

Association between ultrasound assessment of glenohumeral subluxation and shoulder pain, muscle strength, active range of movement and upper limb function in people with Stroke

ABSTRACT

Background: Glenohumeral subluxation (GHS) is a commonly reported post-stroke complication which has a negative effect on rehabilitation.

Objective: To explore the association between GHS and **other clinical outcomes in people with post-stroke hemiplegia.**

Methods: Patients with post-stroke hemiplegia (n=105, 71±11 years, **median time since stroke 5.6 weeks**), who gave informed consent, were recruited. GHS was assessed by the ultrasound method. Assessment of shoulder pain (visual analogue scale), **active range of movement (AROM)**, muscle strength (Medical Research Council Scale), muscle tone (Modified Ashworth Scale) and the upper limb section of the Motor Assessment Scale (MAS) was undertaken.

Results: GHS was present in 65 (62%) patients. There was a moderate negative correlation between GHS and muscle strength ($r=-0.54$, $p<0.01$); MAS score ($r=-0.58$, $p<0.01$); flexion ($r=-0.54$ $p<0.01$), abduction ($r=-0.53$ $p<0.01$), and external rotation ($r=-0.52$ $p<0.01$) but not between GHS and muscle tone ($r=-0.18$, $p>0.05$) and pain ($r=0.06$, $p>0.05$). Stepwise linear regression analysis showed that muscle strength, external rotation of the shoulder and GHS were associated with upper limb function (adjusted $R^2 = 0.83$, $p<0.01$).

Conclusion: The relationship between GHS, shoulder **AROM**, muscle strength and upper limb function suggests that patients with GHS are more like to have poor motor recovery.

Key words: Glenohumeral subluxation, pain, muscle strength, active range of movement, upper limb function, ultrasound

INTRODUCTION

Impaired motor control of the upper extremity is one of the most frequent findings which persist in 30% to 66% of stroke patients at 6 months [1,2]. Although impairment and functional loss can be severe in the hand [3] musculoskeletal problems in the shoulder region are key features which pose challenges to active rehabilitation [4-5]. Glenohumeral subluxation (GHS) is one of the most recognised complications following stroke and has a reported incidence of up to 48% [6-7]. It has been suggested that GHS itself may trigger additional post-stroke complications which, in turn, delay restoration of upper limb function [8-10]. The most notable of these are pain, altered shoulder range of motion and poor function in the affected upper limb [10-13].

A systematic literature review was conducted to explore the association between pain and GHS [14]. The results of the studies in the systematic review suggest that the association between pain and GHS is equivocal [14]. Of 14 studies included in the review, seven showed an association while another seven found no association, suggesting that not all patients with GHS necessarily experience shoulder pain. Similarly, despite the existence of plausible explanations for limited external rotation at the shoulder following stroke, the association between GHS and restricted external rotation is unclear. Some studies report an association while others found none [15-16].

The association between GHS and upper limb function is well reported in the literature. A case-control study explored this in 107 people with recent stroke (≤ 30 days) [17]. GHS at baseline was found to be independently associated

with poor upper limb function at follow-up. Likewise, a more recent observational study reported that the presence of GHS at the early stage of stroke can be a predictor of poor outcome of the affected upper extremity and the degree of GHS can predict function of the affected hand [18]. Similarly, several other randomized control trials (RCTs) investigating the effects of functional electrical stimulation (FES) to deltoid and supraspinatus muscles showed reduction in GHS and improved function [19-20]. Conversely, another RCT reports a beneficial effect of FES in the prevention of GHS in acute stroke patients, however, there was no significant difference between groups with regard to upper limb function [21]. Overall, meaningful comparison of findings is challenged by the methodological heterogeneity of the studies, lack of objective outcome measurements, and small sample sizes. Therefore conclusions cannot be drawn regarding the association between GHS and other clinical outcomes such as pain, muscle strength and upper limb function.

To evaluate the effectiveness of treatment interventions, accurate, reliable and valid outcome measures are required. Plain radiographs are frequently reported in research studies but problems relating to cost, time involved and risks inherent to exposure to radiation [22] limit their utility in the clinical setting. Current clinical measurements for GHS include the fingerbreadth palpation method [23]. More recently, diagnostic ultrasound has also been used for the assessment of GHS in people with post-stroke hemiplegia by measuring the acromion-greater tuberosity (AGT) distance between the lateral border of the acromion and the apex of the greater tuberosity of the humerus

[24-25]. One of the advantages of ultrasound method is that it can be done at the bedside.

Recently, we reported findings from a prospective study that compared ultrasound and fingerbreadth palpation methods [26]. The area under the receiver operating curve (ROC) was 0.73 (95% CI 0.63-0.83) suggesting that the ultrasound method has good agreement when compared with the fingerbreadth palpation method. A cut-off point of ≥ 0.2 cm AGT measurement difference between affected and unaffected shoulders generated a sensitivity of 68% (95% CI 51%-75%), a specificity of 62% (95% CI 47%-80%) and a positive likelihood ratio of 1.79 (95% CI (1.1–2.9). This cut-off point is used to differentiate subluxation from non-subluxation in the current study. The purpose of this study was to use this ultrasound method to explore the association between GHS and other post-stroke **clinical outcomes** such as shoulder pain, muscle strength, muscle tone, **active** range of movement (**AROM**) and upper limb motor function.

METHODS

A prospective study design was used and approval was received from a xxxxxx Xxxxxxx xxxxxxxx (xxx) Research Ethics Committee, xxxxxxxx xxxxxxxx, xxxxxxxx, xxx. People with stroke resulting in one-sided weakness, who were able to sit upright and over 50 years of age, were eligible to participate; this is the age group most likely to be associated with stroke [27]. Diagnosis/presence of GHS was not a requirement to be able to participate in the study. Patients with other neurologic conditions, traumatic brain injury,

brain tumours or other serious co-morbidities, shoulder pathology, and recent surgery to the neck, arm, or shoulder, unavailable for testing, and unable to volunteer for any reason, were excluded.

Patients were recruited from four local hospital trusts in the xxxxxx xxxxxx of xxxxxx and from the xxxxx xxxxxx xxxxxx xxxxxxxxxxxx (xxxx), a voluntary organisation which runs social clubs in a number of day centres for patients with stroke in xxxxxx. Six centres located in and around the xxxxxx area were approached for the recruitment of patients. Each patient gave informed written consent to take part and, for those who lacked mental capacity, appropriate procedures were followed and involved a family member signing a 'personal consultee agreement form' in the presence of the patient.

Apparatus

A portable diagnostic ultrasound (TITAN model, L38/10-5 MHz broadband, Sonosite Ltd, Hitchin, UK) machine was tested and calibrated according to the manufacturers' guidelines prior to commencement of the data collection process.

Rater

Ultrasound measurements of AGT distance were undertaken by an experienced physical therapist (PK) at all the research sites (Hospital and Day Centres). The training protocol consisted of a one day manufacturers course, supervised training from a consultant radiologist, pilot work on 6 healthy volunteers and reliability studies on healthy volunteers [28] and patients with

stroke (n=64) [25]. The same therapist (PK) was also involved with the general neurological clinical examination of the upper limb.

Procedure

Baseline demographic data including age and gender, date of onset, type of stroke, site of stroke, and side affected were collected from patients medical records by the chief researcher (PK). For patients at day centres, age, gender, date of stroke, side affected, and if available, type of stroke was gathered directly from the patients, as no medical records were available.

All patients were able to sit upright in a wheelchair / armless chair as required for clinical and ultrasound measurements. Assessments were conducted at the hospital bedside or in the day centres. For ultrasound measurements of AGT distance, each patient was placed in the standardized position to allow measurement of AGT distance [25]. AGT distance was defined as the relative distance between the lateral edge of the acromion process of scapula and the nearest margin of the superior part of the greater tuberosity of the humerus [28]. A dark linear acoustic shadow beneath the acromion helped to identify the lateral edge of the acromion. The tendon of supraspinatus was clearly visible as a thick band (acoustic hyperechoic appearance) at its point of insertion, which facilitated identification of the greater tuberosity. Three ultrasound images of the right shoulder were obtained, and AGT distance was measured on each image. This was repeated on the left shoulder. In order to ensure the rater was blind to measurements, the values displayed were obscured by placing a sticker on the ultrasound screen.

The general neurological examination included assessment of muscle strength in the shoulder muscles (Medical Research Council Scale) [29] and muscle tone [30-31] on both affected and unaffected sides. Muscle tone was classified as low tone (grade 0), normal (grade 1) and high (grades 2-5) as described by Culham et al [31]. For both muscle strength and tone, the shoulder flexors, abductors, and internal and external rotators were assessed. Upper limb motor function was assessed by the upper arm section of the Motor Assessment Scale [32]. This assesses the patients ability to perform motor tasks of increasing difficulty on a scale of 0 (poor function) to 6 (good function). Active range of movement (AROM) for both affected and unaffected shoulder flexion, abduction and external rotation was assessed by visual inspection [33, 34]. To make it functionally relevant, all AROM measurements were undertaken with the patient seated in an armless chair. The patient rested his/her arm by the side of the body (shoulder in neutral position) and performed flexion and abduction movements. For the assessment of internal and external rotation AROM, patients were asked to align their arm with the trunk, elbow was bent to 90° and the forearm was placed in the mid-prone position. Patients were instructed to move their hand towards the abdomen (internal rotation) and away from the body (external rotation). If patients were unable to perform an active movement of the shoulder due to loss of voluntary control, they were scored '0'. Patients were asked to actively move the shoulder for flexion, abduction, internal and external rotation and an estimate of range of motion in degrees was recorded by the examiner. A horizontal visual analogue scale for pain (a valid report of subjective pain) was used to

record degree of pain. Each patient was asked to rate the presence of pain in the affected shoulder as 0 (no pain) to 100 (worst imaginable pain) at rest [35].

Data Analysis

Data were analyzed using SPSS (version 22.0, IBM UK, Business Analytics, Middlesex, UK). Descriptive statistics were used to describe group characteristics (i.e., gender, side, type of stroke, age, time since onset) and the mean (SD) of AGT distance for both affected and unaffected shoulders were calculated. The relative difference in distance between affected and unaffected shoulders within individual patients was used to identify patients with subluxation. A cut-off point of ≥ 0.2 cm AGT measurement difference between affected and unaffected shoulders was used to differentiate subluxation from non-subluxation [26]. The mean of the difference between shoulder measurements was used in all data analyses.

To explore the association between GHS and other clinical outcomes the following statistical analysis was performed. The Chi-square test was used to compare the subluxed and non-subluxed group with respect to gender, side, and type of stroke. The unrelated t-test was used to compare groups with respect to age and time since onset of stroke. The Mann-Whitney U test was used to analyse the differences between the groups for Motor Assessment Score (MAS), muscle strength, tone, and pain. The unrelated t-test was used to analyse the difference in the mean range of shoulder movements between subluxed and non-subluxed.

Pearson Correlation Coefficients were calculated to explore the association between GHS and shoulder range of movements. The association between muscle strength, upper limb function (motor assessment scale), shoulder pain, and muscle tone and GHS was calculated using the Spearman Order Correlation Coefficient.

To evaluate the factors associated with GHS, a step-wise linear regression model was generated: The dependent variable was GHS and independent variables were muscle strength, AROM (flexion, abduction, external rotation), and MAS score.

To evaluate variables significantly associated with upper limb function, another step-wise linear regression model was then generated. For this model, the dependent variable was the MAS score and independent variables were muscle strength, AROM (flexion, abduction, external rotation), shoulder pain, muscle tone, GHS. For all statistical tests, probability values of <0.05 were considered significant.

RESULTS

One hundred and fifteen patients with stroke were approached to participate in the study. Ten patients were excluded because they did not meet the inclusion criteria. Therefore, 105 agreed to participate and were recruited into the study. Seventy patients were from hospital settings and 35 patients from stroke day centres. Of the recruited patients, 22 (21%) had aphasia. Of the

105 patients, 60 patients in hospital settings and five patients in the day centres were wheelchair users at the time of data collection.

Based on the diagnostic accuracy results [26] the optimal cut-off point of >0.2 cm AGT difference between unaffected and affected shoulders was used to classify patients with or without subluxation as diagnosed by the ultrasound method, and 65 (62%) patients showed presence of GHS. Of these, 33 (51%) had a mean AGT distance of between 0.2 and 0.5 cm suggesting a minor subluxation.

Table 1 shows the demographic characteristics of patients who took part in the study. No significant differences were found between subluxed and non-subluxed groups with respect to gender, age, time since onset and type of stroke as assessed by ultrasound methods ($p > 0.05$). However, there was a significant difference between groups ($p=0.029$) for the side affected with a greater number of patients having right sided weakness in the subluxed group.

Between Group Differences in Clinical Outcomes

Data on clinical outcomes relating to the shoulder, such as muscle strength, Motor Assessment Scale (MAS), muscle tone, range of motion and pain for both subluxed and non-subluxed groups is presented in Table 2.

There was a significant difference between subluxed and non-subluxed groups for MAS ($p<0.01$), muscle strength ($p<0.01$) and muscle tone ($p=0.02$) but not for pain ($p>0.05$). The unrelated t-test found a significant difference in

the mean range of flexion ($t=6.78$, $df=103$, $p<0.01$, two-tailed), abduction ($t=6.43$, $df=103$, $p<0.01$, two-tailed) and external rotation ($t=6.07$, $df=103$, $p<0.01$, two-tailed) AROM between subluxed and non-subluxed shoulders.

Correlation between GHS and Clinical Outcomes

Table 3 summarises the findings on the correlation between GHS and other clinical outcomes.

Of the 65 patients with GHS, 59 (90%) patients had muscle strength ≤ 3 . Spearman's Rank Correlation coefficient showed a moderate negative correlation between GHS and muscle strength ($r= -0.54$, $p<0.01$) suggesting patients with less muscle strength are more likely to have a greater AGT distance.

Fifty five (85%) patients with GHS had a MAS score of ≤ 6 . Spearman's' Rank Correlation Coefficient also showed a moderate negative correlation between MAS and GHS ($r= -0.58$, $p<0.01$) suggesting patients with GHS are more likely to have poor upper limb function. Similarly, a moderate negative correlation was found between GHS and flexion ($r=-0.54$ $p<0.01$), abduction ($r=-0.53$ $p<0.01$), and external rotation ($r=-0.52$ $p<0.01$) AROM but not between GHS and muscle tone ($r = - 0.18$, $p>0.05$) and pain ($r=0.05$, $p>0.05$).

Association between GHS and other Clinical Outcomes

The Motor Assessment Scale (MAS) score was the only factor associated with GHS (adjusted $R^2 = 0.32$, $p < 0.01$) (Table 4).

Upper Limb Function

Three factors were associated with upper limb motor function, muscle strength, external rotation of the shoulder and GHS (adjusted $R^2 = 0.83$, $p < 0.01$) (Table 5).

DISCUSSION

The aim of this study was to undertake an exploratory analysis of the association between the ultrasound method of GHS and other post-stroke clinical outcomes in the shoulder (pain, muscle tone, muscle strength, active range of movement) and upper limb function. This study found an association between GHS and muscle strength; upper limb function; flexion, abduction, and external rotation AROM but not between GHS and muscle tone and pain. Stepwise linear regression analysis showed muscle strength, external rotation of the shoulder and GHS were associated with upper limb motor function.

This study did not find an association between GHS and pain and this in agreement with the findings of other studies [36-38]. These findings suggest that not all patients with shoulder GHS necessarily experience shoulder pain [39]. Only five (5%) patients reported some degree of pain in their hemiplegic shoulder. Of these five patients, four had GHS. There was no significant difference between patients with and without pain with regard to GHS.

In this study, patients were asked to report pain on a 0 -100 Visual Analogue Scale (VAS) at rest. Simple questioning of patients regarding shoulder pain in

the early stages may not be sufficient. Dromerick et al [40], found that 40% of patients who denied pain at rest showed signs of pain during physical examination (palpation and active movement). Therefore, assessment of hemiplegic shoulder pain should include passive and active range of motion and when performing functional tasks.

In this study, we found that, of the 65 patients with GHS, 90% (n=59) had muscle strength of ≤ 3 . These findings are in agreement with several previous studies which report a direct relationship between loss of supraspinatus muscle activity and GHS [41-42]. One of these reported that weakness of supraspinatus muscle was found in 94% of patients with stroke [40], further supporting our findings. In addition, several intervention studies confirm the relationship between shoulder muscle inactivity and GHS, and report that activation of shoulder muscles using functional electrical stimulation (FES), especially of supraspinatus and deltoid muscle, is effective in preventing GHS [16,19-21].

We found a moderate correlation between GHS and AROM (abduction, $r = -0.53$; $p < 0.01$; flexion, $r = -0.54$; $p < 0.01$; external rotation, $r = -0.51$, $p < 0.01$) and this is in agreement with several previous studies [15, 20-21]. Chantraine *et al* [19] report both reduction in GHS and improvement in flexion and abduction range of movement of shoulder following application of FES. Similarly, a randomised controlled trial reported a correlation between GHS and external rotation i.e. patients with greater degree of GHS tended to have less external rotation [20]. However, this was not maintained at the 18 week

follow-up period as patients showed improvement in GHS but did not improve their external rotation. Although controversy exists with regard to the relationship between GHS and AROM, normal muscle function is crucial both for initiating movement and preventing GHS. Furthermore, improvement in AROM is strongly linked with enhanced upper limb function which is essential for leading a functionally independent life following stroke [43].

In agreement with several other studies [17-18,44], this study also found a relationship between GHS and upper limb function suggesting patients with GHS are more likely to have poor motor recovery. In their RCT with 26 stroke patients, Faghri et al [44] reported that patients in the experimental group (n=13) had significantly reduced GHS and improved upper limb function in comparison with the control group (n=13) at the end of FES training. Similar findings were reported by another RCT [16]. At the 18 week follow up period, GHS continued to be present in the control group and patients showed poor upper limb function when compared to the FES group who had reduction in GHS and good upper limb function. Findings from these intervention studies provide further support on the association between GHS and upper limb function.

Interestingly, in this study, GHS was a factor associated with upper limb function. Nearly 50% of patients diagnosed with GHS based on the ultrasound method had a AGT distance between 0.2–0.5 cm. Other factors were also linked to upper limb function including muscle strength and external rotation of the shoulder. Although muscle strength was one of the main factors

associated with upper limb function, inclusion of GHS in the linear equation model enhanced the explanatory power of the relationship between these variables. This is in agreement with a previous study that reported GHS may be an important factor associated with arm recovery [17].

Study Limitations

This study has several limitations. Firstly, all neurological clinical assessments which included assessment of shoulder pain, muscle tone, muscle strength, power, AROM and upper limb impairment were undertaken by the same researcher (PK) who was also involved with ultrasound scanning of the shoulder. An independent assessor could have been involved with this general assessment to reduce the possibility of research bias. However, the potential for bias was minimised as all neurological assessments were conducted after blind ultrasound measurements. Secondly, this study used a clinically pragmatic assessment tool for the assessment of muscle tone and, as a result, it is possible that some of the patients were misdiagnosed. This may be a potential reason for the lack of association between GHS and muscle tone. Thirdly, AROM was assessed by visual inspection. There is evidence on the reliability of this method when, as in this case, it is undertaken by an experienced physiotherapist. Future studies could assess AROM using a goniometer. Accuracy in this population would be dependent on a number of factors including the ability of patients to sustain shoulder joint positions due to muscle weakness during placement of the goniometer. Fourthly, other clinical parameters such as unilateral neglect, spasticity in biceps muscle were not collected. Finally, hospital populations of stroke

patients are likely to differ from those in day centres. Future studies should consider investigating if the outcomes would be different between these populations.

CONCLUSION

Findings from this study suggest that the presence of GHS is related to a reduction in shoulder ROM, muscle strength and upper limb function. Given that loss of muscle strength is a significant risk factor for post-stroke GHS, it is critical that patients with severe motor loss (≤ 3 on MRC scale) are supported with preventative measures. These could include positioning, exercise and functional electrical stimulation to prevent GHS. These interventions should be considered as soon as patients are medically stable and able to sit upright.

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