A Novel Technique For The Quantification Of Active Tendon Forces: Application To The Subscapularis Tendon

Methods
Subjects. Following a cadaveric study, ethical approval was obtained for insertion and retrieval of AIFPs from the rotator cuff as previously described [1]. This was extended to include further patients and in situ calibration of the AIFP. Informed consent was given. Exclusion criteria were applied, including pathology of the subscapularis tendon. This resulted in per-operative abandonment of one subject.

Protocol. The experimental technique was initially tested using a cadaveric model. Preoperatively, the subject’s myometer reading at maximum subscapularis contraction, resisted internal rotation with the arm at the side and the elbow flexed to 90°, was obtained [2].

Subjects were anaesthetised using a combination of general anaesthetic and Inter-scalene block. Following diagnostic arthroscopy an arm at the side and the elbow flexed to 90°, was obtained [2]. Maximum subscapularis contraction, resisted internal rotation with the tendon fibres, then tension on the tendon will result in deflection of the AIFP and an increase in voltage.

An arthroscopic grabber (Tissue Tensioner - Smith and Nephew) was modified to allow the insertion of a load cell in a slot at the handle of the grabber. A load cell was made using foil strain gauges to measure the deflection of a beam in one direction. A handle was fixed to this deflection beam, to allow rotation out of the plane of force application, to minimise torsion on the beam. This load cell and handle could be inserted in an arthroscopic surgery sleeve prior to fixing in the handle of the arthroscopic grabber.

The AIFP was connected and zeroed. Using the antero-superior portal, the modified arthroscopic grabber was inserted and the subscapularis tendon clamped on one side of the AIFP. The load cell was inserted in the arthroscopic grabber handle through an arthroscopy sleeve. A load was applied to the tendon by manual application of force at the load cell handle only. Simultaneously the readings from the strain gauge amplifier, and the AIFP were recorded. This was repeated for different levels of force and provided a calibration curve for actual force on the tendon with AIFP output. The AIFP remained in situ and the load cell was removed. Postoperatively, the AIFP was kept in the tendon while the patient recovered motor control. When the myometer reading of maximum contraction at internal rotation reached 50% of pre-anaesthesia levels the patient’s arm was manipulated passively from full external rotation to full internal rotation at full adduction. The patient was then asked to repeat this movement actively. Different levels of contraction were measured using the myometer up to the maximum internal rotation. At all stages the output from the AIFP in the subscapularis tendon was recorded. On completion of the measurements, the AIFP was removed by pulling a removal suture that fixed to the device.

Results
The load cell calibration was linear with an r² value of 1.00. Force in the subscapularis tendon for two subjects is presented in Figure 1.

Discussion
To our knowledge this is the first time a force probe has been successfully calibrated for the measurement of in vivo active tendon forces. There are many applications for such a technique outside the rotator cuff, including soft tissue reconstruction of the knee, the Achilles tendon and spinal ligaments.

Limitations of the study include potential alteration of AIFP position during retrieval, because the output of the device did not significantly change for a large internal rotation force. During retrieval of this AIFP the removal suture snapped, leaving the probe in the inferior recess. This was removed with a second arthroscopy.

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References