

Declaration of conflicting interests The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

- Balram A, Hsu A, Rapp T, Mehta V, Bindra R. Large solitary glomus tumor of the wrist involving the radial artery. *Am J Orthop (Belle Mead NJ)*. 2014, 43: 567–70.
- Carroll RE, Berman AT. Glomus tumors of the hand: review of the literature and report on twenty-eight cases. *J Bone Joint Surg Am*. 1972, 54: 691–703.
- Heys SD, Brittenden J, Atkinson P, Eremin O. Glomus tumour: an analysis of 43 patients and review of the literature. *Br J Surg*. 1992, 79: 345–7.

Rohit Singh*, Geeta Karpoor and Adrian Chojnowski

Norfolk Norwich University Hospital,
Norwich, UK

*Corresponding author: rohitamolsingh@hotmail.com

© The Author(s) 2018

Article reuse guidelines:

sagepub.com/journals-permissions

doi: 10.1177/1753193418766839 available online at <http://jhs.sagepub.com>

Alterations to wrist tendon forces following flexor carpi radialis or ulnaris sacrifice: a cadaveric simulator study

Dear Sir,

Loss of function of flexor carpi radialis (FCR) or flexor carpi ulnaris (FCU) may result from laceration of the tendon, high median or ulnar nerve injury (Isaacs and Ugwu-Oju, 2016), and, in the case of FCR, use of the tendon for stabilization of the trapeziometacarpal or intercarpal joints. The effects of loss of these flexors have not been evaluated biomechanically. The aim of this study was to understand the importance of the wrist flexors using a physiological wrist simulator, and to observe alterations in wrist tendon forces in the absence of the FCR and FCU.

Nine fresh-frozen cadaveric specimens were used. All soft tissue was resected 5 cm proximal to the wrist, except six muscles, FCR, FCU, extensor carpi radialis longus, extensor carpi radialis brevis (ECRB), extensor carpi ulnaris and abductor pollicis longus (APL), which were dissected at their musculotendinous junctions. Specimens were mounted on a validated physiological wrist simulator (Shah et al., 2017). Motion at the wrist was recreated using linear actuators by applying tensile loads via steel

cables sutured to the tendons of the six muscles. Load cells monitored tendon forces, while an eight-camera optical motion capture system was used to obtain the joint angles, through clusters of retro-reflective markers fixed to the third metacarpal and the radius. A control strategy, which drove joint kinematics while simultaneously ensuring muscle forces remained within physiological bounds (Shah and Kedgley, 2016), was employed to replicate active wrist motions in real-time. The absence of FCR and FCU were individually simulated in nine and eight specimens, respectively, by switching off the corresponding actuator during the entire range of motion. In the absence of FCR, multiple cycles of 50° flexion–30° extension (FE) and radioulnar deviation (RUD) (15° ulnar to 15° radial) were simulated. In the absence of FCU, complex motions were also simulated, including dart-throwing motion (20° extension with 15° radial deviation to 20° flexion with 15° ulnar deviation), and clockwise (CCD_{cw}) and anticlockwise (CCD_{acw}) circumduction (combining 30° in FE with 10° RUD) (Shah et al., 2017). Muscle forces were evaluated as a function of joint kinematics, at every 10° in FE and 5° in RUD. Wilcoxon-signed rank tests were performed to identify significant differences in muscle forces with and without FCR and FCU ($p < 0.05$).

In the absence of FCR, the forces of ECRB and extensor carpi ulnaris were significantly lower throughout FE and RUD, while the APL force was higher throughout FE and radial deviation (Figure 1). The sum of all muscle forces was lower in the absence of FCR throughout FE and RUD, with the decrement being greater than the FCR force in intact specimens. In the absence of the FCU, the ECRB force was significantly lower throughout all motions, while the FCR force was higher from maximum extension to neutral in FE, for ulnar deviation greater than 10° in RUD and dart-throwing motion, and throughout CCD_{cw} and CCD_{acw}, except between maximum radial deviation and maximum flexion.

Higher synergist forces observed in the absence of FCR or FCU, especially at joint angles where the force of the intact flexor was high, indicated that the remaining flexors tried to compensate for the loss of FCR or FCU. However, lower antagonist forces for a majority of the range of motion indicated a decrease in co-contraction of the wrist muscles in the absence of FCR or FCU. This finding was reinforced by the lower sum of all muscle forces throughout the ranges of motion in the absence of FCR. The resultant reduction in wrist joint reaction force could contribute to joint weakness. Moreover, while higher forces in synergists could result in muscle strain, fatigue, pain and reduced range of motion, a large reduction in individual muscle forces, like ECRB, could lead to

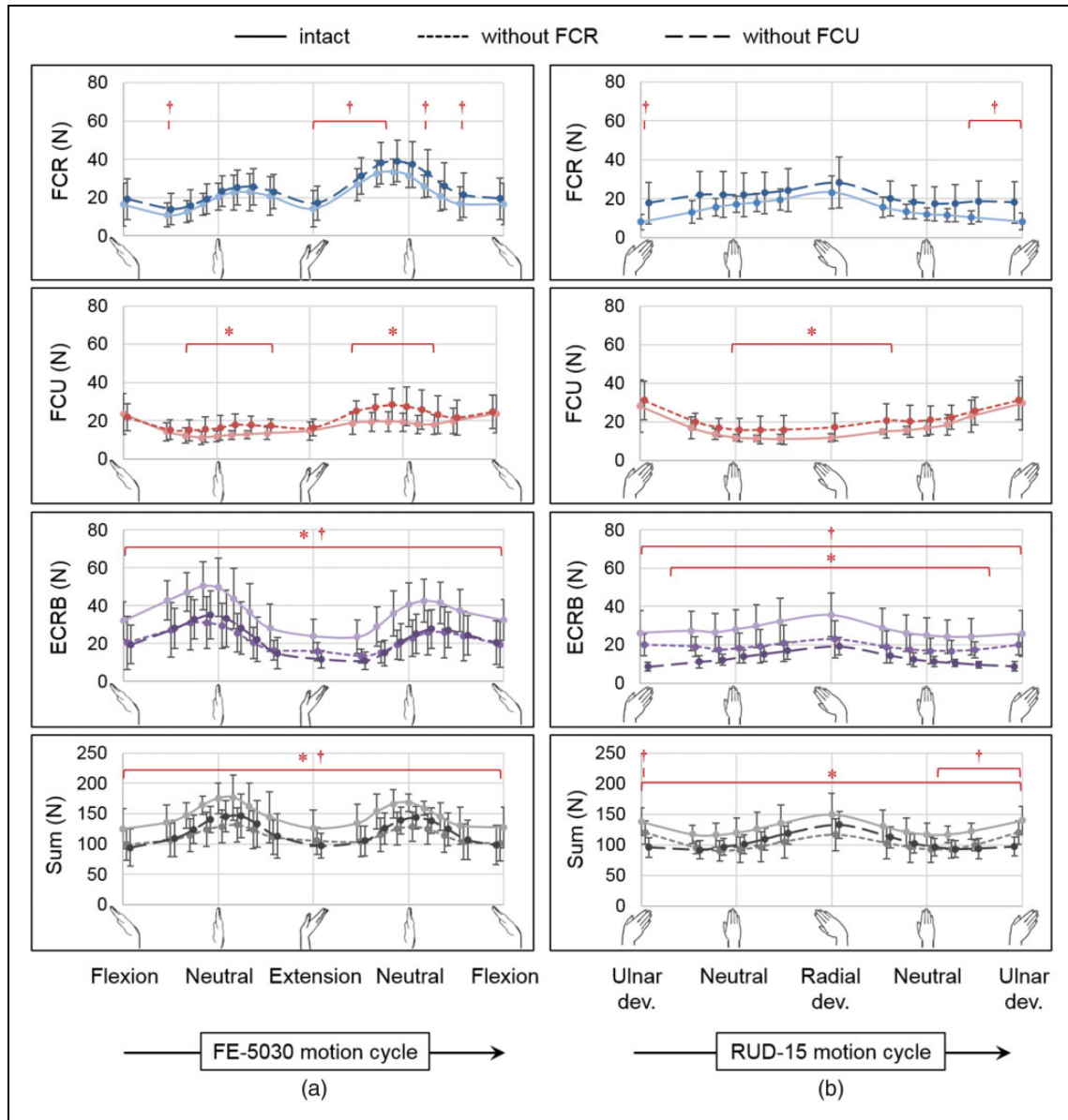


Figure 1. Muscle forces (mean \pm standard deviation) for FCR, FCU, ECRB and the sum of all forces, in (a) flexion-extension (FE-5030) and (b) radioulnar deviation (RUD-15) for the intact case (solid line), in the absence of FCR (dotted) and FCU (dashed). The asterisk (*) indicates statistically significant differences between the intact and the FCR-absent groups, while the dagger (†) indicates statistically significant differences between the intact and the FCU-absent groups ($p < 0.05$).

disuse atrophy of the muscle in vivo, as has also been reported in tendon transfers (Castle and Reyman, 1984). These alterations in tendon forces could be important after harvest of FCR for reconstructions, or for tendon transfers employing already weakened donor muscles.

The replication of wrist motions in vitro using only six tendons was a limitation of this study. These tendons were selected since they insert at the base of the metacarpals, thereby primarily

affecting the wrist. All muscles contributing to wrist torque, including the extrinsic muscles of the fingers and the thumb, will be considered for future experiments.

In conclusion, the absence of a muscle resulted in a rise in the synergistic forces, with a simultaneous decrease in the antagonistic forces, which was greater than the synergistic force increase. Thus, during any reconstructive procedure that utilizes a tendon, there is likely to be an alteration in the

forces exerted by other wrist muscles, the implications of which should be considered during rehabilitation, and in the assessment of ultimate range of motion and functional ability.

Declaration of conflicting interest The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: this work was supported by The Royal Society [RG130400] and Arthritis Research UK [20556].

Ethics statement Ethical approval for the use of these specimens was obtained from the Tissue Management Committee of the Imperial College Healthcare Tissue Bank, according to the Human Tissue Act.

References

- Castle ME, Reyman TA. The effect of tenotomy and tendon transfers on muscle-fiber types in the dog. *Clin Orth Rel Res.* 1984, 186: 302–10.
- Isaacs J, Ugwu-Oju O. High median nerve injuries. *Hand Clin.* 2016, 32: 339–48.
- Shah DS, Kedgley AE. Control of a wrist joint motion simulator: a phantom study. *J Biomech.* 2016, 49: 3061–8.
- Shah DS, Middleton C, Gurdezi S, Horwitz MD, Kedgley AE. The effects of wrist motion and hand orientation on muscle forces: a physiologic wrist simulator study. *J Biomech.* 2017, 60: 232–7.

**Darshan S. Shah¹, Claire Middleton²,
Sabahat Gurdezi², Maxim D. Horwitz²
and Angela E. Kedgley^{1,*}**

¹Department of Bioengineering, Imperial College London, London, UK

²Department of Hand Surgery, Chelsea and Westminster Hospital, London, UK

*Corresponding author: akedgley@imperial.ac.uk

© The Author(s) 2018
Article reuse guidelines:



sagepub.com/journals-permissions

doi: 10.1177/1753193418783176 available online at <http://jhs.sagepub.com>

Temporary tourniquet use after epinephrine injection to expedite wide awake emergency hand surgeries

Dear Sir,

Injection of epinephrine with local anaesthesia is now used for many hand surgical procedures, including

those in an emergency setting (Gong and Xing, 2017; Lalonde, 2017). However, in emergency settings, a lot of the injuries are open ones, which ideally should be treated as soon as possible. Elective wide-awake hand surgeries usually begin 20–30 minutes after injecting local anaesthetic (Lalonde, 2017), which is not ideal for open hand trauma with active bleeding.

The optimum vasoconstrictive effect of epinephrine, when mixed with local anaesthetic, takes 25–30 minutes to develop (Bashir et al., 2015; McKee et al., 2015). This delay is at best irksome, but at worst, may encourage procedures to start under sub-optimal conditions. Most awake patients will tolerate an arm tourniquet for 10–15 minutes without major discomfort. Therefore, to save time and improve efficiency, we recommend using a temporary tourniquet to begin hand surgery under local anaesthesia. The tourniquet can be released when the patient starts to find it uncomfortable, by which time the vasoconstrictive effect of the epinephrine should be established.

For 58 patients who we treated as an emergency basis, we applied the tourniquet immediately after injection of local anaesthesia with epinephrine with attention to some technical points (Table 1). We then prepared the surgical field and began debridement and repair, which usually started about 5 minutes after injection. The tourniquet was applied for 5–10 minutes. Our patients typically could tolerate the tourniquet for 5–10 minutes without sedation. After 10 minutes, patients started complaining of discomfort in the arm. At that time, we released the tourniquet. Because about 10 minutes had passed since the epinephrine injection, the bleeding was remarkably decreased. The diminished bleeding allowed us to confirm the sufficiency of debridement of non-viable tissues and to start repairing the soft tissues or fixing phalangeal or metacarpal fractures with Kirschner wires.

Following tourniquet release, we immediately performed compression haemostasia for about 1 minute, because at this moment reperfusion of the vessels transiently neutralizes the vasoconstriction of epinephrine. After about 1 minute of compression, the haemostatic effect of epinephrine was effective.

In patients who are extremely intolerant to tourniquet, surgeons may release the tourniquet sooner. However, in our experience, all the patients tolerated temporary use of tourniquet for at least 5 minutes. The discomfort accelerated only after about 10 minutes. Releasing the tourniquet within 10 minutes causes no major discomfort for most wide-awake patients, but it speeds up the surgery and allows better