Ultrasonographic Evaluation of Zone II Flexor Tendon Lacerations and Repairs: A Cadaveric Study

Kristin Buterbaugh, MD[1]
Joshua Gordon, MD[1]
Nikolas Kazmers, MD[2]
Viviane Khoury, MD[3]
David Bozentka, MD[1]
David Steinberg, MD[1]

[1]University of Pennsylvania
Department of Orthopedic Surgery

[2]University of Utah
Department of Orthopaedics

[3]University of Pennsylvania
Department of Radiology

Introduction

Identifying zone II flexor tendon lacerations is a clinical challenge. Based upon thresholds described in the literature, the percentage of tendon laceration may influence whether surgical repair versus observation is recommended.[1] Flexor tendon lacerations involving greater than 50% of the tendon are thought to have improved outcomes with surgical repair.[2] Lacerations involving less than 50% typically undergo a trial of nonoperative management. Some controversy exists regarding the cutoff at which surgical repair is indicated.[3,4,5]

Accurately determining the percentage of tendon laceration involvement is difficult short of an exploratory operation, which may ultimately reveal a laceration that does not require repair. Validation of a noninvasive test that accurately characterizes partial lacerations may improve clinical decision making by avoiding unnecessary surgery or missed near-complete ruptures. Ultrasound is a potential candidate for this purpose, however validation studies are lacking. In a focused cadaveric pilot study, our team explored the use of ultrasound to evaluate the extent of partial zone II flexor tendon lacerations of non-thumb digits.

Materials and Methods

This study was performed in the Human Tissue Lab of the Department of Orthopaedic Surgery at the University of Pennsylvania. Non-thumb digits were prepared in eight fresh-frozen below-elbow cadaveric specimens. 32 flexor tendons were randomized into three groups: no laceration, low grade laceration (10-40% tendon laceration), and high grade laceration (60-90% tendon laceration).

The flexor digitorum profundus was exposed between A3 and A4 pulleys through midlateral incisions. A flap was raised as a single soft tissue sleeve to avoid air within the tissue planes. Tendons were randomly selected to remain intact, receive low-grade or high-grade lacerations. Partial lacerations were randomly assigned to the radial or ulnar aspects of the tendon, and the intended segment was measured with digital calipers. A keith needle was placed based on caliper measurement to mark the exact extent to which the tendon should be lacerated. Lacerations were carried out sharply with a knife in the transverse plane. Static and dynamic ultrasound were performed on each specimen with a linear-array 14 MHz transducer by a blinded fellowship-trained musculoskeletal radiologist. Actual values and ultrasound measurements of the percentage of tendon laceration were compared using the paired t-test. Sensitivities and specificities were calculated.

Results

Our study found that ultrasound was accurate in identifying and characterizing clinically relevant high-grade zone II flexor digitorum profundus partial lacerations as evaluated by a single fellowship-trained musculoskeletal radiologist. It was inaccurate in detecting and characterizing the extent of low-grade partial lacerations.

For high-grade lacerations, sensitivity and specificity were 0.83 and 0.85, with positive likelihood ratio and negative likelihood ratio values of 5.56 and 0.20, respectively. When considering lacerations accurately diagnosed as low- or high-grade, the percentage of tendon involvement was underestimated by ultrasound for low-grade lacerations (absolute difference -14.1%, $p = 0.03$), but no different than actual values for high-grade lacerations (-6.7%, $p = 0.22$). For lacerations that were detected, ultrasound correctly identified the side of laceration in 100% of specimens. Three (25%) of high-grade tears were misdiagnosed as low-grade. These results are summarized in Tables 1 and 2.

Discussion

Ultrasound provides a viable alternative for the evaluation of partial flexor tendon lacerations, with accuracy for clinically-pertinent high-grade lacerations that are likely to require repair. Validation of a noninvasive, fast, reliable test that accurately identifies partial lacerations may reduce the need for exploratory surgery in flexor tendon injuries. Ultrasound is dynamic, inexpensive, and readily available to hand surgeons and emergency departments, making it particularly attractive.

Other work has evaluated the use of ultrasound in the diagnosis of complete extensor tendon transection,[6] trigger finger diagnosis,[7]

Table 1. Summary of anatomic and ultrasonoi,ranbic data

Ultrasound Imaging Findings	Surgically-Created Laceration (Gold Standard)			
	Intact	Low-Grade Partial Laceration	High-Grade Partial Laceration	Total
Intact	6	9	2	17
Low-grade Partial Laceration	2	3	3	8
High-Grade Partial Laceration	0	0	7	7
Total:	8	12	12	32

Table 2. Ultrasound Test Characteristics by Laceration Type

Test Characteristic	Laceration Type	
	Low-Grade	High-Grade
Sensitivity	0.25	0.83
Specificity	0.85	0.85
LR+	1.67	5.56
LR-	0.88	0.20
PPV	0.50	0.77
NPV	0.65	0.89

Abbreviations: LR - likelihood ratio, NPV - negative predictive value, PPV - positive predictive value

tendon excursion,[8,9] and the presence of flexor tendon injury.[10,11] Despite these advances, complete characterization of the ability of ultrasound to differentiate partial flexor tendon lacerations is lacking. Only one study performed by Zhang *et al*. evaluated the efficacy of ultrasound in diagnosing flexor tendon lacerations in the hands of a single experienced ultrasonographer.[15] However, it does not systematically validate the ability of ultrasound to measure the extent of lacerations.

Conclusions

Our findings support the optimal use of ultrasound, ideally decreasing the number of unnecessary surgical explorations or missed high grade partial lacerations. It helps characterize the potential clinical use of this imaging modality and elucidates the limitations of ultrasound in evaluating low-grade partial flexor tendon lacerations. These results provide hand surgeons and radiologists with clinically-important data not currently in the literature. Future directions include introducing a second fellowship-trained musculoskeletal radiologist ultrasonographer to further validate inter and intra observer reliability.

References

1. McCarthy DM, Boardman ND, Tramaglini DM, Sotereanos DG, Herndon JH. Clinical management of partially lacerated digital flexor tendons: a survey [corrected] of hand surgeons. *J Hand Surg Am.* 1995 Mar;20(2):273-5.

2. Haddad R, Scherman P, Peltz T, Nicklin S, Walsh WR. A biomechanical assessment of repair versus nonrepair of sheep flexor tendons lacerated to 75 percent. *J Hand Surg Am.* 2010 Apr;35(4):546-51.

3. al-Qattan MM. Conservative management of zone II partial flexor tendon lacerations greater than half the width of the tendon. *J Hand Surg Am.* 2000 Nov;25(6):1118-21.

4. Balk ML, Sotereanos DG. Partial flexor digitorum profundus lacerations. *Oper Tech Orthop* [Internet]. Elsevier; 1998 Apr 4 [cited 2015 Aug 31];8(2):67–72.

5. Okano T, Hidaka N, Nakamura H. Partial laceration of the flexor tendon as an unusual cause of trigger finger. *J Plast Surg Hand Surg.* 2011 Sep;45(4-5):248-51.

6. Kim HR, Lee SH. Ultrasonographic assessment of clinically diagnosed trigger fingers. *Rheumatol Int.* 2010 Sep;30(11):1455-8.

7. Tat J, Kociolek AM, Keir PJ. Validation of color Doppler sonography for evaluating relative displacement between the flexor tendon and subsynovial connective tissue. *J Ultrasound Med.* 2015 Apr;34(4):679-87.

8. Korstanje JW, Schreuders TR, van der Sijde J, Hovius SE, Bosch JG, Selles RW. Ultrasonographic assessment of long finger tendon excursion in zone v during passive and active tendon gliding exercises. *J Hand Surg Am.* 2010 Apr;35(4):559-65.

9. Wu TS, Roque PJ, Green J, Drachman D, Khor KN, Rosenberg M, *et al.* Bedside ultrasound evaluation of tendon injuries. *Am J Emerg Med.* 2012 Oct;30(8):1617-21.

10. Soubeyrand M, Biau D, Jomaah N, Pradel C, Dumontier C, Nourissat G. Penetrating volar injuries of the hand: diagnostic accuracy of US in depicting soft-tissue lesions. *Radiology.* 2008 Oct;249(1):228-35.

11. Zhang GY, Zhuang HY, Wang LX. Value of high frequency ultrasonography in diagnosis and surgical repair of traumatic finger tendon ruptures. *Med Princ Pract.* 2012;21(5):472-5.