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Differential movement of the median nerve and biceps brachii at the elbow in human cadavers

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A R T I C L E I N F O

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A B S T R A C T

Background: It is important to establish if mechanical testing for physical problems in the human is specific or non-specific for structures - e.g. muscle and nerve. The median nerve at the wrist can be moved in preference to its adjacent flexor digitorum longus muscle, but it is necessary to know if this specificity extends to the elbow. We therefore measured mechanical behaviour of the median nerve at the elbow compared to its adjacent muscle - biceps brachii.

Methods: This cross-sectional study on nine fresh frozen cadaver upper limbs used differential variable reluctance transducers and Vernier callipers to measure strain and excursion in the median nerve and biceps brachii during cervical contralateral lateral flexion in glenohumeral abduction: 0°, 30°, 60° and 90°.

Findings: Proximal excursion and strain with contralateral lateral flexion occurred in the median nerve primarily at 60° and 90° abduction ($p < 0.05$), but no changes occurred in the muscle ($p > 0.05$).

Interpretation: This study provides evidence of emphasising load to peripheral nerve over biceps at the elbow during cervical contralateral lateral flexion.

1. Introduction

A key question in mechanical testing for clinical physical diagnosis is whether specific structures – e.g. muscle and nerve – can be moved differently or not (Butler, 2000; Coppieters et al., 2003; Herrington et al., 2008; Shacklock, 1995; Shacklock, 2005). Differential movement is desirable for specificity purposes because this would allow diagnosis to focus on which structure contains dysfunction or impairment through provocative testing in the patient. If the nerve and muscle can only be moved similarly, testing would be non-specific. However, if they can be moved differentially, testing would be specific and make targeted treatment more possible.

Studies have measured excursion and strain of the median nerve at the wrist with cervical movements (Brochwicz et al., 2013; Coppieters et al., 2009; McLellan and Swash, 1976; Wright et al., 1996), where the nerve moved proximally but the adjacent muscle (flexor digitorum longus) did not. Hence, the effect at the wrist is specific (Bueno-Gracia et al., 2020). It is now necessary to know if this specificity extends to the elbow because currently there are no data on this.

Therefore, we aimed to investigate the capacity of cervical contralateral lateral flexion to move differentially the median nerve at the elbow, as opposed to its adjacent biceps brachii muscle, with the purpose of establishing if differential diagnosis through specific physical testing may be possible.

In an upper limb position that elongates the entire median nerve tract to the cervical nerve roots (glenohumeral abduction/elbow extension), we used cervical contralateral lateral flexion to tension and move the median nerve proximally and measure mechanical behaviour of biceps brachii muscle.

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2. Methods

2.1. Study design

This was a cross-sectional study in fresh frozen cadavers in which differential variable reluctance transducers (DVRTs) were applied to fresh-frozen cadavers to measure the effect of contralateral lateral flexion on the strain and excursion of the median nerve and biceps brachii muscle at the elbow. Body donations were made to the institutional university anatomy laboratory and the institutional ethics committee approved the present study (CBAS-2018-07-4).

2.2. Cadaver specimens

Specimens were excluded if they showed less than 90° shoulder abduction, 90° shoulder external rotation, full elbow extension or 60° wrist extension (Byl et al., 2002). One of the specimens was excluded because there was evidence of surgical scars in one upper limb, however, even though that limb was excluded, we still used the opposite limb. We used 9 upper extremities from 5 cadavers (3 males and 2 females, aged 69–78 years). After storing the cadavers at 3 °C and bringing them to room temperature, a skin flap (10 × 8 cm) was cut at the distal part of the anterior arm to expose the median nerve and distal end of the biceps brachii. The subcutaneous tissues were kept intact so as not to intrude on the nerve and muscle (Fig. 1). In order to prevent drying, the data were collected data immediately after dissection.

2.3. Strain and excursion measurement

We measured strain and excursion of the median nerve and the biceps brachii at the proximal elbow.

2.4. Strain

Two DVRTs (Microstrain, Burlington, VT, USA) with a stroke length of 6 mm and resolution of 1.5 μm were inserted (with barbed pins) between 4 and 6 cm proximal to the medial condyle of the humerus, one each into the nerve and muscle (Fig. 1). Calibrations of voltage output into length measurements were made according to the manufacturer's specifications. We recorded changes in the relative strain because transducer position could influence the strain values: strain = [(end length − start length)/start length] × 100.

2.5. Excursion

A reference marker (metal screw) was inserted into the anterior aspect of the medial condyle and we measured longitudinal excursion with a digitial Vernier caliper as the distance between the screw and the distal barb of each DVRT (nerve and muscle (Vernier Digital, GOCHANGE IP54 150 mm/6in).

We calculated reliability of strain and excursion in a pilot trial in two additional upper extremities.

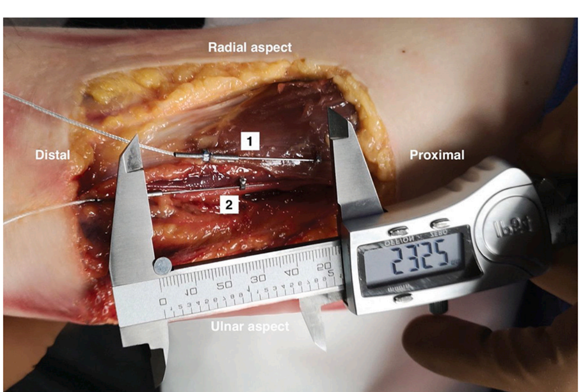

Fig. 1. Dissected right upper limb at elbow showing the position of the strain gauges: (1) biceps brachii muscle, (2) median nerve. Orientation: left - distal; right - proximal; up – radial; down – ulnar.

2.6. Movements

With the specimen in supine and the neck in the neutral position, one examiner placed the upper limb in: 0° shoulder abduction and external rotation in the horizontal plane, full elbow extension, full forearm supination and full wrist extension. The shoulder was then placed at 0°, 30°, 60° and 90° glenohumeral (shoulder) abduction. Each abduction angle was deemed a different starting position and median nerve strain in each of these positions was assigned as 0% strain. We randomized the sequences for these four positions using an online software (https://www.random.org).

We used a universal goniometer and applied standard goniometry guidelines (Norkin and White, 1995) to measure shoulder abduction and contralateral lateral flexion. Another examiner moved the cervical spine into maximal contralateral lateral flexion - determined by strong resistance and an inability to go further, perceived by this examiner.

Strain and excursion were measured at the shoulder abduction angles above (0°, 30°, 60° and 90°) and we blinded the examiner who performed the contralateral lateral flexion to the: output from the strain gauges, excursion readings, and effects of the manoeuvre on the nerve and muscle.

2.7. Statistical analysis

To determine absolute reliability, we calculated the intra-class correlation coefficient (ICC) model (3,1) with a two-way mixed model and absolute agreement type at a 95% confidence interval (CI). The standard error of measurement (SEM) and the minimum detectable difference (MDD) were also calculated for the strain and excursion of the median nerve and biceps brachii in the pilot trial - interpretation of ICCs: 0.00 to 0.25 = little to no relationship, 0.26 to 0.50 = fair degree of relationship, 0.51 to 0.75 = moderate to good relationship, and 0.76 to 1.00 = good to excellent (Portney and Watkins, 1993).

The mean strain and excursion of the median nerve and biceps brachii associated with contralateral lateral flexion were calculated at: 0°, 30°, 60° and 90° shoulder abduction. Normal distribution of the sample was analysed using the Shapiro-Wilk test ($p > 0.05$). Due to the limited amount of data, differences in the strain and excursion at 0°, 30°, 60° and 90° of shoulder abduction between the median nerve and the biceps brachii was calculated using Mann-Whitney U test. A p value <0.05 was considered significant and we processed the raw data with SPSS Statistics Version 22.0.

3. Results

In the pilot trial, there was excellent reliability for median nerve strain and excursion. Standard error of measurement and MDD at 95% confidence interval were small (Table 1). We did not calculate the ICC (1,3) for the muscle because the variation in strain and excursion in biceps brachii before and after the neck movement was zero. The mean angle for lateral flexion over all tests was 37°. No correlation was found between range of cervical movement and the amount of nerve strain or excursion.

3.1. Strain

The mean median nerve strain increased with contralateral lateral flexion at all shoulder abduction angles: greatest at 60° (3.36% ± 2.17%); 90° (1.86% ± 2.78%). Neck movement did not affect the strain in biceps brachii in any shoulder position (Table 2). The MDD was

Table 1
Reliability of strain and excursion measurements for median nerve at different angles of elbow flexion.

	Elbow flexion degrees	ICC(1,3)	SEM	MDD
Strain (%)	0°	0.92	0.63	1.75
	30°	0.87	0.78	2.15
	60°	0.88	0.75	2.08
	90°	0.97	0.48	1.33
Excursion (mm)	0°	0.98	0.30	0.84
	30°	0.98	0.33	0.92
	60°	0.98	0.32	0.89
	90°	0.97	0.30	0.82

$ICC_{(1,\ 3)}$: Intra-class correlation coefficient; SEM: Standard error of measurement; MDD: Minimum detectable difference.

Table 2
Strain and excursion change for the median nerve and biceps brachii during contralateral lateral flexion at different degrees of elbow flexion.

		0°	30°	60°	90°
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Strain (%)	Nerve	0.91 (2.23)	1.87 (2.16)	3.36 (2.17)	1.86 (2.78)
	Muscle	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
p-value		<0.043	<0.008	<0.012	<0.068
Excursion (mm)	Nerve	2.11 (2.15)	3.11 (2.34)	4.08 (2.28)	3.92 (1.71)
	Muscle	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
p-value		<0.018	<0.012	<0.008	<0.008

SD: Standard Deviation.

higher than the differences in strain at 0° and 30° abduction so we did not consider the nerve strain in those elbow positions to be relevant.

3.2. Excursion

The median nerve displaced proximally in all shoulder positions with the greatest at 60° abduction (mean 4.08 ± 2.28 mm). No changes in biceps brachii excursion occurred in any position.

4. Discussion

Cervical contralateral lateral flexion produced differential (specific) movement in the median nerve at the proximal elbow - mostly at 60° abduction and less at 90°. Biceps brachii was not affected so this supports using the neck this way to differentially move - or at least emphasize - the median nerve at the elbow.

For nerve strain, the data from studies on the effect of neck and shoulder movement on the median nerve vary from 0.3% to 9.1% (Brochwicz et al., 2013; Wright et al., 1996), for which there may be several explanations: 1. location of measurement (wrist versus elbow), 2. ultrasound was sometimes used and this is an indirect measurement, 3. living subjects and cadavers may differ viscoelastically, 4. differences in limb position and movement technique. In placing our study in context, our strain values fell inside other studies so our data are consistent with general principles of nerve and muscle biomechanics and what other groups have found.

For proximal excursion, no studies have analysed the effect of neck and shoulder movement on the nerve near the elbow but we found it to be greater than the MDD at all angles of shoulder abduction (2.11 mm–4.08 mm) and greatest again at 60°. Our data on excursion are also in keeping with other studies: 2.3 mm to 3.4 mm in the forearm (Brochwicz et al., 2013) and upper arm (Coppieters et al., 2009; McLellan and Swash, 1976). Abduction (90° to 110°) produces 4.7 mm mean at the elbow in cadavers (Wright et al., 1996) and 5.2 mm and 3.4 at the distal arm and middle forearm in living subjects (Dilley et al., 2003), respectively. As expected, we found less nerve excursion with distance from the neck.

Even though strain and excursion did not differ greatly between 0°, 30° and 60° shoulder abduction, it was maximum at 60°. This may have been because this angle was sufficient to impart forces between the neck and the elbow, but the capacity of the nerve to dissipate tension was not fully absorbed compared to higher ranges of shoulder abduction.

Generalisability of our study to the clinical setting is limited by: sample size, the fact that cadavers were used (not conscious for reporting of subjective responses), and there was no study of other mechanisms: contractile or connective tissue (e.g. fascia).

Our data give support for specificity with gross structures – nerve and muscle - but more study is needed at a finer level - mesoneurium and epimysium - to ascertain at what level of analysis specificity remains or deteriorates.

5. Conclusion

Cervical contralateral lateral flexion resulted in significant excursion and strain in the median nerve at the elbow in the shoulder-abducted position (60°–90°), but biceps brachii did not move. These results offer preliminary support for using this neck and arm manoeuvre to move the nerve and muscle differentially, which in the future may aid diagnosis of various elbow problems.

Financial disclosure and conflict of interest

The authors of the manuscript affirm that they have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript, except as disclosed in an attachment and cited in the manuscript. Any other conflict of interest (i.e., personal associations or involvement as a director, officer, or expert witness) is also disclosed in an attachment.

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