ORIGINAL RESEARCH

Etiology of Spontaneous Extensor Tendon Injury in Northern-China Rice Farmers

Chang-long Zhou, PhD; Yan-Bo Xiao, BM; Chun-Yang Xi, PhD; Nan Zhang, PhD

ABSTRACT

Background • Spontaneous extensor tendon injury is caused by repeated finger flexion and wrist movement. This rare disease has a relatively high incidence in northern China, mostly among rice farmers. This study aimed to elucidate the etiology of spontaneous extensor tendon injury in rice farmers.

Methods • Morphologic changes in the extensor tendons and wrist extensor retinaculum in wrist dorsiflexion were studied via ultrasound examination of the hands of 30 healthy adult men, and 34 patients with a non-rupture extensor tendon injury and 11 patients with spontaneous ruptures of the extensor tendons were also enrolled in the study. The daily workload and potential causes of injuries were assessed.

Results • Ultrasound images of healthy male hands showed that during wrist dorsiflexion, the extensor retinaculum of the wrist forms differently shaped trochleas as the dorsiflexion angle changes. Histopathologic examination of the wrist extensor retinaculum revealed that the inner face was abraded evenly, the synovial membrane on the surface of the wrist extensor retinaculum disappeared, the internal coarse fibers were exposed and there was fibrous debris, suggesting that dry friction occurred before the rupture.

Conclusions • From clinical observation it could be concluded that the severity and progress of swelling and pain are related to the force applied during rice transplantation as abrasions were found at the front of the wrist extensor retinaculum. (*Altern Ther Health Med.* 2021;27(5):100-107).

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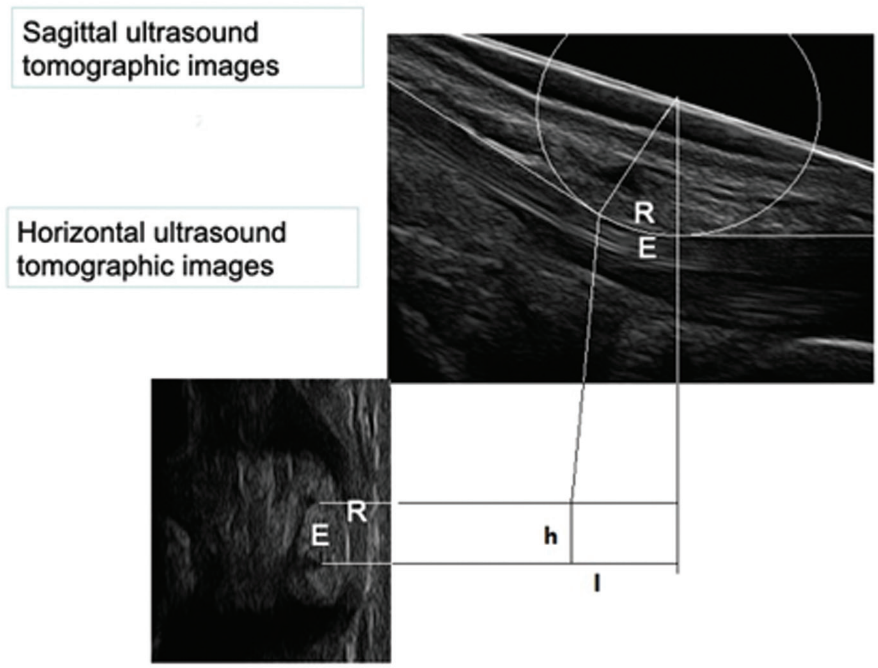
INTRODUCTION

Spontaneous tendon injury is usually the result of tendon abrasion caused by fracture malunion or erosion of the tenosynovium and tendon by arthromeningitis or rheumatoid arthritis.[1-3] However, spontaneous tendon rupture can also occur in certain people whose jobs require frequent flexion and extension of the wrist or fingers. Such ruptures have been reported, for instance, in athletes, production line workers, pastry cooks, painters and rice farmers.[4-7] Takami and colleagues reported 3 cases of spontaneous extensor tendon rupture,[8] and Van Heest and colleagues reported the impact of the wrist extensor retinaculum with the extensor tendon in 7 athletes.[9] Hundreds of cases of spontaneous extensor tendon rupture have been reported in northern China, and all of the patients in these reports were rice farmers whose disease was mainly caused by the process involved in rice transplantation.

Both Van Heest, et al.[9] and Khazzam, et al.[10] believe that there is an impact between the extensor tendon and the wrist extensor retinaculum, and the force of the impact is the cause of an extensor tendon rupture at the wrist extensor retinaculum. However, this theory is based on the anatomy of certain fixed neutral positions of the wrist. The study of the relative movement of the extensor tendon and the wrist extensor retinaculum, taking into account the working elements involved, would undoubtedly lead to a more accurate understanding of the etiology of this disease.

In this study, we explored the causes of extensor tendon injury from many perspectives. The morphologic changes of the extensor tendon and wrist extensor retinaculum during wrist dorsiflexion in healthy volunteers were studied via ultrasound imaging. The intraoperative findings and clinical pathologic characteristics of patients with extensor tendon

Figure 1. The measurement of the trochlea structure of the extensor tendon. R: retinaculum; E: extensor tendon.



injury were studied. Rice farmers with extensor tendon injury were included in this study.

MATERIALS AND METHODS

Study Population

We enrolled 3 groups in this study. The first group included 30 healthy adult male volunteers aged 30 to 40 years (height, 170 to 177 cm), all of whom had no special medical history and no special sports or job history. The second group consisted of 34 patients aged 19 to 55 years with a non-rupture extensor tendon injury, all of whom were rice farmers with complaints of wrist swelling and pain once they started transplanting rice. The third group included 11 patients aged 22 to 45 years (average age, 34.5 years) with spontaneous extensor tendon rupture, all of whom were rice farmers (10 women, 1 man). In these 11 patients, complete ruptures were found in 9. The ultrasound signs of the ruptures included 3 patients with extensor tendon ruptures of the index finger, 8 of the middle finger, and 6 of the ring finger. There were 2 patients with incomplete ruptures who complained of feeling friction when extending and flexing their fingers. All patients verbally agreed to participate in the study, and 11 patients signed the informed consent form.

Ultrasound of the Morphologic Changes of the Wrist Extensor Retinaculum and Extensor Tendons in Wrist Dorsiflexion

The dorsal wrists of the 30 healthy adult volunteers were coated with coupling agent and examined via color Doppler ultrasonography (Mylab90, 18 MHz high frequency probe, Esaote Company, Florence, Italy) with the wrist joints in straight flexion (0°). In the wrist crease-transverse position, the fourth compartment was examined, and no anatomical variations or accessory muscle were found in any of the patients. The wrist joint and ultrasonic probe were then completely immersed in water with the wrist joint in straight flexion (0°). The morphology of the tendons and dorsal wrist extensor retinaculum were observed at the level of the extensor tendon of the middle finger, and the length of the wrist extensor retinaculum was measured and recorded. Keeping the finger extended, the wrist was slowly dorsiflexed, sagittal and transverse images were recorded at different dorsiflexion angles (0°, 15°, 30°, and 45°) and the length of the wrist extensor retinaculum trochlea was measured.

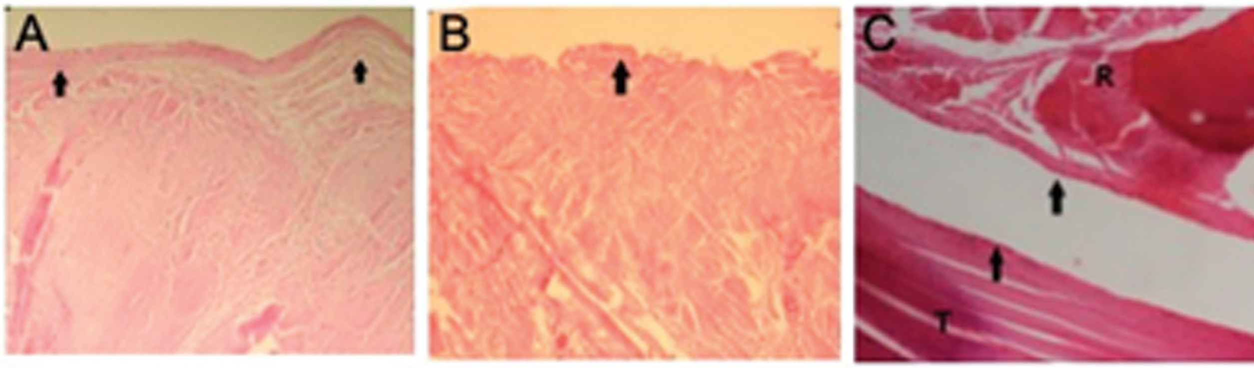
To measure the trochlea length, a line was drawn along the surface formed by the distal and proximal ends of the tendon on the sagittal ultrasound images. The trochlea length was the part of the tendon deviating from the line and producing a radian, which was measured on the image with the scanner's software (see Figure 1).

Intraoperative and Histopathologic Findings in the Wrist Extensor Retinaculum and Extensor Tendons

In the 11 patients with ruptures, the structure of the ruptured extensor tendons and damaged wrist extensor retinaculum were photographed during surgery.

The wrist extensor retinaculum and extensor tendons of freshly frozen specimens, as well as the wrist extensor retinaculum and the stumps of ruptured extensor tendons excised during surgery, were fixed in 10% formalin, dehydrated, rendered transparent, embedded and sliced. The slices were dewaxed, rehydrated, stained for 5 minutes,

Figure 2. Histologic examination of the wrist extensor retinaculum. A. Histologic results of normal wrist extensor retinaculum obtained from fresh frozen specimens of upper limbs. B. Histologic results of wrist extensor retinaculum wear obtained from resected wrist extensor retinaculum in patients. On the left part of the picture, the main portion of the wrist extensor retinaculum is shown. Hematoxylin and eosin (H&E) staining, magnified by 4×10. C. There was a synovial membrane-synovial fluid-synovial membrane structure in the contact surfaces of the extensor tendons and the wrist extensor retinaculum. R: retinaculum; T: extensor tendon. The arrows point to the synovial membrane.



immersed in 0.5% eosin solution for 3 minutes, dehydrated in gradient ethanol, cleared in xylene and finally mounted. The histologic morphology of the wrist extensor retinaculum and extensor tendons was observed via optical microscopy.

Clinical Etiology Investigation

All patients were rice farmers. After interviewing the patients, their chief complaints were summarized to analyze the causes of extensor tendon rupture, taking into account the amount of labor, the angle and speed of rice transplantation movements and the soil status.

Preoperative Examination

Diagnostic criteria for incomplete rupture of the extensor tendon included swelling and pain on the back of the hand near the wrist joint. If pressure was put on the fourth compartment, patients complained of feeling friction and pain when extending the fingers. To evaluate the severity of injuries, the wrist joints were examined using color Doppler ultrasonography (Mylab90) in the sagittal and transverse planes.

Treatment Strategies

In the study, 2 patients with incomplete rupture of the extensor tendon were treated conservatively with immobilization of the wrist joints. The patients' condition was reviewed weekly for 8 weeks. The 9 patients with a complete rupture of the extensor tendon were treated surgically. After brachial plexus anesthesia, an S-shaped incision was made on the dorsal wrist to expose the wrist extensor retinaculum and deep fascia. In 4 patients, the wrist extensor retinaculum was retained and the extensor tendons were placed below the extensor retinaculum before anastomosis. In 5 patients, the wrist extensor retinaculum was incised. Tendon anastomosis was performed in 4 patients, and tendon transplantation was performed in the other 5 patients using the palmaris longus tendon. Patients' wrists were immobilized in a cast for 4 weeks before beginning functional training.

Periodic Re-Examination and Follow-Up

Patients with complete rupture of the extensor tendon were followed up after surgery. They were reexamined monthly, and their status was recorded.

Statistical Analysis

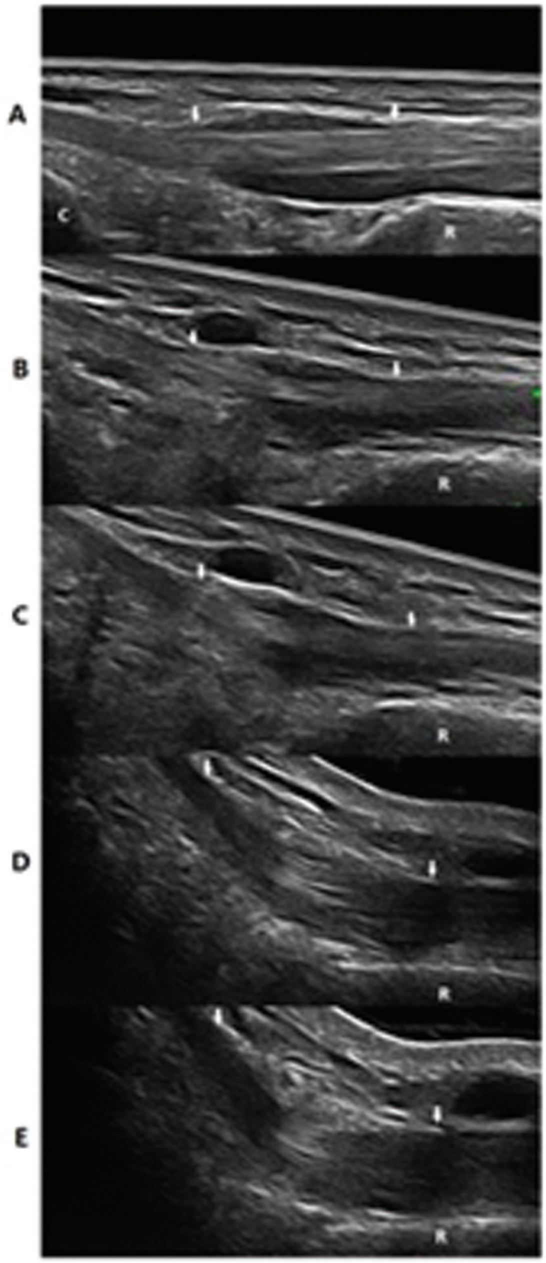
Data were presented as mean ± standard deviation. The data for groups with different wrist angles were analyzed using one-way ANOVA, and pairwise comparison was conducted using the SNK-q test. The value of $P < .05$ was considered statistically significant. All statistical analysis was performed using SPSS software (SPSS Inc., Chicago, Illinois).

RESULTS

Histologic observations in the wrist extensor retinaculum and extensor tendon

The histologic results from the wrist extensor retinaculum in fresh frozen specimens are shown in Figure 2A. The synovial membrane was present on the surface of the wrist extensor retinaculum. At the edges of the synovial membrane, there was synovial subintima between the synovial membrane and the dense fibrous connective tissues of the wrist extensor retinaculum. This part of the synovial membrane had features of both honeycomb and adipose synovial membrane, conducive to the production of synovial fluid. There was no synovial subintima below the central part of the wrist extensor retinaculum, which was directly attached to the dense fibrous connective tissues of the wrist extensor retinaculum, the characteristics of a fiber-type synovial membrane, which is not conducive to producing synovial fluid. There was a synovial membrane, synovial fluid and synovial membrane structure at the contact surface between the wrist extensor retinaculum and the extensor tendons (see Figure 2C).

Figure 3. The sagittal ultrasound images of the wrist extensor retinaculum and extensor tendons when wrist dorsiflexes from 0° to 60°. A. The wrist extensor retinaculum was in flake shape at 0°; B. In a spindle shape at 15°; C. in a spindle shape at 30°; D. in a spindle shape 45°; E. in the shape of an inverted triangle with a blunt downward tip. The wrist extensor retinaculum is shown between the 2 arrows; R: radius; C: capitate bone.



Pathologic results of the examination of the wrist extensor retinaculum in patients are shown in Figure 2B. The inner face of the wrist extensor retinaculum was abraded evenly. The synovial membrane on the surface of the wrist extensor retinaculum had disappeared, and the internal coarse fibers were exposed, accompanied by fibrous debris. The changes in the extensor tendons were the same as in the wrist extensor retinaculum. The structure of the inner collagen fibers of the tendons had become loose, with a lot of debris at the ends of the fibers.

There was a synovial membrane-synovial fluid-synovial membrane structure between the wrist extensor retinaculum and the extensor tendons. The synovial membrane disappeared, and the surface of the wrist extensor retinaculum was abraded in patients with extensor tendon rupture. It can be inferred that the relative movements of the wrist extensor retinaculum and extensor tendons underwent dry friction before the rupture of the tendons.

Morphologic Changes in Normal Wrist Extensor Retinaculum and Extensor Tendons During Wrist Dorsiflexion

Sagittal ultrasound images of 30 healthy adult volunteers are shown in Figure 3. As the wrist dorsiflexed from 0° to 60°, the shape of the wrist extensor retinaculum changed from flake to spindle and finally to an inverted triangle with a blunt downward tip, but the contact interface of the extensor tendons and wrist extensor retinaculum was always smooth. During movement, the length of the wrist extensor retinaculum was shortened, but its thickness increased. The anterior fibers of the wrist extensor retinaculum moved dorsally and proximally, and the entire wrist extensor retinaculum moved proximally. As a result, the main portion of the wrist extensor retinaculum gradually moved from the dorsal side of the semilunar bone to the dorsal side of the distal radius. During the whole process, the wrist extensor retinaculum provided a trochlea to guide the rotation of the extensor tendons at the wrist without an impact or compression between them. The measurement results of the trochlea showed that the trochlea length was gradually shortening during wrist dorsiflexion from 15° to 30° to 45° and finally 60°, and the pairwise comparisons between the groups showed significant differences ($P < .05$). Transverse ultrasound images demonstrated that when the wrist dorsiflexed at any angle, an arc shape was formed by the wrist extensor retinaculum, and muscle fibers converged towards the top of the arc without obvious changes in the contact length (see Figure 5).

Analysis of Clinical Manifestations and Etiology

The age of patients in this study was between 19 and 55 years (mean, 35 years). The patients have been engaged in rice planting for 1 to 37 years (mean, 14 years). Every day, each patient transplanted 1.2 to 1.5 acres of rice and repeated rice transplantation movements an average of nearly 20 800 times daily. Based on the patients' chief complaints, we found that the severity and advanced rates of swelling and pain were related to the magnitude of the force involved in rice transplantation, correlated with the hardness of the soil. The longer they worked, the more severe the swelling and pain in their dorsal wrists became.

Patients with extensor tendon injury could be divided into 3 categories. The first category (n = 34) only complained of swelling and pain but not a feeling of friction or dysfunction, and ultrasound images showed no signs of rupture. In the second category (n = 2), the extensor tendons were incompletely ruptured with a feeling of friction but without physical signs of tendon rupture; ultrasound images showed no sign of tendon rupture. In the third category (n = 9), the extensor tendons were completely ruptured with physical signs of tendon rupture, and ultrasound images also showed signs of tendon rupture. In all cases of complete extensor tendon rupture, severe pain suddenly occurred, accompanied by the clicking sound of tendon rupture, and immediately after the metacarpophalangeal joints of the middle or ring finger or both could not be fully extended.

In rice farmers, the relative movements of the extensor tendons and wrist extensor retinaculum occurred in the presence of boundary lubrication. Most patients with extensor tendon rupture complained that the soil they had been planting in was hard. The hardness of the soil was correlated with the force exerted on the fingers, as well as the tendon load. The increase of the tendon load might lead to boundary lubrication failure, resulting in dry friction causing abrasion of tendon structures.

Figure 4. The trochlea lengths at different wrist dorsiflexion angles.

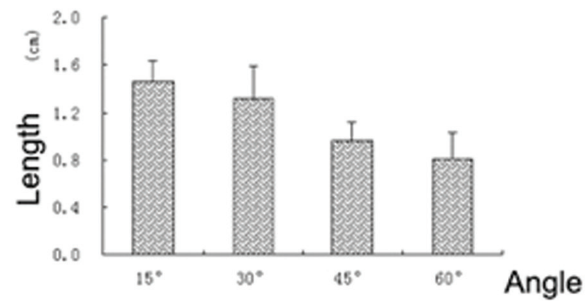


Figure 5. Transverse ultrasound images of the wrist extensor retinaculum and extensor tendons when wrist dorsiflexes from 0º to 60º. When wrist dorsiflexes, an arc shape is formed by the wrist extensor retinaculum and muscle fibers converged towards the top of the arc. R: retinaculum; E: extensor tendons.

Ultrasound and Intraoperative Findings of extensor Tendon Rupture

Ultrasound examination showed enhanced blood flow around the tendon injury, but no morphologic changes were observed in patients with an incomplete rupture of the extensor tendon. However, 3 types of characteristic changes was observed in patients with a complete rupture. First, the transverse ultrasound images showed that the number of tendons in the fourth compartment was reduced in patients with incomplete tendon rupture, while under normal circumstances there were 4 to 5 tendons in the fourth compartment. Second, the diameter of the tendons in the fourth compartment decreased, and the thinner structures were composed of incomplete ruptured tendons and residual tendon sheaths. Finally, sagittal ultrasound images showed that the cord-like structures of the tendons were interrupted in every patient with tendon rupture (see Figure 6).

During surgery, once the wrist extensor retinaculum and deep fascia were exposed it could be seen that the deep fascia fibers in front of the wrist extensor retinaculum were deranged, and the leading edge of the wrist extensor retinaculum was longer and slightly curled towards the dorsal side. After the deep fascia was incised, obvious tissue edema could be seen, with tendon debris and a lot of synovial fluid. The extensor tendons of the index, middle, and ring fingers had all been injured to varying degrees, and all the tendons had 2- to 3-cm abrasion lesions. The distal stump of the tendons was umbrella-like and relatively thick, while the proximal stump was taper-like and relatively thin. Both stumps were coarse. The worn area was below the wrist extensor retinaculum with the fingers and wrist in a slightly flexed position (see Figure 7A). The wrist extensor retinaculum became evenly thinner, and the inner surface became coarser. In 1 patient, after the wrist extensor retinaculum was incised, a smooth groove formed by friction from the tendons was found on the inner surface of the wrist extensor retinaculum (see Figure 7B).

Treatment Strategies and Outcomes

All patients were followed up every week. The 2 patients with an incomplete tendon rupture were treated conservatively, with the wrist joints immobilized. After 8 weeks, the symptoms were alleviated in both patients and the friction feeling disappeared, without wrist joint or finger dysfunction. In 5 patients who underwent incision of the wrist extensor retinaculum, a bowstring formed when the wrist joint was in dorsiflexion, and the tendons had severe adhesions to the

Figure 6. Comparison between wrist ultrasound images of patients with an extensor tendon rupture and healthy volunteers. A. The transverse ultrasound image of the fourth compartment in a healthy volunteer; B & C. The transverse ultrasound image of the fourth compartment of patient with an extensor tendon rupture; Comparing A with B, it could be seen that the number of tendons is reduced in patients; Comparing A with C, it could be observed that the diameter of tendons was thinner in patients; D. The sagittal ultrasound image of a patient with an extensor tendon rupture; E. The sagittal ultrasound image of the fourth compartment in a healthy volunteer; Comparing D and E, it could be seen that the cord-like structures of the tendons were interrupted in patients.

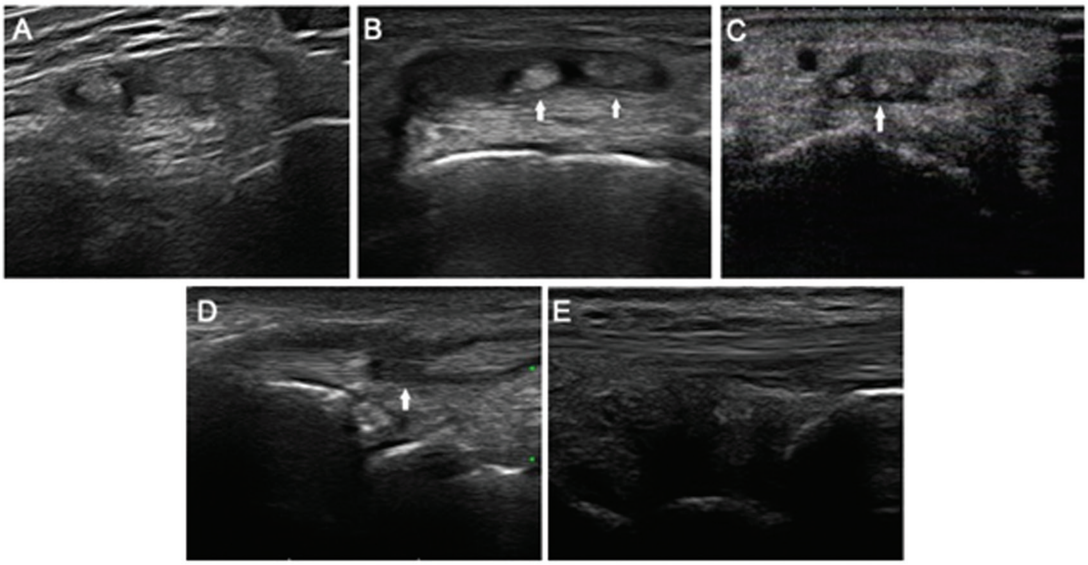
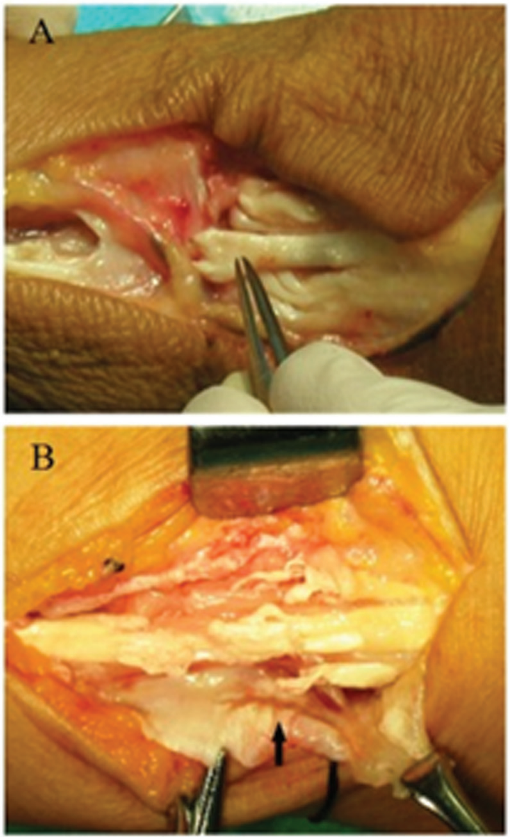


Figure 7. Intraoperative anatomical findings. A. Interruption of tendons; B. Abrasion of wrist extensor retinaculum.



surrounding soft tissues. In 4 patients who had undergone tendon transplantation with retention of the wrist extensor retinaculum, wrist flexion was restricted when clenching the fist and wrist extension was restricted when extending the fingers. According to the Standards for Function Evaluation after Hand Tendon Repair adopted by the Hand Surgery Society of the Chinese Medical Association,[19] the efficacy in all patients was excellent at 100%. No re-rupture occurred in any patients during follow-up.

DISCUSSION

Fatigue injury of the extensor tendon is rare. However, hundreds of cases of spontaneous rupture of the extensor tendons have been reported in China, mainly from Jilin and Heilongjiang Provinces.[11-14] All of the patients were rice farmers, and in most cases onset was observed in young and middle-aged people. The affected hands were the dominant hands. The injuries were mostly fatigue ruptures caused by rice transplantation.

Takami and colleagues[8] proposed that extensor tendon rupture occurs as a result of the tendon forming a sharp angle turn at the leading edge of the wrist extensor retinaculum, leading to mechanical wear of the tendon. Both Van Heest, et al. and Khazzam, et al. believe that there was impact between the extensor tendons and the wrist extensor retinaculum, and the force of the impact was the cause of the rupture at the wrist extensor retinaculum.[9,10,15,16] In this study, the results of histologic examination of the wrist extensor retinaculum revealed that the inner face of the wrist extensor retinaculum was abraded evenly, the synovial membrane on the surface of the wrist extensor retinaculum had disappeared, the internal coarse fibers were exposed and there was some fibrous debris. All these findings suggested that there was dry friction between the wrist extensor retinaculum and extensor tendons.

However, the ultrasound findings in 30 healthy volunteers demonstrated that during wrist dorsiflexion, the wrist extensor retinaculum forms a smooth trochlea with different morphologies at different dorsiflexion angles, and the rotation of the extensor tendons in the wrist is guided by the trochlea. The contact surface of the wrist extensor retinaculum and extensor tendons was smooth, and no sharp corners were found. Extensor tendons entered the wrist extensor retinaculum from the proximal end, rotated dorsally, completed the rotation as they passed through the trochlea formed by the wrist extensor retinaculum and came out the distal end to the dorsal side of the palm. Hence, there was no impact between the extensor tendon and the wrist extensor retinaculum. However, when the dorsiflexion angle increased, the length of the trochlea was shortened, and the width of the contact surface between the wrist extensor retinaculum and extensor tendons remained almost the same, leading to the shrinking of the contact surface between the wrist extensor retinaculum and the extensor tendon. Further, according to the mechanical model established by Moore[7,17,18] if the dorsiflexion angle increased with unchanged tendon tension, the pressure increased and thus frictional resistance increased. As a result, the gradually increasing frictional resistance was focused on the gradually shrinking contact surface—the risk factor for mechanical wear.

Histologic examination revealed the synovial membrane-synovial fluid-synovial membrane structure between the wrist extensor retinaculum and extensor tendons. Under normal circumstances the wrist extensor retinaculum and extensor tendons do not come into contact with each other. With this lubrication system, no severe abrasions occur, and the system is capable of self-healing. Nevertheless, in a clinical survey, patients with extensor tendon ruptures always complained that the soil in which they had been planting was hard. Furthermore, once a tendon ruptured, the other tendons would rupture within a very short time, because a conjoined tendon would increase the load on the other tendons. Therefore, it could be assumed that the strength of the force exerted on the tendons plays a key role in the development of extensor tendon rupture. With boundary lubrication, continuously working in relatively hard soil may lead to boundary lubrication failure, resulting in dry friction, which causes mechanical wear and structural damage of the wrist extensor retinaculum and extensor tendons. Once the structures were damaged, the synovial membrane on the surface of the wrist extensor retinaculum disappeared, the muscle fibers were exposed, the interface became coarser and mechanical wear was accelerated. Since the hardness of the extensor tendons is decreased compared with the wrist extensor retinaculum, the extensor tendons ruptured due to abrasion. That is why this injury occurs rapidly and involves all the extensors.

We conducted a broad evaluation of rice farmers and found that most patients had symptoms of swelling and pain without any movement disorders. Some patients had cysts in the fourth compartment of the wrist joint. However, patients were still able to work. In most patients, symptoms could be alleviated with rest, with no lasting dysfunction. In 2 patients, there was a feeling of friction when extending the fingers, but the patients had no physical signs of tendon rupture and ultrasound images confirmed no tendon rupture. Therefore, a diagnosis of incomplete rupture of the extensor tendons was made. After immobilization for 8 weeks, the symptoms were alleviated and the friction disappeared in both patients, and they could perform any movement except extension of the fingers and wrist. Of the patients, 9 with physical and ultrasound signs of tendon rupture were treated surgically. During postoperative follow-up, it was found that in patients whose wrist extensor retinaculum had been resected a bowstring formed in the extensor tendons and there were severe tissue adhesions in the early postoperative phase, but the movements of the fingers and wrist recovered satisfactorily in the long term. However, in patients whose wrist extensor retinaculum had been retained, movements of the fingers and wrist were significantly restricted. The ultrasound images of 30 healthy volunteers in this study revealed that during wrist dorsiflexion, the wrist extensor retinaculum formed a smooth trochlea with different morphologies at different dorsiflexion angles to guide the rotation of the extensor tendons at the wrist. The tendon sliding movements would be affected if the tendon anastomotic stoma was stuck at the wrist extensor retinaculum.[19] Hence, if a surgeon wishes to retain the wrist extensor retinaculum as much as possible during surgery, he/she should try their best to make create a smooth anastomotic stoma that is far away from the wrist extensor retinaculum.

CONCLUSION

In summary, we investigated the etiology of spontaneous injury of the extensor tendons in rice farmers by studying the ultrasound imaging findings in the wrists of healthy people during the process of wrist dorsiflexion and the intraoperative findings in surgeries for treatment of extensor tendon rupture. The causes of this disease could be described as follows. First, in wrist dorsiflexion, the contact surface of the extensor tendons and wrist extensor retinaculum shrinks, resulting in the concentration of stress. Second, the tendon load (namely, the strength of the force) influenced by the hardness of the soil is crucial in the progression of the disease. Third, the damage to the lubrication structures of synovial membrane-synovial fluid-synovial membrane and the explosion of coarse structures are the reasons the tendons rupture rapidly.

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