ORIGINAL REPORT

ULTRASONOGRAPHIC MEASUREMENT OF SHOULDER SUBLUXATION IN PATIENTS WITH POST-STROKE HEMIPLEGIA

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Objective: **To evaluate the ultrasonographic measurement of shoulder subluxation in patients with post-stroke hemiplegia.**
Design: **Prospective, single blind study.**
Patients: **A total of 41 patients with post-stroke hemiplegia were included (24 men and 17 women, mean age 56 years (standard deviation 11), age range 34–78 years).**
Methods: **Clinical evaluation of the affected shoulder was assessed using the Motricity Index scores and the Modified Ashworth Scale. Two ultrasonographic measurements were taken to check intra-rater reliability. The shoulder subluxation ratio was determined as the ratio of the radiographic vertical and horizontal distance, and the ultrasonographic lateral and anterior distances in the affected shoulder divided by that in the unaffected shoulder.**
Results: **Intraclass correlation coefficients of the repeated ultrasonographic lateral/anterior distance measurements in the unaffected and affected shoulders were 0.979/0.969 and 0.950/0.947, respectively. Ultrasonographic lateral/anterior distance ratios were negatively correlated with Motricity Index scores of the affected shoulder abduction ($r = -0.490$, $p < 0.001$/ $r = -0.671$, $p < 0.001$). Ultrasonographic anterior distance ratio was negatively correlated with Modified Ashworth Scale score of the affected shoulder ($r = -0.374$, $p < 0.05$). However, there was no correlation between radiographic distance ratios and clinical evaluation scores.**
Conclusion: **We strongly recommend ultrasonography as a diagnostic tool to measure the degree of shoulder subluxation in patients with post-stroke hemiplegia.**

Key words: ultrasonography, shoulder subluxation, post-stroke hemiplegia.

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Shoulder subluxation is defined as increased translation of the humeral head relative to the glenoid fossa. The reported incidence of shoulder subluxation in hemiplegic patients after stroke varies between 17% and 84% (1, 2). Shoulder subluxation in hemiplegic patients has been recognized as a difficult problem to manage and is associated with the development of causes of hemiplegic shoulder pain, such as rotator cuff tear, brachial plexus injury, and complex regional pain syndrome type I (1–5). As hemiplegic shoulder pain can interfere with functional activities and comprehensive rehabilitation treatment, the prevention and appropriate treatment of shoulder subluxation are suggested as early and vigorously as possible (6). Therefore, it is important for the clinician to identify the presence of shoulder subluxation and its characteristic patterns (anterior or inferior), to measure the degree of shoulder subluxation, and to evaluate the effectiveness of clinical interventions, such as shoulder supports and neuromuscular electrical stimulation (7–9).

A variety of methods for measurement of shoulder subluxation in hemiplegia has been developed without the acceptance of a standardized and validated method. Most methods currently used to measure shoulder subluxation can be divided into 2 classes: clinical and radiographic. To date, 3 clinical methods have been developed: palpation, the number of finger-breaths that can be inserted between the inferior aspect of the acromion and the superior aspect of the humeral head (10), calipers or a tape measure to assess arm length discrepancy (10), and use of thermoplastic jig (11). However, these clinical methods are examiner-dependent, have limited resolution, lack precision, and may not detect small changes in glenohumeral displacement.

Radiography has been used to obtain an objective measurement of shoulder subluxation in post-stroke hemiplegia (7–10, 12–14). Radiographic measurements of shoulder subluxation can be divided into qualitative and quantitative methods. Qualitative radiographic method is described as present or absent, or classified into a limited number of categories (13). Quantitative radiographic methods involve using a single anteroposterior (A-P) view or tridimensional techniques based on multiple plain radiographs of the shoulder. These methods are based on a comparison between the affected and unaffected shoulders and seem to give more precise shoulder subluxation measurement than do clinical methods. However, radiography involves patient exposure to radiation, and tridimensional techniques are not feasible for the clinician because they require specialized processing equipment that is not commercially

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available (10, 12). At present, radiographic methods such as a single A-P view are inadequate in identifying variations from inferior subluxation. In addition, its use is limited to patients who are able to maintain an upright sitting position. Therefore, we have developed a new ultrasonographic method to measure shoulder subluxation after stroke.

The purposes of our study were to determine the intra-rater reliability of the ultrasonographic method, to evaluate the correlation between imaging methods, such as radiography and ultrasonography, and the clinical evaluations, such as the motor impairment and spasticity of the affected shoulder, and to identify which method is adequate for the measurement of shoulder subluxation in patients with post-stroke hemiplegia.

MATERIAL AND METHODS

Patients

Forty-one patients with post-stroke hemiplegia with shoulder subluxation (24 men and 17 women, mean age 56 years (standard deviation (SD) 11), age range 34–78 years) were included in this study. Twenty-nine patients had cerebral infarction and 12 had cerebral haemorrhage. Twenty-six patients had left hemiplegia and 15 right hemiplegia. We excluded patients with previous strokes, previous shoulder surgery, aphasia or cognitive impairment which could interfere with their understanding of instructions during motor impairment assessment, and severe motor impairment who could not maintain an independent upright sitting position when taking the radiograph. Patients with full-thickness tear of the rotator cuff were also excluded because superior migration of the humeral head in radiograph is associated with tears of the rotator cuff and resultantly decreased acromiohumeral distance (15). The institutional ethics committee approved our study, and informed consent was obtained from the patients or their family. All patients were transferred to the Department of Rehabilitation Medicine after initial acute treatment at the Neurology and Neurosurgery Departments or other hospitals.

Procedures

Radiographic, ultrasonographic, and clinical evaluations were performed on the day of the transfer or admission. Mean length from stroke onset to these evaluations was 30 days (range 18–43 days). Motor impairment of the affected shoulder abduction was recorded 5 scores from 0 to 33 according to the Motricity Index (MI) (16), and spasticity of the affected shoulder was assessed on a grade from 0 to 5 according to the Modified Ashworth Scale (MAS) (17).

Radiography

Radiographs of the affected and unaffected shoulders were taken in an A-P projection with the patient seated and arms dependent in a neutral position on the same day of the ultrasonographic examination. The distance measurements of shoulder subluxation from a single radiograph, as described by Brooke et al. (7), were used. Three reference points were initially identified: the central points of the glenoid fossa and the humeral head, and the most inferolateral point on the acromial surface of the acromioclavicular joint. The vertical distance (VD) of the glenohumeral joint was measured from the inferior acromial point to the central point of the humeral head, and the horizontal distance (HD) was measured between the central points of the glenoid fossa and the humeral head (Fig. 1). A specialist in physical and rehabilitation medicine who was unaware of the patients' ultrasonographic results performed the radiographic measurements independently.

Ultrasonography

The ultrasonographic examination of both shoulders was performed first as part of the ultrasonographic measurement of shoulder subluxation, followed by single contrast arthrography only when ultrasonography showed findings of a full-thickness rotator cuff tear. The supraspinatus, infraspinatus, subscapularis, and biceps tendon were examined in the transverse and longitudinal planes. Rotator cuff tendon abnormalities were described as follows: normal, a tendinopathy, a partial-thickness tear, and a full-thickness tear (18, 19). Diagnostic criteria for the tendinopathy were thickened and heterogeneous tendon without discrete defects and an ill-defined hypoechoic defect with indistinct borders. The following criteria for the partial-thickness tear included flattening of the bursal side of the tendon and a distinct hypoechoic or mixed hyperechoic and hypoechoic defect that involves only the partial width of the tendon. The main criteria for the full-thickness tear were complete non-visualization of the tendon, allowing the deltoid muscle to approximate the humeral head, and the presence of a focal hypoechoic or anechoic defect that extended from the bursal to the articular surface of the tendon. In addition, fluid in the biceps tendon and the subacromial-subdeltoid (SASD) bursa were assessed. The definitive diagnosis for the full-thickness tear of the rotator cuff was made if contrast medium was leaked out from the glenohumeral joint to the SASD bursa during single contrast arthrography.

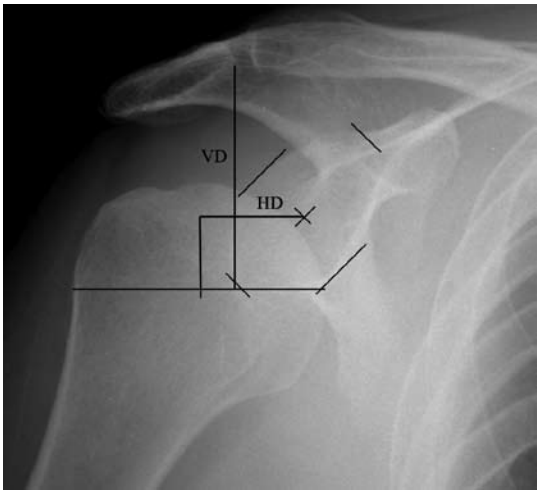

Fig. 1. Measurement of vertical (VD) and horizontal distances (HD) from radiograph. The VD of the glenohumeral joint was measured from the acromial point to the central point of the humeral head, and the HD was measured between the central points of the glenoid fossa and the humeral head.

Two ultrasonographic measurements were taken at a 1-hour interval to check intra-rater reliability and averaged for each shoulder. B-mode ultrasonography was performed independently using an ultrasonographic equipment with a 5–12 MHz linear array transducer (SonoAce 9900®, Medison, Seoul, Korea) by a specialist in physical and rehabilitation medicine with 5 years of musculoskeletal ultrasonographic experience who was blinded to the clinical and radiographic results. All patients were examined in the upright sitting position with arms dependent in a neutral position, without the arm support, and instructed to relax during ultrasonographic examination. Four anatomic reference points taken on ultrasonography were used to measure shoulder subluxation: the anterior and lateral borders of the acromion, and the apices of the greater and the lesser tuberosity of the humerus. First, the examiner palpated and marked these anatomical structures bilaterally and then performed the ultrasonography. We distinguished the greater and lesser tuberosities by identification of the bicipital groove. Then we measured the lateral distance (LD) between the lateral border of the acromion and the greater tuberosity (Fig. 2) and the anterior distance (AD) between the anterior border of the acromion and the lesser tuberosity (Fig. 3) in the affected and unaffected shoulders. In case of a severe shoulder subluxation, split-screen imaging was used.

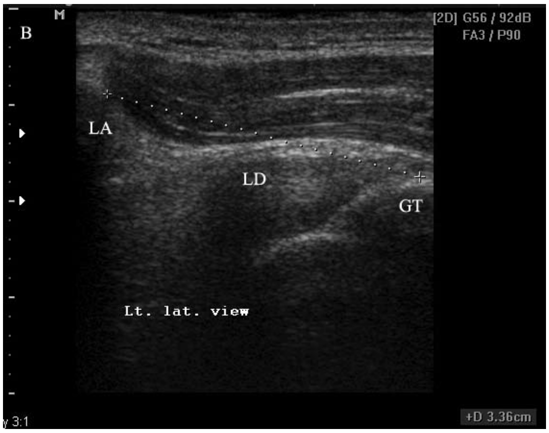

Fig. 2. Measurement of lateral distance (LD) from ultrasonography. The LD from the lateral border of the acromion (LA) to the apex of the greater tuberosity (GT) was measured. LD was 33.6 mm for the affected shoulder.

Considering the normal anatomic variation, the shoulder subluxation ratio was determined as the ratio of the radiographic and ultrasonographic distance measurement in the affected shoulder divided by that in the unaffected shoulder.

Statistical analysis

Statistical analyses were performed by SPSS/PC windows version 12.0 (SPSS Inc., Chicago, IL, USA) with the level of significance set at less than 0.05. Data are presented as mean with SD. The paired *t*-test was used to test for significant differences of radiographic and ultrasonographic distances between the affected and unaffected shoulders. The intraclass correlation coefficient (ICC) was used to examine intra-rater reliability of repeated ultrasonographic distance measurements. Spearman's rank correlation coefficients were calculated to test relationships between the shoulder subluxation ratios and the clinical evaluation scores

Fig. 3. Measurement of anterior distance (AD) from ultrasonography. The AD from the anterior border of the acromion (AA) to the apex of the lesser tuberosity (LT) was measured. AD was 44.2 mm for the affected shoulder. Split-screen imaging was used to measure the affected shoulder subluxation.

RESULTS

Clinical evaluation scores

The median MI score (interquartile range) was 14.0 (5) for the affected shoulder abduction. The median MAS (interquartile range) was 1.0 (1) for the affected shoulder.

Ultrasonographic findings of rotator cuff and biceps tendon

In the affected shoulders of 41 patients, ultrasonography revealed 12 patients (29%) with partial-thickness tear, 11 patients (27%) with tendinopathy, 17 patients (42%) with fluid in the SASD bursa, 9 patients (22%) with fluid in the biceps tendon, and 18 patients (44%) without the ultrasonographic abnormalities of rotator cuff. In the unaffected shoulders of 41 patients, ultrasonography found 3 patients (7%) with partial-thickness tear, 9 patients (22%) with tendinopathy, 5 patients (12%) with fluid in the SASD bursa, 4 patients (10%) with fluid in the biceps tendon, and 29 patients (71%) without the ultrasonographic abnormalities of rotator cuff.

Radiographic and ultrasonographic distances

The mean radiographic VD was 40.2 mm (SD 7.3) and 30.1 mm (SD 4.9), the mean radiographic HD was 22.3 mm (SD 4.4) and 18.3 mm (SD 3.9), the mean ultrasonographic LD was 31.5 mm (SD 6.9) and 21.9 mm (SD 4.0), and the mean ultrasonographic AD was 42.5 mm (SD 8.2) and 29.3 mm (SD 3.6), for the affected and unaffected shoulders, respectively. All radiographic and ultrasonographic distances of the affected shoulder were significantly greater than those of the unaffected shoulder ($t = 10.6, 6.0, 15.5, 11.4$, $p < 0.001$). The mean radiographic VD and HD ratios were 1.35 (SD 0.23) and 1.24 (SD 0.26), and the mean ultrasonographic LD and AD ratios were 1.45 (SD 0.28) and 1.46 (SD 0.27), respectively.

Intra-rater reliability of ultrasonographic distance measurements

The ICCs of the repeated ultrasonographic LD/AD measurements in the unaffected and affected shoulders were 0.979/0.969 and 0.950/0.947, respectively.

Correlation between shoulder subluxation ratios and clinical evaluation scores

Ultrasonographic LD/AD ratios were negatively correlated with MI scores of the affected shoulder abduction ($r = -0.490$, $p = 0.001$/ $r = -0.671$, $p < 0.001$). Ultrasonographic AD ratio was negatively correlated with MAS score of the affected shoulder ($r = -0.374$, $p < 0.05$). However, there was no correlation between radiographic distance ratios and clinical evaluation scores (Table I).

DISCUSSION

Subluxation most commonly occurs during the flaccid stage after stroke (20). In patients with post-stroke hemiplegia, the humeral head is displaced inferiorly and anteriorly by a loss of

Table I. *Correlation between shoulder subluxation ratios and clinical evaluation scores.*

	Shoulder subluxation ratio			
Clinical evaluation score	Vertical distance	Horizontal distance	Lateral distance	Anterior distance
Shoulder abduction MI	$r = -0.297$	$r = -0.184$	$r = -0.490$*	$r = -0.671$*
Shoulder MAS	$r = 0.121$	$r = 0.230$	$r = -0.192$	$r = -0.374$†

*$p < 0.01$, †$p < 0.05$.
Values are Spearman's rank correlation coefficient.
MI: Motricity Index; MAS: Modified Ashworth Scale.

normal shoulder muscle activity, particularly the supraspinatus and posterior deltoid muscles, and the weight of the upper limb stretches the joint capsule, muscles, tendons and ligaments, resulting in inferior and anterior shoulder subluxation (10). Shoulder subluxation is likely to be reduced in most hemiplegic patients who develop the spasticity and motor recovery of the affected upper limb (21). However, no study has been reported about correlations between the degree of shoulder subluxation and clinical evaluation using the MI scores and the MAS in hemiplegic patients. Therefore, we selected the MI score and the MAS to assess the motor impairment and the spasticity of the affected shoulder, respectively.

In our study, no correlation was found between radiographic shoulder subluxation ratios and clinical evaluation scores with respect to the degree of shoulder subluxation. These results are different from those of previous studies, which reported that radiographic measurements had correlations with clinical methods, such as palpation and anthropometry (10–12). We can suggest a possible explanation for this discrepancy. Radiographic measurements only assessed inferior shoulder subluxation, as did clinical methods, whereas the MI score and the MAS of the affected shoulder have a close relationship with inferior and anterior shoulder subluxation together. Therefore, radiographic measurements cannot assess the sum of inferior and anterior shoulder subluxation. Ultrasonographic distance ratios of shoulder subluxation were negatively correlated with the motor impairment of the affected shoulder abduction and the degree of the affected shoulder spasticity. In addition, ultrasonographic distance ratios were higher than radiographic VD ratio, possibly because the latter ratio only indicates inferior subluxation, whereas ultrasonographic distance ratios indicate the sum of inferior and anterior subluxation. Therefore, these can provide more useful information than radiographic VD ratio in assessing anterior shoulder subluxation. Based on the results of our study, the anterior shoulder subluxation seems to play a more important role in the degree of shoulder subluxation than the inferior shoulder subluxation on clinical grounds.

Many radiographic measurement methods of shoulder subluxation have been reported (7–9, 13, 14). Severe inferior shoulder subluxation has a tendency to show medial displacement of the humeral head. It indicates that hemiplegic patients with severe inferior subluxation also have anterior subluxation and that HD ratio disparity may hence be used to evaluate anterior shoulder subluxation (12). Therefore, we chose the radiographic method reported by Brooke et al. (7) and measured the VD ratio for inferior shoulder subluxation and the LD ratio for anterior subluxation. In our study, there was no correlation between radiographic HD ratio and clinical evaluation scores, suggesting that radiographic HD ratio may only be used for the evaluation of anterior subluxation in cases of severe shoulder subluxation. We used the different landmarks in both radiographic and ultrasonographic measurements of shoulder subluxation. Therefore, it is impossible to compare the 2 methods directly.

Five important factors should be considered in developing a new method to measure shoulder subluxation in patients with post-stroke hemiplegia (22). First, subluxation should be assessed in tridimensions. Secondly, patients should be assessed in a seated position. Thirdly, patient position should be standardized during the measurement. Fourthly, the reference points should be based on the definition of shoulder subluxation. Finally, the affected shoulder subluxation should be measured relative to the unaffected shoulder to account for normal anatomic variation. In our study, ultrasonography was selected among currently available tridimensional imaging techniques, such as computorized tomography and magnetic resonance imaging, to measure shoulder subluxation because it can provide three-dimensional visualization of the shoulder in upright position without ionizing radiation.

On ultrasonography, the interface of bone and soft tissue is highly reflective, seen as a bright line with acoustic shadowing, and the high reflectivity of cortical bone and the tomographic nature of ultrasonography make it ideal for evaluation of bony contours. When the upper limb is hanging down the side, the greater tuberosity lays laterally, the lesser tuberosity anteriorly, and they are separated from each other by the bicipital groove. Therefore, the clinician can easily perform ultrasonographic measurement of shoulder subluxation with a basic degree of familiarity with both normal shoulder anatomy and the ultrasonographic appearance of bony structure. In our study, the anterior and lateral borders of the acromion, the greater and lesser tuberosities of the humerus were used as the ultrasonographic landmarks for the measurement of shoulder subluxation because these bony structures are highly echogenic and easily seen on ultrasonography.

To the best of our knowledge, our study is the first to use the ultrasonographic method to measure shoulder subluxation in patients with post-stroke hemiplegia. We calculated the ICC of the 2 measurements obtained from ultrasonography for the affected and unaffected shoulders as an index of the reproducibility and found excellent agreement between repeated measurements, confirming the high reproducibility of ultrasonographic measurements. The ICC of the unaffected shoulder was a little higher than that of the affected shoulder. In our study, split-screen imaging was used to measure cases of severe shoulder subluxation, which might be a potential source of error in repeated measurements. Therefore, the use of extended field-of-view imaging may better facilitate the measurement of larger distances and may thus have the potential for more accurate measurement and follow-up comparison (23).

Ultrasonography possesses several obvious advantages over radiography for the evaluation of shoulder subluxation in patients with post-stroke hemiplegia. First, ultrasonography can be used for serial evaluation of shoulder subluxation without exposure to ionizing radiation. Secondly, ultrasonography can easily be performed at the bedside and for patients who cannot independently maintain an upright sitting position. In such a case, a nurse may assist the patient to maintain a sitting position during ultrasonographic examination. Thirdly, ultrasonography can simultaneously measure inferior and anterior shoulder subluxation. Fourthly, ultrasonography directly measures the distance of shoulder subluxation and there is no need to standardize distances to the X-ray source and film. Finally, ultrasonography is a useful and widely available imaging technique to assess the painful shoulder in hemiplegia by the trained and experienced clinician with appropriate, high-resolution equipment. This is very important in patients with hemiplegic shoulder pain who may exhibit shoulder subluxation.

Our study had a few major limitations. First, ultrasonography could not be compared with the gold standard for the measurement and characterization of shoulder subluxation in post-stroke hemiplegia because no imaging method is currently used as it. Secondly, we did not assess the inter-rater reliability of the ultrasonographic measurements with more than one examiner. Finally, the study population was relatively small. Therefore, further research is needed to assess the variation of inter-rater reliability according to the experience of the examiner in a large population. Nevertheless, the results of our study suggest that ultrasonography can be used as a valuable method for the measurement of shoulder subluxation in hemiplegia.

In conclusion, we found good agreement between repeated ultrasonographic measurements and confirmed high reproducibility of ultrasonography for the measurement of shoulder subluxation in patients with post-stroke hemiplegia. Our study also revealed that ultrasonographic distance ratios, especially AD, had high correlation with clinical evaluation scores of the affected shoulder. Based on this confirmation of the advantages of ultrasonographic measurements, we strongly recommend ultrasonography as a new, tridimensional, diagnostic tool to measure the degree of shoulder subluxation in patients with post-stroke hemiplegia. Further study should focus on a more detailed ultrasonographic exploration of the determinants of hemiplegic shoulder subluxation and evaluating interventions for this.

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