, bone, and muscle. There is no statistically significant difference between GSI and MRI in the display of tendon rupture, thickening, deletion and compression. The display of tendon adhesion, degeneration and tendon sheath lesions is not as clear as MRI, and the difference is statistically significant. By analyzing the imaging characteristics of each tendon lesion and comparing it with CT energy spectrum imaging, MRI is still the first choice of examination in hand and foot tendon lesion, especially in showing the early pathological changes of tendon and tendon sheath disease, and evaluating the postoperative functional rehabilitation effect of tendon, with obvious advantages. The imaging characteristics of each tendon lesion are analyzed and compared with CT energy spectrum imaging, and it is found that MRI is still the first choice in the examination of hand and foot tendon lesion, especially in the display of early pathological changes of tendon and tendon sheath disease, as well as the evaluation of postoperative functional rehabilitation effect of tendon. CT energy spectrum imaging can clearly show the morphological changes of hand and foot tendon. By virtue of VR, MPR, CPR and other image post-processing technologies, the abnormal changes of tendon shape can be well demonstrated. Its image is intuitive, provides accurate surgical positioning for clinical practice, and has a good clinical application prospect in evaluating the postoperative effect of tendon. The image is straightforward and provides accurate surgical positioning for the clinic. CT spectroscopy imaging has a good clinical application prospect in evaluating the effect of tendon surgery, in addition, it has a high diagnostic value in the display of hand and foot tendon lesions and is a powerful complement to MRI.

Compliance with ethical standards

Conflict of interest Author Jing Wu declares that he has no conflict of interest. Author Xi Yang declares that he has no conflict of interest. Author Jianmei Gao declares that he has no conflict of interest. Author Sheng Zhao declares that he has no conflict of interest. Author Liang Wang declares that he has no conflict of interest. Author Tianyou Luo declares that he has no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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