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Research Article

How Long is Your Clavicle? A Prospective Cadaveric Study Comparing the Validity of Ultra- sound and Manual Measurement of Clavicle Length

Bagouri E*, Paul Mccormack, Sheba Basheer and Manjit S Bhamra

Pinderfields General Hospital, The Mid-Yorkshire Hospitals, NHS Trust, Wakfield, United Kingdom

***Corresponding Author:** Bagouri E, Pinderfields General Hospital, The Mid-Yorkshire Hospitals, NHS Trust, Wakfield, United Kingdom.

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Abstract

Introduction: The rising trend of operative fixation of clavicles has raised questions about the clinical effects of shortening and the best methods to measure it. Most surgeons rely on X-rays or clinical examination however Furey., et al. have reported poor correlation between x-rays and CT findings.

Aim: The aim of this study is to test the validity of ultrasound as a quick and non-invasive measurement method in comparison to traditional manual measurements of clavicle length.

Methods: Nineteen cadavers (38 clavicles) were identified for potential inclusion in this study. Data was collected prospectively by two investigators using a standardised technique, the sterno-clavicular and acromio-clavicular joints were identified manually, marked and the lengths of the clavicles were measured using a metal ruler. Next, the markings were erased and the measurements were repeated following the same protocol after identification of the joints using ultrasonography (US). Finally, following dissection, the clavicles were re-measured under direct vision.

Results: We obtained Manual, US aided and direct measurements were taken from 35 clavicles (18 cadavers) using the described technique. Only paired results, either manual or US-aided with a corresponding direct clavicle measurement, were used for comparative analysis. Median clavicle length in all groups was 140 mm (ranges: Manual 130-165, US-aided 110-165, Direct 130-150). Statistical analysis was conducted using parametric tests (GraphPad Software, Inc. CA). We defined statistical significance as a p-value of 0.05 or less. Using a paired t-test, manual measurement (with palpation of adjacent joints) when compared to measurement under direct vision yielded a two tailed p-value of 0.0011, suggesting a very significant difference in the paired measurements. However, US-aided measurement when compared to direct measurement demonstrated no significant difference between the paired measurements (two-tailed p-value = 0.2001).

Conclusion: This study demonstrates that US-aided measurement of clavicle length may be more accurate than traditional manual measurement using palpation of clavicle length. Ultrasound has the benefit of being safe, non-invasive and involves no exposure of the patient to ionizing radiation. This study was conducted in cadavers with the associated limitations. Further study is required to validate these findings in vivo.

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Keywords: Fractures; DMCF; Clavicle Length

Introduction

Fractures of the clavicle are very common, making up 2.6% of all fractures [1]. Of these, 80% are estimated to occur in the middle third of the bone [1,2]. For decades, most displaced midshaft clavicle fractures (DMCF) were treated non-operatively that was supported by the outcomes of large series reporting high union rates [3]. However, since the turn of the century there has been an increasing trend towards operative fixation. This remains a topic of much debate.

A large multi-centre level 1 study has demonstrated a higher rate of non-union and malunion in nonoperatively managed patients [4], with apparently superior outcomes yielded by operative fixation. These included higher patient satisfaction, earlier return to work and better pain relief. However, surgical intervention has its own reported risks, for example as infection, cosmetic effects of the scar and, rarely, injury to the lung, brachial plexus or vascular structures. There is an increased incidence of secondary operative intervention due to hardware irritation resulting in removal. Clearly the risk of malunion but also of exposing patients to unnecessary surgery should be minimized. In order for this to be possible, clarification regarding the indications for operative fixation is required [4].

One major factor to consider in the management of DMCF has been the degree of displacement and specifically the degree of clavicular shortening. Numerous papers have aimed to quantify this, with most suggesting that shortening of 1.5 – 2 cm or more correlates to high incidence of symptomatic mal-union or non-union (reference). Thus, significant shortening is now generally accepted as an indication to consider fixation.

However, there remains a paucity of evidence on suitable measurement techniques to calculate clavicular shortening. Commonly, plain radiography has been used. Manual measurement based on palpated landmarks and comparison to the contralateral side, if uninjured, is another option [13]. Unfortunately, radiographs of the clavicle are rarely calibrated and thus are unlikely to permit accurate measurement of the degree of shortening. This is evidenced by the findings of Archer., *et al*. who reported poor correlation of radiographic measurements compared with those gained via computerised tomography (CT) [8].

It is clear that agreement on an accurate, non-invasive, quick, safe and preferably low cost method of measuring clavicular length would be of benefit in the assessment of shortening in DMCFs. It may also provide an important tool for use in future study design. This cadaveric study set out to investigate the potential of ultrasound as a measurement tool and compare its accuracy to manually estimated measurement of clavicle length.

Methodology

Was obtained for this study as well as.

Nineteen cadavers (38 clavicles) from a local university anatomy school were identified for potential inclusion in this study. Data was collected prospectively by two investigators usinga standardised technique. Both investigators are higher specialty trainees in Trauma and Orthopaedic Surgery with no previous formal radiology training.

The sterno-clavicular and acromio-clavicular joints were identified manually by palpation andmarked with a straight line drawn along both joint lines using an easily erasable marker. Thelength of the clavicle was then measured using a metal ruler, measuring the straight line between the middle of the two joint lines.

Next, the markings were erased and measurements were repeated using the same standard protocol, but after marking the joint lines using an ultrasound machine. The same machine was used for the entire study.

Finally, the clavicles were dissected out so they could be measured directly. This was done by medical students within the university within their upper limb anatomy term. The direct clavicle measurements were thus obtained four weeks after the initial measurements, following the same measurement protocol but after directly visualising the relevant joints.

Data was added manually to a spread sheet and statistical analysis was conducted usingparametric tests (GraphPad Software, Inc. CA).

Results

Manual (palpated), US guided and direct clavicular measurements were taken from 35 clavicles (18 cadavers) using the described technique. Three clavicles could not be assessed with the ultrasound probe due to fixed lateral flexion of the cadaver's head preventing adequate space. Only paired results, either manual or US-guided with a corresponding direct clavicle measurement, were used for comparative analysis.

Median clavicle length in all groups was 140mm (ranges: Manual 130-165, US-aided110-165, Direct 130-150).

Statistical analysis was conducted using parametric tests (GraphPad Software, Inc. CA). Statistical significance was defined

by a p-value of ≤ 0.05). Using a paired t-test, manual measurement (with palpation of clavicle length) when compared to measurement under direct vision yielded a two tailed p-value of 0.0011, suggesting a very significant difference in the paired measurements.

However, US-guided measurement when compared to direct measurement demonstrated nosignificant difference between the paired measurements (two-tailed p-value = 0.2001).

Linear regression analysis also demonstrated a stronger correlation between the direct andUS-aided measurements (R^2 38.8%, R = 0.62) as opposed to between the direct and palpated measurements (R^2 29.7%, R = 0.54).

Discussion

The publication of the Canadian Orthopaedic Trauma Society's multi-centre study has shedlight on the rising incidence of non-union and malunion associated with non operative management of DMCFs. Furthermore, it has prompted increased research around the indications for fixation of DMCF and the mechanical and functional effects of clavicular shorteningassociated with malunion [4].

Several researchers have looked into the radiological and clinical effects of malunion, they reportedits association with orthopaedic symptoms, such as weakness, easy fatiguability and scapular winging, neurologic effects including thoracic outlet syndrome, not to mention the cosmetic symptoms associated such as shoulder asymmetry and scars due to surgical intervention [5-7]. Most surgeons now accept 1.5-2 cm as an indication for operative fixation.

Ledger., *et al*. studied the mechanical effects of shortening on patients with more 1.5cm shortening using computer tomography and three-dimensional reconstructions of both shoulders for static anatomical assessment, they also assessed the shoulders bio-mechanically, for strength and velocity, and functionally using patient self-administered questionnaires. He reported significant alteration of anatomy of the sternoclavicular joint and the scapular position, the results also showed reduced power and peak velocity in the affected shoulders [9]. Similar results were reported by Hillen., *et al*. who used a computer model to examine the effect of shortening on maximal muscle moments and eventually function. They concluded that shortening affects the function and related that to the patients residual complaints after malunion [10].

Despite the abundance of evidence exploring the morbidity associated with shortening of theclavicle there is little agreement on the best method to measure the clavicle length. Surgeons usually rely on plain radiographs or manual measurements to assess the change in clavicle length. Inter-rater agreement among surgeons is one of the main challenges that limit the usefulness of radiographs in the assessment of clavicle fractures. Stegeman., *et al*. found that actual clavicular length calculated from two-dimensional imaging was inaccurate when compared to three-dimensional referencing, but did note very high inter-observer reliability in taking measurements from plain films [11]. They thus suggested that calculating proportional shortening may be more reliable than an absolute measurement, such as the 1.5 or 2 cm commonly quoted.

Grant Jones and the Moon Shoulder group have also investigated this by asking two raters to review 30 clavicle radiographs and comment on the degree of shortening in millimetres, displacement, comminution and their preferred treatment method - operative or non-operative. Inter-rater agreement was weak to minimal on shortening with no agreement for the restof the questions, despite the radiographs being standardised to facilitate accurate measurement and both raters being senior surgeons who were aware of the premise of the study.

They concluded that plain X-rays are insufficient to reliably assess the degree of shortening and therefore need for surgery on this basis [12]. Hingsammer., *et al*. concluded that referencing the contralateral clavicle is a reliable option in surgical planning [13], however this practice perhaps raises the dilemma as to whether we should be routinely exposing patients to additional radiation. In our experience, many radiology departments are reluctant to carry outsuch investigations.

Our study aimed to evaluate the efficacy of ultrasound (US) as a non-invasive tool to enablequick and accurate estimation of clavicle length. Advantages of US include its relative portable nature when compared to radiography and CT, with most hospital trusts possessing portable scanners. It is also quick to use and does not involve exposure of the patient to ionising radiation. Finally, estimation of the clavicle length by scanning for the sternoclavicular joint and acromioclavicular joints as landmarks should not lead to significant discomfort for the patient even if this investigation is carried out in the setting of acute midshaft clavicle fracture.

The results of our study suggest there is no statistically significant difference between US-guided estimation of clavicle length

and direct measurement of the bone post dissection (p = 0.2). This contrasts with a highly significant difference noted between measurements taken from manually estimated surface landmarks and direct bone measurement (p = 0.001).

A potential use for US measurement of the clavicle could be in fracture clinic assessment ofshortening in the setting of displaced mid-shaft fracture. Here, the length of the injured side could be compared to the uninjured side and a proportional or actual measurement of shortening calculated. As data collection in this study was carried out by two Orthopaedic Registrars without any prior musculoskeletal US training, this suggests that the technique is relatively easy to learn and reproducible.

We acknowledge that there are some limitations to our study, including the relatively small sample size (35 clavicles) included in the study. There are also clearly differences between performing US imaging on cadavers compared with imaging patients who may well demonstrate discomfort and/or bony tenderness. However we feel that the technique we have described could still provide clinically useful information without causing undue pain and we seek to validate this in further studies. We did not formally assess inter-rater variability, but all measurements were performed by two investigators of similar grade and orthopaedic experience in order to minimize this potential source of bias.

Conclusion

This study demonstrates that US-aided estimation of clavicle length may be more accurate than traditional manual measurement using palpation of surface landmarks. Ultrasound has the benefit of being safe, non-invasive and involves no exposure of the patient to ionizing radiation. This study was conducted in cadavers with the associated limitations. Further study is required to validate these findings in living adults.

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