ORIGINAL ARTICLE

The diagnostic value of ultrasonography and magnetic resonance imaging in missed hand tendon injuries

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ABSTRACT

BACKGROUND: Patients with hand tendon injuries may present to the hand surgery clinic in the late stage after being examined in emergency departments. Even if an approximate idea has been obtained in physical examination of these patients, diagnostic imaging is usually requested for reconstructive approach, correct planning of surgical incisions and medicolegal reasons. The primary purpose of this study was to determine the overall accuracy of Ultrasonography (USG) and Magnetic Resonance Imaging (MRI) in patients with late presentation of a tendon injury.

METHODS: The surgical findings and imaging reports of 60 patients (32 females, 28 males) who underwent surgical exploration, late secondary tendon repair or reconstruction with a diagnosis of late-presenting tendon injury in our clinic were evaluated. Comparisons were made of 47 preoperative USG images (18-874 days) and 28 MRI (19-717 days) results for 39 extensor and 21 flexor tendon injuries. The imaging reports were interpreted as partial rupture, complete rupture, healed tendon and adhesion formation and these were compared with the surgical reports in terms of accuracy.

RESULTS: In extensor tendon injuries, the sensitivity and accuracy values were both 84% for USG and 44% and 47% for MRI, respectively. In flexor tendon injuries, the sensitivity and accuracy values were 100% for MRI and 50% and 53%, respectively, for USG. Of the 4 sensory nerve injuries, 4 were missed on USG and 1 on MRI. The results obtained with USG and MRI in the late-presenting patients in this study were lower than those reported in previous USG and MRI studies in the literature.

CONCLUSION: Scar formation with tendon healing causes a change in anatomy, which could prevent accurate evaluation. Therefore, it would be beneficial for surgeons to start evaluating their patients with easily accessible ultrasonography; thus, surgical morbidity should be reduced.

Keywords: Hand tendon injuries; late presentation; magnetic resonance; ultrasonography.

INTRODUCTION

Hand tendon injuries, in the form of lacerating wounds and penetrating injuries, are frequently encountered in the emergency department. Such injuries are considered severe, especially if they involve the flexor tendons. Tendon injuries may be overlooked when trauma patients undergo routine physical examination in emergency departments.[1] The most likely cause of overlooked hand injuries is the lack of a comprehensive clinical examination.[2]

It is known that some emergency department physicians try to perform primary repair with local infiltrative anesthesia in hand tendon injuries. However, these injuries should be carefully evaluated by hand surgeons and tendon surgery should be expertly managed. The surgical exploration method should be preferred in cases with suspicious clinical findings[3] and with imaging methods used complementary to

physical examination, aggressive surgical approaches can be prevented.[4] Plain radiographs and ultrasound (US) have now become the first-line examination in traumatic and non-traumatic tendon lesions because a detailed physical examination method that can detect partial tendon injuries has not been defined yet.[5] In X-ray imaging, bone structures and foreign bodies are evaluated by taking separate films of the hand and wrist. Ultrasound is considered a valuable tool in evaluating foreign bodies such as glass and splinter in soft tissue and detecting ruptured tendons, as it allows dynamic examination of the tendon.

Wu et al. found US to be more sensitive and specific than physical examination (97% vs. 86% accuracy) in detecting tendon injuries. However, that study had no statistical data on complete and partial tendon injuries.[6]

In addition to the advantage of lower cost, US has the feature of making comparisons with the unaffected hand and completing it with dynamic maneuvers.[7] With dynamic examination, the type and location of tendon tears, as well as postoperative adhesions around the tendon, are widely evaluated. When planning tendon repair and reconstruction surgery, it is essential to determine whether the tear is partial or full thickness, to know the demarcation line for the retracted tendon ends on the skin, to measure the gap between tendon ends and to draw the surgical incision areas.

Although magnetic resonance imaging (MRI) is very sensitive, it is not recommended for use in acute tendon injury in the United States of America (USA), as it is a highly expensive examination and accessibility may be limited.[8] However, MRI is the gold standard for differentiation between tendon rupture and adhesion in patients with reduced mobility after primary tendon surgery.[9,10]

The surgical plan for the treatment of flexor tendon injuries may change according to the timing of surgery. Primary repair is usually possible if performed within the first 24 hours. Repair performed in the first 7-10 days is known as delayed primary repair. When patients present after 2-3 weeks, primary repair is often not possible, and in these cases, staged reconstructions with tendon grafts are required.[9] Any delay in flexor tendon surgery is defined by Tang as a delayed primary repair that can be performed even 4 weeks after the injury.[11] In another study, a secondary surgical protocol is used when the patient presents 3 to 4 weeks after the initial injury or in cases where there is excessive tissue loss for which primary tendon repair would not be appropriate. Here, the type of injury, deterioration of tendon sheaths and adhesion formation are more important than elapsed time in deciding on secondary surgery.[12] In the current study, unoperated patients who presented more than 2 weeks after hand trauma and had limited hand movements were considered late stage patients.

Improper planning in secondary surgery can result in direct economic loss for the patient associated with treatment and sometimes job loss due to prolonged sick leave.[13] Thus, secondary surgery may cause unsatisfactory results for the patient.[14] In cases of missed tendon cut injuries, medicolegal problems are frequently encountered. Therefore, it has become inevitable that physical examination should be supported with imaging to prevent legal issues.

Most previous studies on the diagnostic examination of tendon injuries have been conducted on patients with an acute presentation at the emergency services.[3,6,15] As tendon reconstruction surgery is frequently performed in our clinic, there was a need to investigate the benefits of US and MRI as imaging modalities due to some unsatisfactory reports. The primary purpose of this study was to determine the overall accuracy of US and MRI in non-operated patients with missed tendon injuries.

MATERIALS AND METHODS

This is a retrospective study for missed and late-presented tendon injuries. The patients who received first aid in the Emergency Department after the injury and then presented at our clinic in the late stage with limited mobility between October 2019 and December 2020 were included. Patients who presented earlier than 2 weeks after the trauma and who did not proceed to surgery were excluded. Sixty patients (32 female, 28 male) were included.

The surgical reports were compared with the physical examination findings, US and MRI reports.

Tendon injuries were grouped as follows according to the available reports:[16,17]
• Partial rupture: <50% loss (fibre discontinuity) of tendon integrity, swelling around fibres
• Complete rupture: Complete gap between tendon ends filled with fluid or granulation tissue
• Healed tendon: Regular thickening and fibrillar continuity in the tendon
• Adhesion formation: Decreased movement of the tendon with fibrillar continuity of the surrounding tissues.

Stata MP13 (StataCorp. Stata Statistical Software: Release 13) was used for descriptive and inferential analyzes. The Shapiro-Wilk test was used to assess normality. Mean with standard deviation (std) along with the maximum and minimum values were used to present the metric data. Chi-square and Fisher exact tests were used for categorical variables. T-Test was performed to analyze the parametric data between groups. Mann Whitney U test was performed to analyze the non-parametric data between groups. A p-value less than 0.05 was accepted as significant.

The study was approved by the ethics committee of the Ankara City Hospital. (17th February 2021/E1-21-1553).

RESULTS

Sixty patients, 28 men and 32 women, were included in the study. The mean age was 37.97±14.23. There were 39 extensor and 21 flexor tendon injuries in the study group (Table 1). The true positive (TP) rate with US is statistically higher for the extensor tendon (84.38% vs. 40.00%, p=0.008). The TP rate with MRI was statistically higher for the flexor tendon (90.91% vs. 41.18%, p=0.013).

When the US findings of extensor tendon injuries were compared with the surgical findings, the accuracy was 84%. The MRI findings of flexor tendon injuries were reported with 100% accuracy compared to the surgical findings (Table 2). Results of the physical examination (PE) were not compared as these are the findings of a senior hand surgeon and do not represent the physical examination accuracy of the general orthopedic surgeon population.

The US and MRI results showed no significant difference between the groups according to the zones (p=0.680 for US,

p=0.420 for MRI). The MRI results also showed no difference according to surgical findings. On the other hand, US results are significant. For partial rupture and healed tendon, accuracy is 100% but the false negative ratio is high for complete rupture and adhesion formation (Table 3).

The TP rate for partial rupture is 100% with US. The false negative (FN) rate for complete rupture was determined to be statistically higher (27.03%). The MRI results showed no significant difference according to the percentages of surgical findings (p = 0.128) (Table 4).

The mean time was 80.36 days for US and 97.44 days for MRI. Time has no significant effect on the accuracy of the results for either US or MRI.

DISCUSSION

Tendon injuries in the hand can be easily missed during a routine physical examination in emergency departments,[1] and the most likely cause of overlooked hand injuries is the lack of a comprehensive clinical examination,[2] especially if the

Table 1. Demographics, zone distribution, and the results of physical exam (PE), ultrasonography (US) and magnetic resonance imaging (MRI) are given according the flexion and extension injuries.

		Total (n=60) (n, %)	Extensor tendon (n=39) (n, %)	Flexor tendon (n=21) (n, %)	P
Age		37.97 (14.23)	39.36 (13.41)	35.38 (15.65)	0.3058
Gender	Female	32 (53.33)	22 (68.75)	10 (31.25)	0.515
	Male	28 (46.67)	17 (60.71)	11 (39.29)	
Zone	1	9 (15.00)	3 (7.69)	6 (28.57)	0.000
	2	20 (33.33)	6 (15.38)	14 (66.67)	
	3	12 (20.00)	12 (30.77)	0	
	4	2 (3.33)	2 (5.13)	0	
	5	12 (20.00)	11 (28.21)	1 (4.76)	
	6	3 (5.00)	3 (7.69)	0	
	7	2 (3.33)	2 (5.13)	0	
PE	TP	51 (85.00)	35 (89.74)	16 (76.19)	0.317
	TN	1 (1.67)	0	1 (4.76)	
	FP	3 (5.00)	1 (2.56)	2 (9.52)	
	FN	5 (8.33)	3 (7.69)	2 (9.52)	
US	TP	33 (70.21)	27 (84.38)	6 (40.00)	0.008
	TN	2 (4.26)	0	2 (13.33)	
	FP	1 (2.13)	0	1 (6.67)	
	FN	11 (23.40)	5 (15.62)	6 (40.00)	
MRI	TP	17 (60.71)	7 (41.18)	10 (90.91)	0.013
	TN	2 (7.14)	1 (5.88)	1 (9.09)	
	FP	0	0	0	
	FN	9 (32.14)	9 (%52.94)	0	

TP: True positive, TN: True negative, FP: False positive, FN: False negative.

Table 2. The results of physical exam (PE), ultrasonography (US) and magnetic resonance imaging (MRI) are given and compared. The p values arefor the comparison between US and MRI.

		PE (n, %)	US (n, %)	MRI (n, %)	p
Total n=60	TP	51 (85.00)	33 (70.21)	17 (60.71)	
	TN	1 (1.67)	2 (4.26)	2 (7.14)	
	FP	3 (5.00)	1 (2.13)	0	0.0705
	FN	5 (8.33)	11 (23.40)	9 (32.14)	
	PPV	0.94	0.97	1.00	
	NPV	0.17	0.15	0.18	
	Sensitivity	0.91	0.75	0.65	
	Specificity	0.25	0.67	1.00	
	Accuracy	0.87	0.74	0.68	
Extension n=39	TP	35 (89.74)	27 (84.38)	7 (41.18)	
	TN	0	0	1 (5.88)	
	FP	1 (2.56)	0	0	0.0067
	FN	3 (7.69)	5 (15.62)	9 (52.94)	
	PPV	0.97	1.00	1.00	
	NPV	0.00	0.00	0.1	
	Sensitivity	0.92	0.84	0.44	
	Specificity	0.00	-	1.00	
	Accuracy	0.90	0.84	0.47	
Flexion n=21	TP	16 (76.19)	6 (40.00)	10 (90.91)	
	TN	1 (4.76)	2 (13.33)	1 (9.09)	
	FP	2 (9.52)	1 (6.67)	0	0.2142
	FN	2 (9.52)	6 (40.00)	0	
	PPV	0.89	0.86	1.00	
	NPV	0.33	0.25	1.00	
	Sensitivity	0.89	0.50	1.00	
	Specificity	0.33	0.67	1.00	
	Accuracy	0.81	0.53	1.00	

TP: True positive, TN: True negative, FP: False positive, FN: False negative.

Table 3. The results of ultrasonography (US) and magnetic resonance imaging (MRI) are given and compared according to the injury zones.

ZONE	TP (n, %)	TN (n, %)	FP	FN (n, %)	p	TP (n, %)	TN (n, %)	FP	FN (n, %)	p
1	5 (60.50)	0	0	3 (37.50)		3 (75.00)	0	0	1 (25.00)	
2	6 (42.86)	2 (14.29)	1	5 (35.71)		7 (70.00)	1 (10.00)	0	2 (24.00)	
3	8 (88.89)	0	(7.14)	1 (11.11)		1 (16.67)	1 (16.67)	0	4 (66.67)	
4	2 (100)	0	0	0	0.680	0	0	0	0	0.420
5	9 (90.00)	0	0	1 (10.00)		5 (83.33)	0	0	1 (16.67)	
6	2 (100)	0	0	0		1 (100)	0	0	0	
7	1 (50.00)	0	0	1 (50.00)		0	0	0	1 (100)	

TP: True positive, TN: True negative, FP: False positive, FN: False negatvie.

Table 4. The results of ultrasonography (US) and magnetic resonance imaging (MRI) are given and compared according to surgical findings.

OP	US					MRI				
	TP	TN (n, %)	FP (n, %)	FN	p	TP (n, %)	TN (n, %)	FP	FN (n, %)	p
Partial rupture	6 (100.0)	0	0	0		4 (80.00)	0	0	1 (20.00)	
Complete rupture	26 (70.27)	0	1 (2.70)	10 (27.03)		12 (57.14)	1 (4.76)	0	8 (38.10)	
Healed tendon	1 (100.0)	0	0	0	0.000	0	0	0	0	0.128
Adhesion formation	0	2 (66.67)	0	1 (33.33)		1 (50.00)	1 (50.00)	0	0	

TP: True positive, TN: True negative, FP: False positive, FN: False negative.

examining physician lacks experience and knowledge of the complex anatomy and functionality of the hand. Early diagnosis and treatment rely on a good physical examination, which can guide surgical planning.

Knowing the retracted tendon ends, regardless of the incision level, is important for surgical planning in patients presenting with adhesions in the late stage. However, in cases of late presentation, non-compliant patients and children, imaging becomes more crucial as a physical examination of the hand requires good patient cooperation. In emeregency situation, children, multiple trauma patients and those with alcohol or drug intoxication may not be able to comply with physical examination. Moreover, the patient's response to the clinical examination may be confused with emotional stress or pain.[2] Missed tendon injuries can occur when either the patient or the initial examining physician fails to appreciate subtle findings. Partial tendon lacerations should always be suspected when the patient has significant full range of motion on physical examination, but experiences pain with resisted force. The consequences of missed cases include delayed tearing, scarring with tendon adhesions, triggering and weakness.[18] Missed finger extensor mechanism injuries may occur because the broad expanse of the extensor mechanism can initially maintain posture until softening from the healing process allows the remnants of support to give way.[19] Mistakes made in the physical examination of the extensor tendon can be related to the sagittal band and intertendinous connections; a complete rupture of the tendon should be suspected. Missed finger flexor tendon injuries are much less common than extensor tendon injuries due to a change in the resting position of the hand. Isolated superficial tendon injury with an intact profundus tendon produces a slight change in finger posture and is easily overlooked.[19]

Deep tendon avulsion injuries are often underappreciated by patients, who may believe that their finger is simply "stuck", leading to a delay in seeking medical evaluation until the best window for treatment has passed.[20] A common error in examining flexor tendons is the inability to distinguish between adhesion and rupture in the injured flexor tendon during delayed presentation. Missed dorsal hand extensor tendon

injuries can occur due to movement of adjacent tendinous ligaments or if only one of the two tendons (proprius and communis) is severed, resulting in little initial functional deficit in the index or little fingers.[21] Therefore, relying solely on examination without exploring the penetrating wound can lead to disappointing results.

While US is cheap and easily accessible, it is operator-dependent. However, MRI is considered the gold standard imaging method for hand tendon injuries due to its soft tissue contrast and high resolution.[10] Zhang et al.[15] investigated the value of ultrasonography in zone 2 flexor tendon injuries. Surgical repair was applied to one group based on ultrasound findings and to the other group based on physical examination.[15] The types of tendon injuries, and precise location of the distal end of the ruptured tendon were found to be 100% compatible with the preoperative US and surgical findings.[15] In a study by Abdellatif et al.,[22] the MRI results of complete flexor tendon injuries of the hand were compared with surgical results and MRI detected the location of the tendon tear with 100% accuracy in traumatic cases.[22]

Table 5. The timing of ultrasonography (US) and magnetic resonance imaging (MRI) are given with the results.

	US timing (days) Ort (std) Min-Max	p	MRI timing (days) Ort (std) Min-Max	p
Total	80.36 (141.43) 14-874		97.44 (130.22) 15-575	
TP	81.58 (163.80) 14-874		104.18 (146.39) 15-575	
TN	89 (.) 89-89	0.3661	22 (.) 22-22	0.3556
FP	20 (.) 20-20		–	
FN	85.70 (86.56) 18-302		126.56 (135.93) 19-365	

TP: True positive, TN: True negative, FP: False positive, FN: False negative.

In our study, the false negative reporting rate of US in the flexor region and MRI in the extensor region was significantly high. The main reason for false reports is the inability to distinguish between partial and complete injuries with imaging. Sometimes a partial rupture was reported as complete and a complete rupture as a partial rupture. The reason for this may be the insufficient resolution of ultrasound, as well as the difference in signal intensities of the tissues in MRI in such a delayed period. Swen et al. compared US with MRI in a study examining partial extensor tendon rupture in patients with rheumatoid arthritis.[17] Although ultrasonography seemed slightly better in evaluating partial extensor injury than MRI, it was not found to be sensitive enough to be used in daily practice.[17] A similar result was found in the current study, as the difficulties in examining the tendon of a patient with inflammatory arthritis are similar to those of evaluating a healed partially ruptured tendon.

In extensor tendon healing, chronic lesions are typically surrounded by hypoechoic areas with fibrosis and adhesions, where the ruptured tendon has healed with some elongation and fibrosis. Therefore, extensor lag occurs on physical examination. Lengthening of the tendon after the gap has filled with fibrotic tissue is the most important reason for false negative reporting.[23]

Contradictions with surgical findings increase when imaging is performed long after the injury in our study. When the injured tendon begins to heal, difficulties in imaging arise.[24] In the flexor tendon, adhesions to the other tendon in the same sheath and adhesions to the sheath itself pose serious problems.[25] In such cases, the ultrasound operator must have good knowledge of the anatomy and be able to perform a dynamic evaluation.

Unfortunately, this study did not achieve satisfactory results in imaging the nerves close to the tendons. Of the four sensory nerve injuries, four were missed on US and one on MRI. It is known from the literature that ultrasound, along with clinical examination and electromyography (EMG), is of great diagnostic value in nerve injuries that accompany tendon cuts.[26] Even the electrical pain caused by pressing the injured nerve trunk with the probe, also known as the sonographic Tinel sign, should arouse suspicion in the operator.[27] Therefore, radiologists should simultaneously examine the patient with a US probe as a clinician would.[28]

The question arises as to whether physical examination alone can be relied upon when imaging results are not good in the late stage. In a study by Wu et al., bedside ultrasonography was found to be more sensitive and specific than physical examination alone in detecting tendon injuries presenting at the emergency department.[6] In this study, a 7.5 to 10 MHz linear array transducer was used, similar to ours.[6] High-frequency transducers are known to be safer in demonstrating superficial body structures in the musculoskeletal system, especially in the hand and wrist.[29] Moreover, ultrasonography is less costly and time-consuming than wound exploration and MRI.[6]

False reports may lead to unnecessary surgery and surgical trauma from the unnecessary incisions resulting in soft tissue can make the existing problem more complex. Ravnic et al. reported that even surgeons without ultrasound imaging training could accurately identify the proximal tendon ends with ultrasonography, thereby reducing surgical morbidity.[3] Unnecessary incisions for exploration cause surgical trauma and scar formation around the tendon, which negatively affects the functional outcome.[3]

This study had several limitations. It is a single-center retrospective study with 60 cases. The second limitation is that US evaluation is operator-dependent and the patients in this study were evaluated by different radiologists, although all were experts in the field. A prospective randomized study with a single experienced radiologist would provide better information on this issue.

A major weakness of the study is that an 11MHz probe is not suitable for exploring the hand's tendons and higher frequency probes are usually used for tendons. Another weakness was that we only had 15 patients with both preoperative US and MRI examinations. More valuable inferences could have been obtained if all patients had preoperative US and MRI examinations.

To date, no detailed study has been conducted on the accuracy of delayed imaging. This study aimed to reveal the extent to which imaging is satisfactory in delayed cases.

Conclusion

In conclusion, neither US nor MRI provides results in late-presenting tendon injuries as reliable as in the acute stage. Although MRI evaluation and operative results are considered the gold standard in the literature, it can be considered that as hand surgeons gain experience with US, progress can be made regarding cost and patient benefit especially for non-compliant patients and children.

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Atlanmış el tendon yaralanmalarında ultrasonografi ve manyetik rezonans görüntülemenin tanısal değeri

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AMAÇ: El tendon yaralanması olan hastalar, acil servislerde muayene edildikten sonra geç dönemde el cerrahisi kliniğine başvurabilirler. Bu hastalarda fizik muayenede yaklaşık bir fikir elde edilmiş olsa bile, rekonstrüktif yaklaşım ve cerrahi kesilerin doğru planlanması ve medikolegal nedenler için genellikle tanısal görüntüleme istenir. Bu çalışmanın birincil amacı, geç başvuran tendon yaralanmasının olan hastalarda USG (Ultrasonografi) ve MRG'nin (Manyetik rezonans görüntüleme) genel doğruluğunu belirlemektir.

GEREÇ VE YÖNTEM: Kliniğimizde geç dönem tendon yaralanması tanısı ile cerrahi eksplorasyon, geç sekonder tendon onarımı veya rekonstrüksiyon uygulanan 60 hastanın (32 kadın, 28 erkek) cerrahi bulguları ve görüntüleme raporları değerlendirildi. 39 ekstansör ve 21 fleksör tendon yaralanması için ameliyat öncesi 47 USG (18-874 gün) ve 28 MRG (19-717 gün) sonucu karşılaştırıldı. Görüntüleme raporları kısmi rüptür, tam rüptür, iyileşmiş tendon ve adezyon oluşumu olarak yorumlandı ve cerrahi raporlarla doğruluk açısından karşılaştırıldı.

BULGULAR: Ekstansör tendon yaralanmalarında USG için duyarlılık ve doğruluk değerleri %84, MRG için %44 ve %47 idi. Fleksör tendon yaralanmalarında MRG için duyarlılık ve doğruluk değerleri %100 ve USG için sırasıyla %50 ve %53 idi. 4 duyusal sinir yaralanmasından 4'ü USG'de ve 1'i MRI'da gözden kaçmıştır. Bu çalışmada geç başvuran hastalarda USG ve MRG ile elde edilen sonuçlar, literatürde daha önce USG ve MRG çalışmalarında bildirilenlerden daha düşüktür.

TARTIŞMA: Tendon iyileşmesi ile birlikte skar oluşumu anatomide değişikliğe neden olmakta ve bu da doğru değerlendirmeyi engelleyebilmektedir. Bu nedenle cerrahların hastalarını kolay ulaşılabilen ultrasonografi ile değerlendirmeye başlamaları faydalı olacak ve cerrahi morbidite azalacaktır.

Anahtar sözcükler: Ultrasonografi; manyetik rezonans; el tendon yaralanmaları; geç başvuru.