Research Report

Assessment of Glenohumeral Subluxation in Poststroke Hemiplegia: Comparison Between Ultrasound and Fingerbreadth Palpation Methods

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ABSTRACT

Background: Glenohumeral subluxation (GHS) is a common post-stroke complication. Treatment of GHS is hampered by the lack of objective, real time clinical measurements.

Objective: To compare an ultrasound method of GHS measurement with the fingerbreadth palpation method using a receiver operating characteristics curve (ROC) and to report the sensitivity and specificity of this method.

Design: A prospective study.

Setting: Local hospitals and day centres in the southwest of England.

Patients: Patients with first time stroke (n=105, 51 men, 54 women; mean (SD) age 71(11) years) with one-sided weakness, who gave informed consent, were recruited.

Measurements: Ultrasound measurements of acromion-greater tuberosity (AGT) distance were used for the assessment of GHS. Measurements were undertaken on both shoulders by a research physical therapist trained in shoulder ultrasound with the patient seated in a standardized position. Fingerbreadth palpation assessment of GHS was undertaken by a clinical physical therapist based at the hospital, who also visited the day centres.

Results: The area under the ROC curve 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 $\geq$0.2cm 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).

Limitations: Clinical therapists involved in the routine care of patients conducted the fingerbreadth palpation method. It is likely that they were aware of the patient's subluxation status.

Conclusion: The ultrasound method can detect minor asymmetry (≤0.5 cm) and has the potential advantage over the fingerbreadth palpation method of identifying patients even with minor subluxation.

INTRODUCTION

Glenohumeral subluxation (GHS) is a recognised complication in people with post-stroke hemiplegia. The reported incidence of GHS ranges from 17% to 81% of patients depending on the measurement methods used and the time frames over which it is assessed.[1,2] Severe loss of motor function and apparent absence of supraspinatus contraction are potential risk factors for GHS, but scapular orientation does not contribute to GHS as was originally thought.[3] The association between GHS and other post-stroke complications such as pain and poor motor recovery is uncertain. When present in combination, however, these could have a significant impact on upper limb function.[4] The management of GHS is therefore an important therapeutic goal and various approaches have been used in its prevention and treatment.[5,6] Current approaches have significant problems and limitations to their use and the effectiveness of any one of these for the treatment of GHS is inconclusive.[7] A potential reason for this is the lack of reliable, objective, real time clinical measurements.[8] Current clinical measurements include the fingerbreadth palpation method[9] and plain radiographs.[6,10]

The fingerbreadth palpation method lacks the sensitivity to detect early signs and/or minor subluxations.[8] There is a concern that without treatment subluxation can progress to an uncorrectable level over time.[6] Early GHS can contribute to irreversible partial or complete tears of the non-elastic shoulder capsule.[5,6,11] Radiographs are considered to be objective, and have high reliability and validity,[12] but problems relating to cost, time involved and risks inherent to exposure to radiation[13] limit their utility in the clinical setting. In addition, radiographic diagnosis is not generally recommended for clinical evaluation of GHS.[14] Diagnostic ultrasound is now routinely used for clinical imaging of the shoulder region in patients with musculoskeletal conditions.[15,16,17,18] Recently, several studies have used diagnostic ultrasound to evaluate the incidence and prevalence of soft tissue injuries (rotator cuff tears, biceps tendinitis) in the shoulders of people with post-stroke hemiplegia.[19,20,21,22,23,24,25,26] The ultrasound method is currently being investigated and developed for the assessment of GHS in these patients,[27, 28] however, it is not routinely used in clinical settings. Using a large, static ultrasound machine Park et al[27] report high intra-rater reliability (ICC = 0.979) of ultrasound measurements of GHS. More recently, Kumar et al[28] recruited 26 patients with stroke, and using a new standardized position with the forearm supported found that bedside assessment of acromion-greater tuberosity (AGT) distance, undertaken by a physical therapist trained in shoulder ultrasound, demonstrates good intra-rater reliability (ICC = 0.980) and discriminant validity.

The purpose of this study was to compare ultrasound and fingerbreadth palpation methods of GHS measurements using a receiver operating characteristics (ROC) curve and to report the sensitivity and specificity of these methods. The fingerbreadth palpation method is routinely used in clinical practice and has been tested for both reliability and validity.[29,30,31] Hall et al[29] investigated the concurrent validity of this method by comparing it with plain radiographs. They report a Spearman Correlation Coefficient of 0.760 between the fingerbreadth palpation method and plain radiographs. This study continues this research by comparing ultrasound and fingerbreadth palpation methods.

METHODS

Patients

The study used a prospective design and received approval from the National Health Service (NHS) Research Ethics Committee, North Bristol Trust, United Kingdom. Patients aged over

50 years, with stroke resulting in one-sided weakness and who were able to sit upright, were eligible to participate. Patients with aphasia were eligible to participate in the study. Aphasia was confirmed if a patient had difficulty following simple commands, understanding questions (receptive aphasia) or speaking (expressive aphasia). 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 due to any reason were excluded.

An a priori power calculation was performed for assessing the clinical utility of the ultrasound method as quantified by the area under a receiver operating characteristic (AUROC) curve. To the best of our knowledge, this is the first study of this topic using AUROC curve statistics. Therefore, power calculations were conducted for two AUROC curve values. For standard level of significance ($\alpha = 0.05$, $\beta \leq 0.20$), a minimum sample size of n = 72 and n = 114 would have at least 80% power to determine statistical significance if the true AUROC was equal to 0.70 and 0.65 respectively, assuming an 1:1 ratio between negative and positive cases in the sample (calculations were performed in MedCalc Software, Version 11.1, Belgium). Therefore the aim of this study was to recruit up to 114 patients with stroke.

Patients were recruited from four local hospital trusts in the southwest of England and from the community by accessing the Bristol Area Stroke Foundation (BASF), a voluntary organization which runs social clubs in a number of day centres for patients with stroke in Bristol. Of the several BASF social clubs, six centres located in and around the Bristol 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 the 'personal consultee agreement form' in the presence of the patient.

Apparatus and Raters

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

Ultrasound measurements of AGT distance were undertaken by a physical therapist (Blinded) 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[32] and patients with stroke (n=64).[28]

Clinical assessment of GHS (fingerbreadth palpation method) was performed by one of the senior clinical physical therapists (xxxx Bands 6-8) at each local hospital trust and at the day centres. Seven physical therapists, with 4-15 years' experience of working in stroke rehabilitation, were involved with clinical assessments of GHS. To ensure standardization and familiarization with the testing procedure, each physical therapist practiced the standardized protocol on two stroke patients in the presence of PK. Any issues arising were discussed and clarified at this stage. During actual data collection, physical therapists undertook measurements independently.

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 only age, gender and date of stroke was gathered directly from the patients, as no medical records were available. Assessments were conducted at the hospital bedside or in the day centres. The therapist undertaking clinical assessment of GHS was blind to ultrasound measurements of AGT distance and the therapist undertaking ultrasound measurements was blind to clinical assessment. The order of data collection was as follows:

(1) Clinical assessment of GHS by a clinical physical therapist using the fingerbreadth palpation method:

A standardized protocol was used.[29] Patients were seated in a chair/wheelchair with their both feet flat on the ground/foot rest. The physical therapist first assessed the unaffected side to palpate the gap between the acromion and the head of the humerus and this was repeated on the affected shoulder. Shoulders were positioned in neutral rotation, with the arm hanging by the side (thumb pointing forwards) close to the body with no abduction (Fig 1). Some patients who demonstrated high tone were unable to hang their affected arm freely by the side. For these patients, the shoulder was maintained in internal rotation with slight elbow flexion and the forearm resting on their lap. GHS subluxation was defined as a palpable gap between the inferior aspect of the acromion and the superior aspect of the humeral head that is 1/2 or more fingerbreadth. A 0-5 grading scheme was used: 0–no subluxation, 1 – ½ fingerbreadth gap, 2 – 1 fingerbreadth gap, 3 – 1½ fingerbreadth gap, 4 – 2 fingerbreadth gap, 5 – 2½ fingerbreadth gap.[29].

(2) Ultrasound measurements of AGT distance by PK:

For ultrasound measurements of AGT distance, each patient was placed in the standardized position to allow measurement of AGT distance (Fig 1).[32] The shoulder was in neutral rotation, with the elbow at 90° of flexion and forearm in pronation. The forearms rested on a pillow placed on the patients lap with the elbow joint itself remaining unsupported. Assistance was provided by the researcher if patient was unable to move the arm. The ultrasound transducer then was placed over the lateral border of acromion along the vertical/longitudinal axis of the humerus to scan the shoulder. AGT distance was recorded on the frozen image using an on-screen calliper that automatically calculates distances (Fig 2). AGT distance was defined as the relative lateral 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.[32] 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 (Fig 2). 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.

(3) A general neurological clinical examination of the upper limb by PK:

The general neurological examination included assessment of muscle strength in the shoulder muscles (Medical Research Council Scale)[33] and muscle tone[34,35] 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.[35] For both muscle strength and tone, the shoulder flexors, abductors, and internal and external rotators were assessed.

Data Analysis

Data were analyzed using SPSS (version 19.0, IBM UK, Business Analytics, Middlesex, UK). Descriptive statistics were used to calculate the mean and standard deviation of AGT distance measurements for both affected and unaffected shoulders. The difference between affected and unaffected shoulders was considered as a measure of GHS based on the ultrasound method and was analyzed using repeated-measures analysis of variance (ANOVA), and both sides (affected and unaffected) and time were considered as within subject factors. The standard error of measurement (SEM) was calculated from the ANOVA output. The minimum detectable change with 90% confidence intervals was calculated using the formula: $MDC90 = SEM \times 1.65 \times \sqrt{2}$.[36,37]

The association between the fingerbreadth palpation method (difference between affected and unaffected shoulders) and the ultrasound method was tested using Spearman Rank Correlation Coefficients. This statistical test is used when one of the methods (in this case the fingerbreadth palpation method) generates ordinal data rather than interval or ratio data. Agreement between the ultrasound and fingerbreadth palpation methods was tested using the receiver operating characteristic (ROC) curve, the area under the ROC (AUROC) curve, sensitivity, specificity, negative and positive predictive values and the likelihood ratios for different values of ultrasound measurements of AGT distance.

RESULTS

Over a 16 month period, 115 patients with stroke were approached to participate in the study. Ten patients were excluded because they did not meet the inclusion criteria. Of these, three had serious co-morbidities (intestinal cancer, heart problems), one patient was enrolled but withdrew before finishing data collection, one was discharged from the hospital prior to data collection, and five patients could not visit the day centre on the day of data collection because of personal reasons. Therefore, 105 agreed to participate and were enrolled into the study: 70 patients were from hospital settings and 35 patients from stroke day centres. Of the recruited patients, 22 (21%) had aphasia. Seven patients required alternative positioning (a non-standard modified sitting position) due to the presence of high tone.

A summary of demographic characteristics of the patients are shown in Table 1. The mean AGT distance for the total sample (n=105) was 2.2 (0.6) cm and 1.8 (0.4) cm for the stroke affected and unaffected shoulders respectively. On the stroke affected side, the minimum and maximum AGT values recorded across patients were 1.0cm, 3.7cm and the 95% confidence intervals ranged from 2.0 - 2.3 cm. Corresponding values for the unaffected shoulder were 0.7cm, 3.2 cm, and 1.7-1.9 cm. Repeated measures ANOVA showed a significant mean AGT difference between affected and unaffected shoulder measurements (0.4 (0.5) cm) (F (5, 520) = 53.101, $p = < 0.001$). The SEM for the between-shoulder difference in AGT was 0.08 cm and the MDC90 was ±0.2 cm.

Shoulder subluxation was present in 71 (67%) patients and absent in 34 (33%) patients, using the fingerbreadth palpation method assessment. Of those with GHS, 31/71 (44%) had grade 1 (½ finger gap), 28/71 (39%) had grade 2 (1 finger gap), 8/71 (11%) had grade 3 (1½ fingers gap), and 4/71 patients (6%) had grade 4 (2 fingers gap) subluxation.

The Spearman Rank Correlation Coefficient showed a moderate correlation ($r_s = 0.52$) between the two methods and this was statistically significant ($p < 0.001$). The ROC curve allows seeing, in a simple visual display, how sensitivity and specificity vary around different cut-off points (curved line) (Fig 3). The AUROC curve can have any value between 0 and 1 and a test could be regarded as excellent or not useful based on the following categories: 0.9–1.0 (Excellent); 0.8-0.9 (very good); 0.7-0.8 (good); 0.6-0.7 (sufficient); 0.5-0.6 (bad);<0.5 (test has no diagnostic value).[38,39] If the AUROC curve value is 0.9 to 1.0 i.e. closer to the upper left-hand corner of the ROC curve, it demonstrates excellent agreement between the tests. In contrast, if the value is ≤ 0.5 i.e. on or below the straight line, it suggests that there is poor agreement between the tests[39] (Fig 3). The AUROC curve was 0.73 (95% confidence interval (CI) (0.63–0.83). Based on the AUROC curve, there was a good level of agreement between the ultrasound and the fingerbreadth palpation methods.

Conventionally, on a ROC graph, a pair of diagnostic sensitivity and specificity values for every individual cut-off is plotted with the sensitivity on the y-axis and one minus specificity on the x-axis. The sensitivity and specificity for various cut-off points is presented in Table 2. A cut-off point of ≥0.2 cm AGT measurement difference between affected and unaffected shoulders could be considered optimal because it provides the best trade-off between sensitivity and specificity with a sensitivity of 68% (95% CI 51%-75%) and a specificity of 62% (95% CI 47%-80%). Using this cut-off point, the true value for the sensitivity of the ultrasound method is likely to be between 0.51, the lower boundary on its confidence interval, 0.68, the point estimate, or 0.75, the upper boundary on the confidence interval.

Using the optimal cut-off point of ≥0.2 cm, the usefulness of the ultrasound method is illustrated in Table 3. Likelihood ratios summarize how many times more or less likely patients with subluxation are to have a particular test result than patients without subluxation. The positive likelihood ratio (LR+) of 1.79 suggests that a patient with subluxation (defined as grade of 1 or higher on the five-point fingerbreadth palpation method) is 1.79 more likely to present with an AGT difference greater than 0.2 cm on ultrasound than a patient without palpable subluxation. Flow diagram illustrates comparison of ultrasound method against fingerbreadth palpation method (Fig 4). Using the ultrasound method, 61/105 (58%) patients had a mean AGT difference of ≥ 0.2 cm between affected and unaffected shoulder. Of those with ≥ 0.2 cm AGT distance, 33/61 (54%) demonstrated a mean AGT difference of between 0.2 and 0.5 cm indicating minor asymmetry between the unaffected and affected shoulders.

DISCUSSION

The primary aim of this study was to compare an ultrasound method of GHS measurement with the fingerbreadth palpation method using a receiver operating characteristics (ROC) curve and to report the sensitivity and specificity of these methods. The AUROC curve from this study was 0.73. Presented with pairs of randomly selected patients, one with GHS and one without GHS as determined by the fingerbreadth palpation method, an examiner would classify 73% of the pairs correctly by choosing the one whose AGT distance on ultrasound was the larger of the two.

For the diagnostic ultrasound method to be useful, it is important to select a trade-off between sensitivity-specificity.[40] The cut-off point of ≥0.5cm generated a sensitivity of 40% (Table 3). Examiners who apply a cut-off point of 0.5 cm while using the ultrasound method would fail to identify 6 out of ten patients judged by the fingerbreadth palpation method to have GHS. In contrast, a cut-off point of ≥0.1cm generates a sensitivity of 76% indicating that the ultrasound method would identify 8/10 patients with subluxation. However, this value is associated with a low specificity of 50% indicating that 5 out of 10 patients whose ultrasound measures are asymmetrical by ≥0.1cm or more would have no evidence of GHS on the fingerbreadth palpation test. Unlike these cut-off points, which generate high sensitivity and low specificity or vice versa, a cut-off point of ≥0.2cm generates a sensitivity of 68% and a specificity of 62%. Based on the sensitivity statistic, when the fingerbreadth palpation test indicates GHS, in 68% of those cases the ultrasound measure would also indicate GHS.

The cut-off point of ≥0.2 cm (where the sensitivity is 0.68) may be considered optimal because it helps to 'rule out' GHS by indicating that, among patients with subluxation (defined as a grade of 1 or higher on the five-point palpation scale), 68% will have an AGT difference of at least 0.2 cm. This suggests that ultrasound could potentially be used as a screening tool. This is critical because early diagnosis of GHS would facilitate the application of appropriate treatment and thereby potentially prevent the long term complications associated with GHS. Furthermore, a cut-off point of ≥0.2 cm (where the test's specificity is 0.62) indicates that, with a predicted false positive result of 0.38, among those who demonstrate no subluxation (a zero on the five-point fingerbreadth palpation scale), 62% will have an AGT difference of less than 0.2 cm. Specificity is equally important because applying treatment such as positioning (arm troughs, lap boards), shoulder slings, or strapping to a patient without GHS could reduce the normal gap between the acromion process and the head of the humerus. This position could alter the normal scapulohumeral rhythm required for smooth movement at the shoulder joint resulting in compression of the rotator cuff tendons under the acromion process, which can cause tearing of these structures and result in subacromial impingement.[19]

The cut point of ≥0.2 cm also coincides with the MDC90 value of ±0.2 cm which is in agreement with a previous study.[28] Kumar et al[28] in a study on 26 stroke patients reported a mean AGT difference of 0.4 cm and a MDC90 value of ±0.2 cm between affected and unaffected shoulders. A further study on healthy individuals (n=32; mean (SD) age 64 (11) years) reported a mean AGT difference of 0.1 (0.18) cm (95% CI 0.03 to 0.17) and MDC90 value of ±0.07cm between right and left shoulders.[32] Based on the MDC90 values from these studies, it could be predicted that a change of ±0.2 cm in AGT distance measurements between affected and unaffected shoulders would be necessary to indicate an asymmetry which is not due to measurement error.

In this study, a mean AGT difference of ≤0.5cm between affected and unaffected shoulders was observed in 33 patients suggesting minor subluxation. It is critical to identify minor subluxation in its early stage as application of appropriate treatment can improve upper limb motor function.[5,6] Several studies have reported on the benefits of functional electrical stimulation in the prevention and treatment of GHS in early stages of rehabilitation.[,5,41,42,43] but not in patients with chronic stroke (> 6 months).[6] Findings from these studies suggest that GHS can be prevented by the application of appropriate treatment, but that withdrawal of treatment can lead to subsequent subluxation especially in patients with loss of voluntary control. In the UK, the latest national guidelines for stroke[44], therefore, recommend application of functional electrical stimulation to the supraspinatus and deltoid muscles for any patient with stroke who has developed, or is at risk of developing GHS. Ultrasound has the potential advantage of identifying patients even with minor subluxation (≤0.5 cm) and can provide objective measurements in the early stages of rehabilitation.

In contrast, the fingerbreadth palpation method has the potential advantage of being a quick, equipment-free, method of identifying significant subluxation. However, it lacks the ability to detect early signs of subluxation,[8] is subjective[8,12,31] and insensitive as it cannot detect differences of less than 0.5 cm.[12] Furthermore, the reported correlations for the concurrent validity of the fingerbreadth palpation method in comparison with radiographic measurements range from 0.69 to 0.76[29,30,31] which are described as relatively low.[45]

Limitations of the fingerbreadth palpation method could result in an underestimation of the true prevalence of GHS and this could contribute to the moderate correlation and relatively low sensitivity and specificity values for the ultrasound method found in this study. Due to resource, cost and ethical constraints, it was not possible to undertake radiographs of 210 shoulders.

Our study suggests that ultrasound measurements of AGT have potential value in the prevention and management of GHS in people with stroke. The technique is safe, non-invasive,[15,16,46,47] allows real-time measurements,[48] and requires limited training to produce reliable results of AGT distance.[28,32,49,50] Several other benefits of diagnostic ultrasound have been reported by recent studies in people with stroke.[25,26] A recent study reports that subluxation occurred more frequently in patients (n=182) with a known presence of fluid in the subhumeral and subdeltoid bursae and in patients with reduced functional capacity.[25] Ultrasound was used both as a diagnostic tool and to monitor the effectiveness of the exercise program targeting reduction of subluxation and bursal fluid. Similarly, another study investigated the association between GHS and soft-tissue injuries in 39 people with stroke.[26] Similar to our study, the diagnosis of GHS was done by measuring the lateral AGT distance. The study found that ultrasound complements the assessment of soft tissue injuries in shoulder of people with stroke.[26]

Given these findings, ultrasound has a potential, in both research and clinical practice. Clinically, ultrasound may be used to assess and monitor the effectiveness of treatment interventions for GHS in people with severe paralysis especially during the early stage of rehabilitation. It has also potential to diagnose soft tissue injuries in people with stroke, both with and without GHS and therefore can facilitate management of shoulder pain. In particular it has utility as an outcome measure in intervention studies. The ultrasound method is objective, quantitative and has the potential to detect even small changes in AGT distance measurements.

The current study has several limitations. First, there was a difference in the patient's starting position for the two methods. For the fingerbreadth palpation method patients were in an upright sitting position with their arms hanging freely by their sides, and without arm support. In contrast, for the ultrasound method, the patients forearm was placed in their lap. Patients with loss of motor control are potentially at risk of developing GHS and gravity dependent positions of the shoulder should therefore ideally be avoided.[3] Kumar et al[28] developed a new standardized position with the forearm supported on a pillow, but the elbow itself remained unsupported to allow the effect of gravity. The study reported excellent intra-rater reliability and discriminant validity for the ultrasound method suggesting it has the ability to diagnose GHS even when the forearm is supported. It was not possible to use this newly developed position for the fingerbreadth palpation method because there are no reports on reliability and validity for this method in this position. Secondly, patients were recruited from multiple sites which meant seven different physical therapists were involved in the assessment of GHS using the fingerbreadth palpation method. The reported inter-rater reliability for the fingerbreadth palpation method is between ICC 0.770 – 0.792.[12] This might have contributed to greater variability and have had some effect on the correlation between fingerbreadth palpation and ultrasound methods. Finally, assessors conducting the fingerbreadth palpation method were also the clinical therapist involved in the routine care of study patients at the hospital. It is therefore likely that they were aware of the patient's subluxation status and this might have influenced their judgement on the day of data collection. However, patients (n=35) at the day centre were not known to the clinical therapists.

In conclusion, on the basis of the AUROC curve value of 0.73, this study found a good level of agreement between ultrasound and fingerbreadth palpation methods. The ROC curve findings from this study indicate that a cut-off point of ≥ 0.2 cm could be used to determine the sensitivity and specificity of the ultrasound method to identify asymmetry between affected and unaffected shoulders and facilitate diagnosis of GHS. The ultrasound method has the potential advantage over the fingerbreadth palpation method of identifying patients even with minor subluxation (≤0.5 cm). Ultrasound measurements provide ratio level data and have clinical utility as an outcome measure in intervention studies. Future studies should assess the diagnostic accuracy of the ultrasound method in the assessment of GHS in comparison with radiographic measurements. From an ethical perspective, this could be incorporated into intervention studies which routinely use radiographs to evaluate outcomes.

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Table 1: Demographic characteristics of stroke patients (n=105)

Age (years)	
Mean (SD)	71 (11)
Range	50–90
Gender	
Male, n (%)	51 (48)
Female, n (%)	54 (52)
Type of stroke	
Cerebral Infarction, n (%)	66 (62)
Intracerebral haemorrhage, n (%)	10 (9)
Unspecified	29 (29)
Side affected	
Right, n (%)	51 (48)
Left, n (%)	54 (52)
Aphasia n (%)	22 (21)
Muscle Strength[42] **(Shoulder Flexors, Abductors, Rotators)**	
≤ 3 **n** (%)	79 (75)
≥ 4 **n** (%)	26 (25)
Muscle Tone[44] **(Shoulder Flexors, Abductors, Rotators)**	
Low n (%)	42 (40)
Normal n (%)	40 (38)
High n (%)	23 (22)
Median time since onset of stroke (weeks)	
Median	5.6
Range	(0.4 to 728)

Table 2: Sensitivity and Specificity with 95% CI for Ultrasound method (AGT measurement difference between affected and unaffected shoulders)

Cut-off Points	Sensitivity	95% CI	Specificity	95% CI
≥ 0.5	40%	28 – 52	89%	73 - 96
≥ 0.4	47%	33 – 57	83%	69 - 95
≥ 0.3	55%	39 – 63	74%	62 - 91
≥ 0.2	68%	51 – 75	62%	47 - 80
≥ 0.1	76%	57 – 80	50%	38 - 73

Table 3: AUROC curve statistics with 95% Confidence Intervals for ultrasound method using optimal cut-off point (≥ 0.2 cm)

Optimal cut-off point	≥ 0.2 cm
AUROC curve (95% CI)	0.73 (0.63 – 0.83)
Sensitivity	68% (51-75)
Specificity	62% (47-80)
Positive predictive value	74% (66-88)
Negative predictive value	49% (31-61)
Positive likelihood ratio	1.79 (1.1–2.9)
Negative likelihood ratio	0.55 (0.4–0.8)

AUROC curve – the area under a receiver operating characteristic curve

Figure 1: Participants' standardized position for data collection purpose

A) Fingerbreadth palpation method B) Ultrasound method

Figure 2: Measurement of acromion-greater tuberosity (AGT) distance between the lateral border of the acromion process and the nearest superior margin of the greater tuberosity

Caption:

AC-Acromion process, SUP – Supraspinatus, GT- Greater Tuberosity, AGT (dotted calliper) – Acromion-greater tuberosity distance

Figure 3: Receiver Operating Curves (ROC) for the ultrasound method of assessment of GHS in comparison with the fingerbreadth palpation method

Caption:

Receiver Operating Characteristic (ROC) curve shows the AUROC curve value 0.73 (95% confidence interval 0.63 to 0.83)

Curved Line - sensitivity and specificity vary around different cut-off points

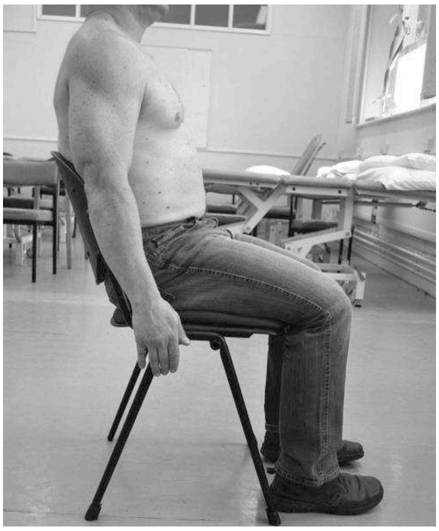
Straight Line – Area under the ROC curve ≤ 0.5 (test not useful)

Cut-off points ≥ 0.1 to ≥ 0.5 cm corresponding to sensitivity and specificity
Optimal cut-off point ≥ 0.2cm indicates 68% Sensitivity and 62% specificity

Figure 4: Flow diagram illustrating comparison between the ultrasound method and the fingerbreadth palpation method based on cut-off point ≥ 0.2cm AGT difference

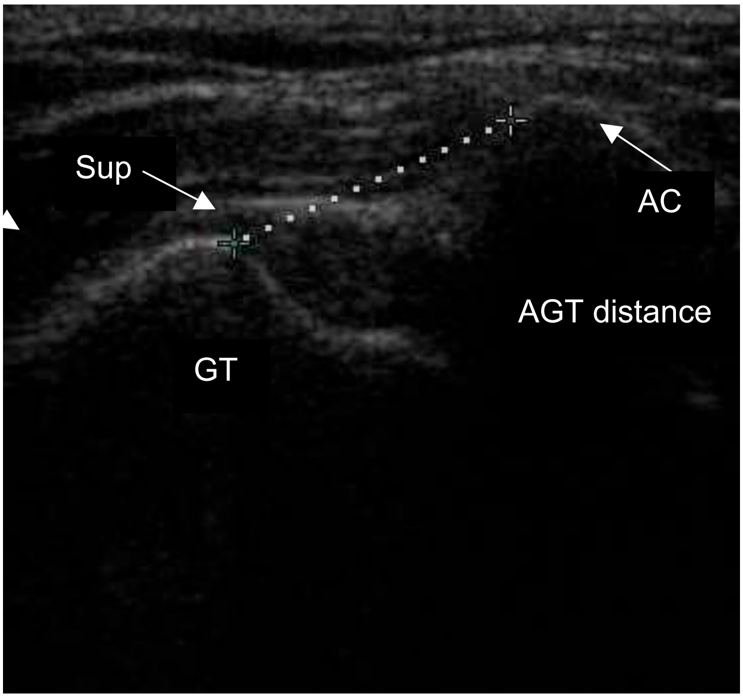
Figure 1

A) Fingerbreadth palpation method



B) Ultrasound method

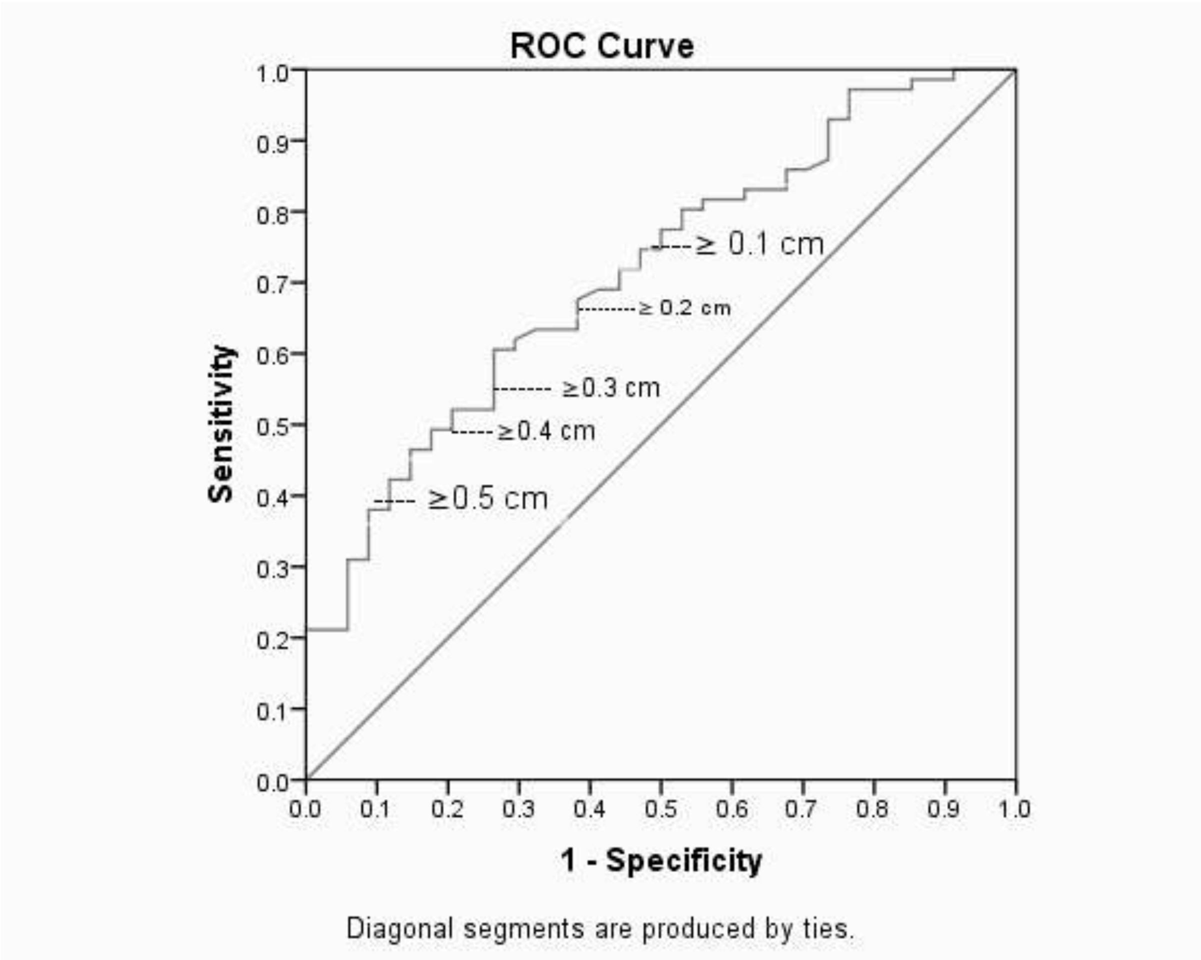
Figure 2



Caption:

AC-Acromion process, SUP – Supraspinatus, GT- Greater Tuberosity, AGT (dotted calliper) – Acromion-greater tuberosity distance

Figure 3



Receiver Operating Characteristic (ROC) curve shows the AUROC curve value 0.73 (95% confidence interval 0.63 to 0.83)

Curved Line - sensitivity and specificity vary around different cut-off points

Straight Line – Area under the ROC curve ≤ 0.5 (test not useful)

Cut-off points ≥ 0.1 to ≥ 0.5 cm corresponding to sensitivity and specificity
Optimal cut-off point ≥ 0.2cm indicates 68% Sensitivity and 62% specificity

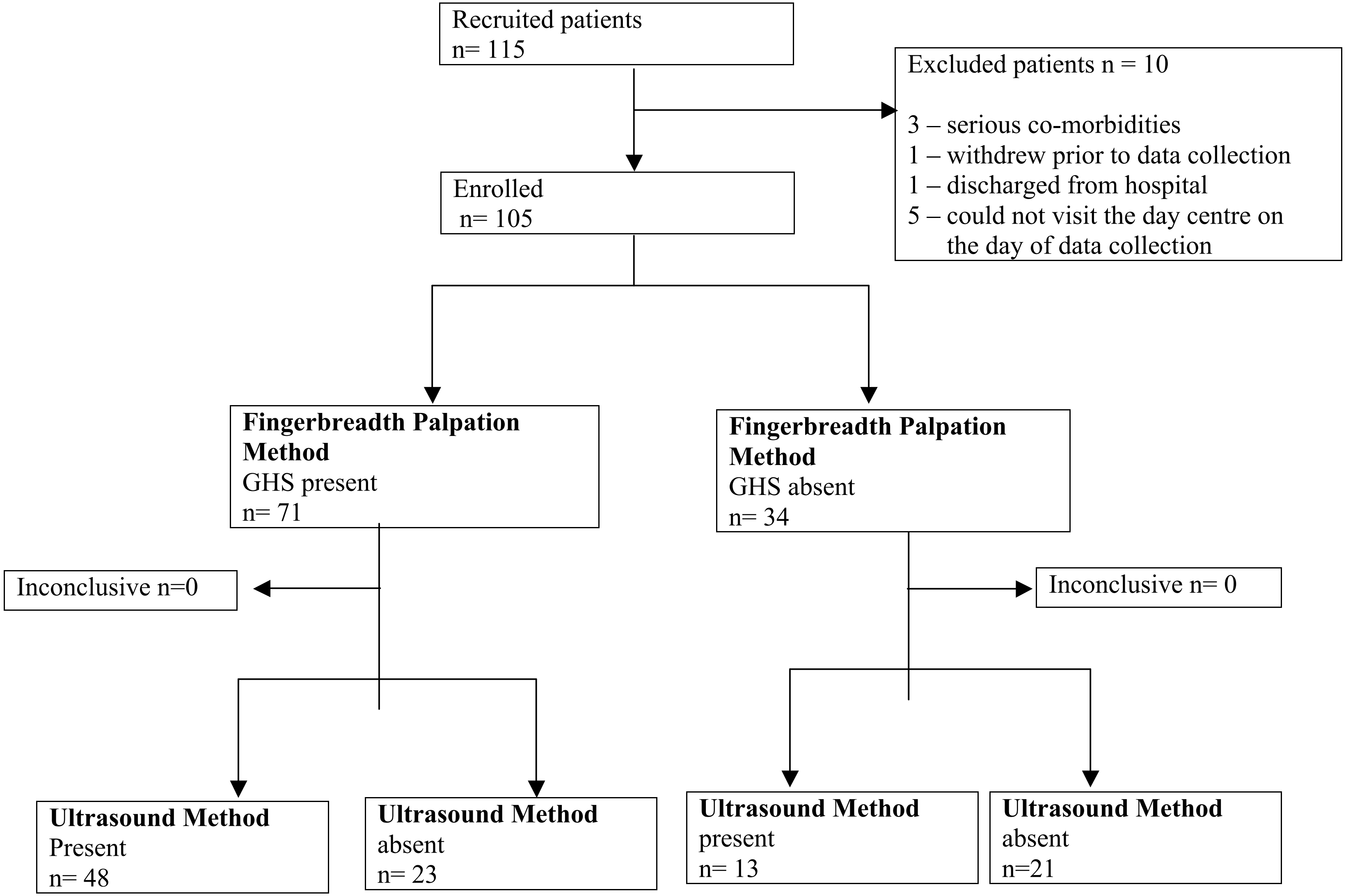


Figure 4: Flow diagram illustrating comparison between the ultrasound method and the fingerbreadth palpation method based on cut-off point ≥ 0.2cm AGT difference