



# Semi-dynamic MRI of climbing-associated injuries of the finger

Frank Schellhammer<sup>1</sup> · Andreas Vantorre<sup>2</sup>

Received: 8 November 2018 / Revised: 11 March 2019 / Accepted: 1 April 2019 / Published online: 29 April 2019  
© ISS 2019

## Abstract

**Objective** Injuries of the flexor–tendon–pulley system are common in rock climbers. The status of the A3 pulley ligament is crucial for grading such injuries. As standard MRI may miss lesions of the A3 pulley ligament, we introduce a semi-dynamic MRI sequence.

**Materials and methods** Twenty-two fingers (14 volunteers, 3 injured climbers) were scanned using a sagittal T1 turbo spin echo sequence (repetition time: 400 ms, echo time: 14 ms, slice thickness: 5 mm) in six consecutive finger positions from stretched to maximum possible flexion.

**Results** No pulley lesion was found in volunteers. Bowstringing was detected in 3 injured fingers including the A3 pulley.

**Conclusion** Semi-dynamic MRI is an technique that is easy to perform to identify injuries of the A3 pulley ligament that were not seen on standard imaging.

**Keywords** Rock climbing · Flexor–tendon–pulley system · MRI

## Introduction

With the mushrooming of climbing facilities, especially in major cities, injuries of the flexor–tendon–pulley system of the fingers are becoming much more frequent [1, 2]. Each finger has eight functional pulleys. Five annular pulleys (A1A5) are strong, focal thickenings of the flexor tendon sheath and of functional importance, whereas the cruciate pulleys (C1–C3) are of major importance to the intrinsic strength of the flexor tendon sheath. In general, rock-climbing-associated injuries affect the A2 pulley, which tears from distal to proximal [3, 4]. MRI has been proven to be a strong tool in identifying direct and indirect signs of ruptured pulley tendons [5]. Grading of such lesions is crucial for the indication of operative treatment [6, 7]. However, in our experience it is still

challenging to identify A3 pulley lesions on MRI with stretched fingers. Therefore, we established a semi-dynamic T1 sequence to evaluate the tenophalangeal distance during non-forced flexion of the finger [8].

## Materials and methods

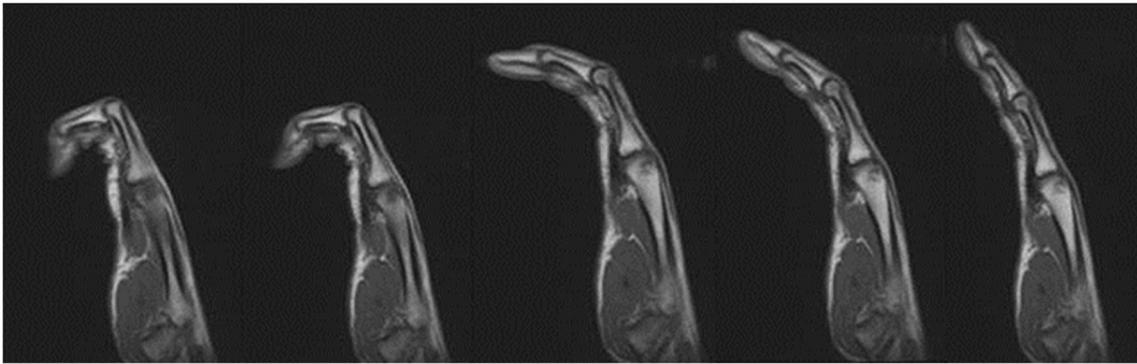
Using a 1.5-T MR scanner (Aera; Siemens, Erlangen, Germany) 14 volunteers (9 men and 5 women) and 3 male climbers with clinical findings of lesions of the flexor–tendon–pulley system were scanned. In prone position, one hand was placed vertical up in a knee coil. Following a standard protocol, a sagittal T1 TSE sequence (repetition time: 400 ms, echo time: 14 ms, slice thickness: 5 mm) was performed in 6 consecutive, non-forced finger positions from stretched to maximum possible flexion (Fig. 1). These positions were on an individual basis and trained before the examination. Imaging of each position took 20 s with a 5-s interval to change position.

Identifiability of the flexor–tendon was evaluated by a 5-point visual scale (0 = poor to 5 = perfect). The tenophalangeal distance was measured at the middle of the proximal phalanx by a PACS-integrated measurement tool. Measurements and evaluations were done independently by one experienced musculoskeletal radiologist

✉ Frank Schellhammer  
fschellhammer@severinskloesterchen.de

<sup>1</sup> Diagnostic and Interventional Radiology, Krankenhaus der Augustinerinnen Köln, Jakobstrasse 27–31, 50678 Cologne, Germany

<sup>2</sup> Network of Sports Medicine in Rock Climbing, Dietrichstrasse 18, 60439 Frankfurt, Germany



**Fig. 1** Sagittal T1-weighted MRI in six different positions of digit III displaying no increase in the tenophalangeal distance during flexion

**Table 1** Results of a visual, five-step evaluation scale for the identifiability of the flexor tendon (0 = none to 4 = perfect)

Flexion	None					Maximum
Identifiability of the flexor tendon ( $\pm$ SD)	$3 \pm 1$	$3.1 \pm 0.7$	$2.9 \pm 0.8$	$3.2 \pm 0.9$	$2.7 \pm 1.1$	$1.8 \pm 1.5$

(FS) and one certified sports scientist (AV). No ultrasound was performed.

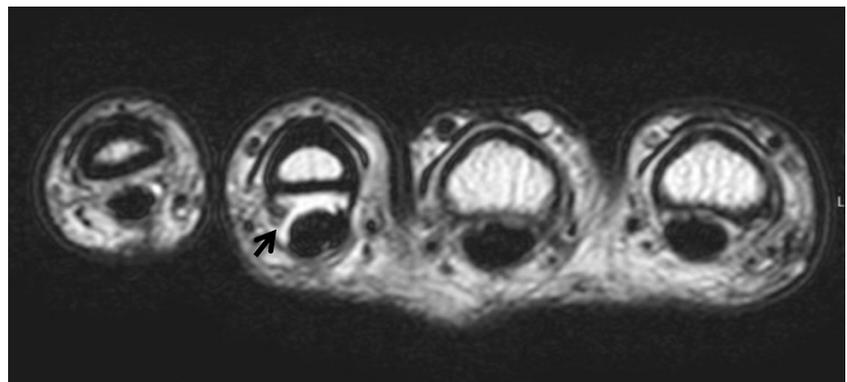
## Results

Twenty-two fingers were evaluated (digit II:  $n = 12$ , digit III:  $n = 8$ , digit IV:  $n = 1$ , digit V:  $n = 1$ ). No pulley lesion was found in scanned volunteers. In each injured finger, we found bowstringing, including the A2 to A4 pulley ligaments ( $n = 3$ ).

In general, identifiability of the flexor tendon was good. The assessment decreased by 1.2 points with progressing flexion (Table 1). The additional twist of the fingers during flexion brings the flexor tendon out of the center of the MR slice selected.

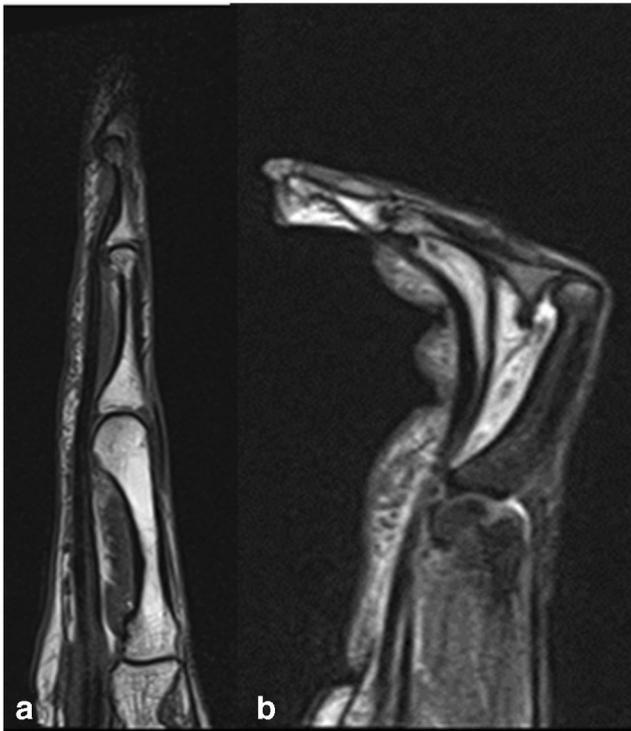
The tenophalangeal distance was 2 mm in volunteers irrespective of the position of their finger. In the case of bowstringing, the tenophalangeal distance increased up to 8 mm.

**Fig. 2** Coronal T1-weighted MRI from the standard protocol shows discontinuity of the medial A2 pulley ligament digit IV (arrow) with tilting of the flexor tendon toward the ruptured side and hematoma in the tenophalangeal space



## Discussion

Patients with pulley injuries report a sudden onset of pain following a slip or forceful maneuver. Frequently, an audible pop may be heard. Discontinuity of the pulley tendon, hematoma between the phalanx and flexor tendon, in addition to tilting of the flexor tendon toward the ruptured side, are all typical signs of lesions of the flexor–tendon–pulley system on MRI (Fig. 2) [9, 10]. However, detection of lesions of the A3 pulley is still challenging. Although there is a tendency toward conservative treatment, the status of the A3 pulley is of major importance for grading and indicating surgery. According to the clinical condition of bowstringing in complete rupture of the flexor–tendon system, the gap between the flexor tendon and the adjacent phalanx should be exaggerated in ruptured pulley ligaments during flexion on MRI. Non-forced flexion of the fingers is a well-tolerated technique in contrast to forced flexion against a firm surface, which might be painful. In our experience, the sagittal T1-TSE sequence



**Fig. 3** Sagittal T1-weighted MRI demonstrating **b** a complex lesion of the flexor tendon pulley system including rupture of the A3 pulley ligament. This was not seen on **a** standard imaging of the stretched finger

used has proved to be a quite robust sequence, which enables us to discriminate the tenophalangeal distance [10].

Owing to the small number of pathological conditions, we have not yet been able to prove a correlation between the extent of a pulley ligament lesion and the expected increase in the tenophalangeal distance. In our study, bowstringing enabled us to define complex lesions of the pulley system in three finger injuries, although standard MRI showed an inconspicuous A3 pulley (Fig. 3). Dynamic ultrasound, which is sensitive for A2 und A4 pulley lesions, might be an alternative [11]. However, it is an operator-dependent technique, the degree of flexion is limited, and it has low sensitivity for associated osseous injuries.

In contrast to the literature, which is predominantly based on ultrasound, our measurements of the tenophalangeal distance in this study were explicitly higher in non-injured volunteers [12]. It is likely that MRI overestimates the tenophalangeal distance. However, it is important to know that the tenophalangeal distance does not change during flexion of non-injured fingers.

## Conclusion

Semi-dynamic MRI is a technique that is easy to perform to identify injuries of the A3 pulley ligament not seen on standard imaging. However, further studies are needed to clarify whether this technique modifies the approach to treatment.

## Compliance with ethical standards

**Conflicts of interest** The authors declare that they have no conflicts of interest.

## References

1. Rohrbough JT, Mudge MK, Schilling RC. Overuse injuries in the elite rock climber. *Med Sci Sports Exerc.* 2000;32(8):1369–72.
2. Crowley TP. The flexor tendon pulley system and rock climbing. *J Hand Microsurg.* 2012;4(1):25–9.
3. Tan MA, Fuss FK, Niegl G. Biomechanics of finger pulleys during climbing. In: Moritz E, Haake S (Eds.) *The engineering of sport 6*, vol 2. New York: Springer; 2006. p. 241–6
4. Schellhammer F, Schwarz T, Boberg A, Riel KA, Vantorre A. Injuries of the finger in rock climber. *Insights Imaging.* 2017;8(Suppl 1):S358.
5. Clavero JA, Alomar X, Monill JM, Esplugas M, Golanó P, Mendoza M, et al. MR imaging of ligament and tendon injuries of the fingers. *Radiographics.* 2002;22(2):237–56.
6. Schöffl VR, Schöffl I. Injuries to the finger flexor pulley system in rock climbers: current concepts. *J Hand Surg Am.* 2006;31:647–54.
7. Bouyer M, Forli A, Semere A, Chedal Bornu BJ, Corcella D, Moutet F. Recovery of rock climbing performance after surgical reconstruction of finger pulleys. *J Hand Surg Eur Vol.* 2016;41(4):406–12.
8. Schellhammer F, Miekley M, Chwilka W, Vantorre A. Dynamic MRI of the finger: evaluation of two different MR-sequences. *Semin Musculoskelet Radiol.* 2018;22(S 01):S1–5.
9. Gupta P, Lenchik L, Wuertzer SD, Pacholke DA. High-resolution 3-T MRI of the fingers: review of anatomy and common tendon and ligament injuries. *AJR Am J Roentgenol.* 2015;204(3):W314–23.
10. Hoff MN, Greenberg TD. MRI sport-specific pulley imaging. *Skeletal Radiol.* 2018;47(7):989–92.
11. Klauser A, Frauscher F, Bodner G, Halpern EJ, Schocke MF, Springer P, et al. Finger pulley injuries in extreme rock climbers: depiction with dynamic US. *Radiology.* 2002;222:755–61.
12. Hauger O, Chung C, Lektrakul N, Botte MJ, Trudell D, Boutin RD, et al. Pulley system in the fingers: normal anatomy and simulated lesions in cadavers at MR-imaging, CT and US with and without contrast material distention of the tendon sheath. *Radiology.* 2000;217(1):201–12.

**Publisher's note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.