Validity of Clinical Measures of Shoulder Subluxation in Adults With Poststroke Hemiplegia

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Key Words: assessment process, occupational therapy • hemiplegia

Objectives. Shoulder subluxation after cerebrovascular accident has been associated with chronic pain, orthopedic complications, peripheral nerve damage, and autonomic dysfunction. Clinical diagnosis and gradation of subluxation is problematic due to the lack of precision in frequently used measures. The objective of this study was to assess the validity of clinical techniques used to assess inferior subluxation of the hemiplegic shoulder by comparing these techniques with radiographic measurement.

Method. In 20 male subjects with hemiplegia, the presence, type, and degree of subluxation was assessed with three clinical measures: palpation, arm length discrepancy, and thermoplastic jig measurement. Anterior-posterior X rays of the hemiplegic shoulder were taken after clinical examination.

Results. Spearman rank correlation coefficients between the X rays and the three clinical measures were relatively low. Palpation had the highest correlation (r = .76), followed by arm length discrepancy (r = .46), and thermoplastic jig measurement (r = .42).

Conclusion. These findings provide cautious optimism about using these clinical measures to identify subluxation. Although detection was best with palpation, the likely inability to determine clinical overcorrecting of subluxation makes use of palpation alone suspect. Improved techniques of arm length measurement may provide a solution to this problem. These findings further necessitate that improved procedures for clinical assessment of subluxation be developed.

An estimated 500,000 Americans are disabled each year by cerebrovascular accidents (CVA), and many of them are left with paresis or complete paralysis of the contralateral upper extremity (American Heart Association, 1993). During the early stages of recovery after a CVA, subluxation of the glenohumeral joint may occur due to the absence of muscular support, stretching of the ligamentous support structures, or weight of the unsupported arm itself (Basmajian, 1986). Tension on the taut joint capsule over time produces laxity in the superior aspect of the capsule and, if left untreated, the resulting subluxation may become irreversible and unresponsive to treatment as fibrous changes occur in the connective tissue of the ligaments and joint capsule (Baker & Parker, 1986; Caillet, 1981; Jensen, 1980; Moskowitz, Goodman, Smith, Balthazar, & Mellins, 1969). Some authors have suggested that if the joint capsule could be prevented from stretching during the acute and flaccid stages of recovery, many patients would develop adequate muscle function to maintain the normal alignment in the glenohumeral joint with partial recovery (Andersen, 1985; Baker & Parker, 1986).

Subluxation is reported to be present in 29% to 75% of patients studied after they had stroke (Fitzgerald-Finch & Gibson, 1975; Miglietta, Lewitan, & Rogoff, 1959;
Moskowitz et al., 1969; Najenson & Pikielny, 1965; Shai, Ring, Costeff, & Solzi, 1984; Smith, Cawkshank, Dunbar, & Akhtar, 1982; Taketomi, 1975); however, there are varied opinions about the importance of identifying and treating subluxation. Davis (1990) stated that subluxation in and of itself is not a problem, rather, that complications may develop if a patient's arm is mishandled during transfers, range of motion, positioning, or other activities. Other studies have found associations between subluxation and shoulder and arm pain (Griffin, 1986; Poulin de Courval et al., 1990; Savage & Robertson, 1982; Tobis, 1957; Van Langenbergh & Hogan, 1988; Van Ouwenderf, Laplace, & Chantraine, 1986), brachial plexus injury (Kaplan, Menôth, Taft, & Betts, 1977; Meredith, Taft, & Kaplan, 1981), peripheral nerve damage (Chino, 1981; Ring, Leillen, Server, Luz, & Solzi, 1985) and changes in autonomic nervous system responses (Finch & Harvey, 1983; Tepperman, Greyson, Hilbert, Jimenez, & Williams, 1984). Although controversy exists about the role that subluxation plays in poststroke complications, it should not be ruled out as a contributor and, therefore, its management remains an important part of a comprehensive treatment plan for persons who have had CVA.

Techniques for measuring subluxation are geared toward analysis of inferior subluxation, although other patterns of subluxation may be present after CVA. Ryerson and Levi (1988, 1991) have described the presence of anterior subluxation. They contended that anterior subluxation is often secondary to the trunk gaining more control of extension than flexion, resulting in retraction and elevation of the scapula on the rib cage. During anterior subluxation, the humerus rests in a position of internal rotation and hyperextension relative to the thorax. Superior subluxation, where no palpable joint space exists, may be present in persons who have considerable return of tone in the trunk and scapula. In this situation, the humeral head is pulled up into the glenoid fossa and becomes lodged under the acromion. There currently are no methods to clinically quantify the presence or degree of anterior or superior subluxation.

Traditionally, occupational therapists have been responsible for identifying the presence of shoulder subluxation, treating the patient to reduce or prevent subluxation, and monitoring the patient's response to intervention (Davis, 1990). Until recently, therapists have relied on general clinical measures such as palpation to identify subluxation and on finger width measurements to determine the extent of subluxation. Agreement on determining the presence or absence of subluxation by palpating the suprascapular space and comparing it to the opposite side has been found among clinicians (Hall, Dudgeon, Guthrie, & Haselkorn, 1992). However, measuring the degree of subluxation has been regarded as imprecise for use in assessing effectiveness of clinical interventions (Caillet, 1981).

Some success has been achieved in attempts to quantify subluxation with clinical measurement tools (Bohannon & Andrews, 1990; Hayes & Sullivan, 1989). To date, four methods of measuring subluxation have been described: (a) radiographic measurement (Carpenter & Millard, 1962; Fitzgerald-Finch & Gibson, 1975; Lev-Toaff, Karasick, & Rao, 1984; Miglietta et al., 1959; Moskowitz et al., 1969; Najenson, Yacubovich, & Pikielny, 1971; Ring et al., 1985; Shai et al., 1984; Smith et al., 1982), (b) palpation (Bohannon & Andrews, 1990; Caillet, 1981; Chino, 1981; Miglietta et al., 1959; Taketomi, 1975), (c) measurement of the distance in centimeters by use of a caliper or tape measure (Hayes & Sullivan, 1989; Prevost, Arsenault, Dutil, & Droin, 1987), and (d) use of a thermoplastic jig (Hayes & Sullivan, 1989; Ritt et al., 1980).

Radiological exams are frequently accepted as the most objective measure of inferior shoulder subluxation. Subluxation on X rays is usually described as present or absent, or is graded by level of severity (Ring et al., 1985; Shai et al., 1984; Smith et al., 1982; Van Langenbergh & Hogan, 1988). However, the cost of X rays, exposure to radiation, and inconvenience of delayed feedback for clinical interventions make this test method impractical to many therapists. Therapists have sought to develop and rely on clinical measures of subluxation to guide practice. Therefore, attention to reliability and validity within and across measurement techniques has received increased attention (Boyd & Torrance, 1992).

Reliability of clinical measures of subluxation has been established in several studies. Bohannon and Andrews (1990) developed a 3-point scale of subluxation for thumb palpation (scored as none [0], minimal [1], or substantial [2]), and, with a sample of 28 patients, achieved a 91.7% agreement rate between two examiners. Boyd and Torrance (1992) used finger width palpation to measure 18 patients and achieved an interclass correlation coefficient (ICC) of .77 ($p < .05$) and .89 ($p < .05$) for two sets of raters.

A few studies have used calipers or a tape measure to assess arm length discrepancy (ALD) as an indicator of subluxation and its severity. Cromwell (1991) reported good interrater ($R = .93$) and intrarater reliability ($R = .94$) when a tape measure was used to assess subluxation through limb length discrepancy. Boyd and Torrance (1992) also achieved adequate levels of agreement in a study that used calipers to measure the subacromial space in centimeters in 36 patients with subluxation: Interrater reliability with the ICC ranged from .77 to .79, and intrarater reliability ranged from .81 to .95.

Hayes and Sullivan (1989) used a thermoplastic jig to clinically measure subluxation in 10 patients and reported an ICC of .89 ($p < .01$) for repeated measures by an individual rater and an ICC of .74 ($p < .01$) for more than one rater. These authors subsequently recommended the jig as a useful tool for clinical measurement of subluxation. However, Boyd & Torrance’s (1992) study on using the jig in measurement of subluxation found lower levels of agreement with clinical examination.
of intrarater (ICC .26 to .53) and intrarater reliability (ICC .51 to .84).

In comparison to the number of studies on the reliability of clinical measures, fewer studies have addressed the validity of these measures. Ritt et al. (1980) conducted the first concurrent validity studies of thermoplastic jig measurement (TJM) by comparing jig to X-ray measures and determined that a strong correlation existed ($r = .83, p < .01$). Boyd et al. (1995) compared radiographic measurement to three clinical measures of subluxation to establish the concurrent validity of a new X-ray technique. They found correlations for each of three measurements (palpation: $r_S = .69$, calipers $r_S = .72$, and jig measurement $r_S = .48$) and concluded that all three had moderate validity.

This literature review suggests that practical clinical measures of subluxation lack sufficient validity and weaken the occupational therapist's ability to use these measures for identifying changes in subluxation during the treatment period. Immediate feedback on treatment interventions to prevent or reduce subluxation is preferable. Therefore, we sought to determine the validity of commonly used clinical measures of subluxation and identify which method(s) have the greatest accuracy for the clinician. This study assessed the concurrent validity of three clinical measures of shoulder subluxation (palpation, ALD, and TJM) of patients with hemiplegia resulting from CVA by comparing their results on these measures with their radiological exams. Statistically significant correlations between each of the clinical measurements of subluxation and the X-ray measurements of subluxation were expected. The strength of the correlation with radiographs was expected to increase with the precision of the clinical method; therefore, we expected that the X-ray would be most strongly correlated with TJM, followed by ALD, and palpation.

**Method**

**Subjects**

Twenty subjects who met the criteria for the study were recruited. These criteria were that the subjects had: (a) a unilateral CVA or multiple CVAs in the same cerebral hemisphere, (b) no previous symptoms or history of orthopedic or neurological trauma in their shoulders, (c) an inability to abduct or flex the hemiplegic upper extremity above a horizontal plane at the shoulder, (d) an ability to transfer with moderate or less assistance, and (e) sufficient cognition to understand the consent form and cooperate with the evaluation. All 20 subjects were men. Their mean age was 63.4 years, with a range from 36 years to 84 years. Mean time since onset of CVA was 36.3 months, with a range of 1 month to more than 10 years. Ten subjects had right hemiplegia and 10 had left hemiplegia.

**Instrumentation**

All three measures (palpation, ALD, and TJM) were taken in the clinic setting. For palpation, subluxation was measured by palpat ing the subacromial space (the distance between the acromion and the superior aspect of the head of the humerus) with the index and middle fingers. The distance in finger widths was recorded on a scale of 0 (no subluxation) to 5 (2½ finger widths subluxation).

ALD was determined by measuring the subject's arm length between the lower border of the acromion process and the apex of the lateral epicondyle. This distance in millimeters then was compared to the same measurement on the subject's unaffected arm. The difference between the two measurements was the amount of subluxation.

For TJM, an L-shaped thermoplastic jig was fabricated. The jig is a 9-in. X 2-in. piece of ½-in. acrylic plastic with a 3-in. arm and a metric tape measure with millimeter increments embedded on the concave side. A 3-in. triangular beak, which may be moved up and down the plexiglass to measure the amount of subluxation, is attached (Ritt et al., 1980). To measure subluxation, the subject's elbow was flexed to 90°, and the short arm of the jig was placed under the elbow while a mark was made on the arm through a hole in the jig. The jig then was turned and the short arm was placed on the acromion. The beak was moved to the mark on the subject's arm and the distance was recorded. This procedure was repeated on the subject's unaffected arm. The difference between the two measurements was the amount of subluxation.

A standard X-ray machine was used to take a single anterior–posterior (A–P) radiographic view of each subject's hemiplegic shoulder. Degree of subluxation on the X-ray was determined by measuring the shortest perpendicular distance in millimeters between tangents drawn through the inferior border of the acromion and the most superior aspect of the head of the humerus of the affected arm (see Figure 1). Golding (1962) measured the distance between the acromion and the humerus in 150 persons' A–P X rays and reported that the normal range for the acromiohumeral distance was 7 mm to 13 mm. Similarly, Cotton and Rideout (1964) established an acromiohumeral distance range of 6 mm to 14 mm in normal A–P radiographs. In the present study, use of an established measurement for normal acromiohumeral joint space permitted the conservative use of radiographs (i.e., X rays were taken of the impaired upper extremity only, and an acromiohumeral joint space of 9.5 mm was used as an indicator).

**Procedure**

Subjects who consented to participate in this study were interviewed by the principal investigator to obtain demographic information. Subjects were also clinically
screened to determine the characteristics of their subluxation (i.e., inferior, anterior, superior, or combination) and the presence of pain in the hemiplegic arm. The presence of anterior subluxation was noted when a palpable space existed posterior to the head of the humerus, within which the glenoid fossa could be identified and the posterior edge of the acromion was prominent. Superior subluxation was suspected if no palpable space could be found. Subjects were also asked if they had any pain at rest and during movement of the hemiplegic arm.

After the interview, each subject was positioned in a stabilization chair—an 18-in. high straight-back wooden chair adapted with two straps, one attached at 18 in. from the floor to maintain the subject's hip position at 90° and a second attached at 28 in. from the floor to maintain the subject's posture and trunk stability during evaluation. The subject's arms were placed unsupported at his sides, in neutral rotation. Shoulder subluxation was measured by one of two therapists who were trained in the three clinical evaluation techniques before the start of the study. Each subject then was evaluated by palpation, ALD, and TJM; the sequence of these evaluations was randomized. Procedural reliability checks were conducted on each examiner at two randomly selected evaluation sessions during the course of the study to assure that the measurement protocols were followed. On both occasions, it was noted that the examiners were following written protocols precisely.

Within 30 min of completion of the three clinical measures, subjects were transported to the radiology department. To reduce the amount of exposure to radiation, each subject received a single standard A-P radiograph of his hemiplegic shoulder with the arm in neutral rotation. All X rays were taken with the subject seated in the same stabilization chair that was used for the clinical examinations. The principal investigator (the first author) assisted in positioning each subject for his X ray to assure uniform measurement techniques. All interviews, clinical examinations, and radiological procedures were conducted on each subject within a 3-hr visit.

Measurements of subluxation based on radiologic images were made at least 1 week after the X ray had been taken by an independent evaluator, who was blind to the results of each subject's clinical evaluation and trained in the established protocol for radiographic measurement of subluxation. Interrater reliability of 10 randomly selected radiographic measurements was .98 between the independent evaluator and a staff radiologist.

Data Analysis

Relationships between each of the three clinical measures of subluxation and the radiologic measure of subluxation were assessed by correlational study with the Statistical Package for the Social Sciences (SPSSx) software. For each subject, a set of four quantitative scores were obtained: palpation (number of finger widths subluxation), ALD (in millimeters), TJM (in millimeters), and radiographic measurement (in millimeters) (see Table 1). Spearman rank correlation coefficients were calculated to establish relationships between subjects' degree of subluxation as measured by each clinical measure and their degree of subluxation as measured by X ray (see Table 2). The level of agreement of the presence of subluxation was also determined, comparing each of the clinical measures to X ray.

Results

On the basis of a critical value that we chose of less than 9.5 mm as a normal joint space, all 20 subjects were thought to have subluxation, occurring across subjects in a range from 9.5 mm to 29.5 mm as measured from the radiographs. The Spearman rank correlation coefficients between degree of subluxation measured by palpation and X-ray were significant ($r_s = 0.76, p < 0.001$) (see Table 2). Palpation had a 90% agreement with X ray regarding the presence of subluxation, with two false-negative findings. The strength of this correlation may have been due in part to the lower sensitivity of palpation as a measure of the degree of subluxation (Boyd et al., 1993). We considered joint space of more than 9.5 mm to be a reasonable finding of subluxation. Use of a larger estimate of normal joint space (i.e., more than 10.0 mm) would have resulted in only one false-negative finding with the palpation measure, but at least three false-

Figure 1. Radiological measurement of inferior shoulder subluxation.
Table 1
Subluxation Measurements and Characteristics, Ranked By Radiologic Degree of Subluxation

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>X Ray (mm)</th>
<th>Palpation Arm Length Discrepancy (1 = ¼ Fingerwidth)</th>
<th>Arm Length Discrepancy (mm)</th>
<th>Thermoplastic Jig Measurement (mm)</th>
<th>Palpation on Exam</th>
<th>History of Shoulder Hand Syndrome</th>
<th>Suspected Anterior Subluxation</th>
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<tr>
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<td>29.5</td>
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Note: N = 20

Table 2
Correlations between X-Ray and Clinical Measures

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<th></th>
<th>Palpation</th>
<th>Arm Length Discrepancy</th>
<th>Thermoplastic Jig Measurement</th>
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<td>X Ray</td>
<td>0.76</td>
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<td>0.42</td>
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<tr>
<td>Significance level</td>
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<td>0.021</td>
<td>0.033</td>
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</table>

2Spearman rank correlation coefficients

positive findings because not all subjects would have been regarded as having subluxation.

Comparison of ALD and X-ray measures resulted in a correlation coefficient of $r_s = 0.46$ (see Table 2). ALD had a 75% agreement with X-ray regarding the presence of subluxation. Five subjects did not demonstrate subluxation according to ALD measures. In addition, four of these five appeared to have superior subluxation, as indicated by a shorter arm length measurement in the hemiplegic arm than in the nonaffected arm and greater evidence of hypertonus in the hemiplegic arm, than did subjects with greater severity of subluxation.

Measurements with the TJM also correlated with X-ray measurements ($r_s = 0.42, p < 0.05$) (see Table 2). Agreement between TJM and X-ray as to presence of subluxation was 80%. Evidence of a shorter hemiplegic arm length determined through TJM was also found among two of the four subjects in whom superior subluxation was suspected on the basis of ALD measures.

Table 2
Correlations between X-Ray and Clinical Measures

<table>
<thead>
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2Spearman rank correlation coefficients

**Subluxation Patterns**

Of the 20 subjects, 5 had clear evidence of anterior subluxation upon palpation; 2 others had evidence of excessive anterior positioning but evidence of anterior subluxation was not clear. Eleven of the subjects (55%) reported the presence of pain in the hemiplegic arm when at rest or when the arm was moved. Of these 11 subjects, 7 exhibited a tendency toward anterior as well as inferior subluxation. Before the study, 5 of the 20 subjects were diagnosed with shoulder-hand syndrome by a radiologist who observed evidence of increased bone demineralization on radiographs of the subjects’ affected shoulder and hand or bone scan of the hand. Of these five subjects, four had strong clinical evidence of anterior subluxation.

**Discussion**

To determine the validity of clinical measures, this study compared three methods of physical assessment of subluxation to X-ray. Spearman rank correlations between radiographs and clinical measures of subluxation ranged from 0.42 to 0.76—all statistically significant but disappointing relative to usual standards of validity. A desirable correlation coefficient for validity testing is usually greater than $r = 0.90$ (Dunn, 1989). In this study, the lower correlations between radiographs and clinical measures may reflect a variety of problems related to clinical stability of subluxation and changes in the subjects over time. They may also reflect measurement error resulting from procedural problems and the sensitivity of measurement.
in millimeters over surface anatomy. We had confidence in the accuracy of radiographic measures but found that the use of X rays was costly, increased the patients' exposure to radiation, and limited the delivery of immediate feedback (due to the need for review of X ray by the radiologist) about the therapist's clinical intervention in various contexts of care. Therefore, our desire to obtain better validity with clinical measures continues.

Some threats to the validity and, perhaps, the reliability of the measurements of subluxation may have been due to clinical features of hemiplegia. Muscle tone and in turn subluxation is likely to be influenced by factors such as changes in the environment (e.g., room temperature, surrounding activity), the subject's posture, and positioning. Given that many of these factors are difficult to control, it may be more helpful to consider acromioclavicular subluxation in the context of a range of measurements. During the day, and with changes in the environment, this range may fluctuate around a mean distance specific to each person. Palpation as a crude measure may be adequate for monitoring wide ranges of subluxation.

Another threat to validity may be experienced from limitations in joint space measurement over surface anatomy. It is likely that lower correlations between ALD, TM, and X ray were due to the greater sensitivity of these scales to variations in surface anatomy. For example, subtle changes in position and tone and differences in surface anatomy on left and right sides of a person's body could easily result in millimeters of discrepancy on a clinical scale.

Measurement discrepancies involving surface anatomy may also result because of difficulty in locating bony landmarks. The high degree of precision on X rays is possible because the examiner can directly measure distances between bones; however, it may not be realistic or practical to attempt to precisely measure the degree of subluxation in millimeters over surface anatomy. Using larger increments such as 1/2 centimeters with instruments such as a caliper, tape measure, or measuring jig may provide adequate feedback for some clinical interventions. Procedures may also be improved by use of more appropriate landmarks. For example, the use of the radiohumeral notch and the acromial angle as landmarks to measure arm length discrepancy may be more appropriate than the coracoid process and lateral epicondyle.

Despite measurement challenges, efforts to detect and quantify the severity of subluxation are needed to evaluate the effectiveness of clinical interventions. Miglietta et al. (1959) stated, “Since the degree of return of motor power and function cannot be predicted, it would appear important to attempt the prevention of subluxation of the shoulder in the hemiplegic patient by every means possible.” (p. 460). Subluxation has most commonly been treated with support devices such as slings and lap trays with the intent of reducing the degree of subluxation by counteracting the pull of gravity on the affected arm (Smith & Okamoto, 1981; Williams, Tafisi, & Minuk, 1988). Studies of the effectiveness of these devices have suggested that a variety of slings, lap trays, and wheelchair arm troughs may be effective (Boyd & Gaylard, 1986; Engstrom & Davies, 1980; Ferreri & Tuminelli, 1974; Iveson, Phillips, & Ream, 1972; Kieran, Willingham, Schwartz, & Firooznia, 1984; Krempen, Silver, Hadley, & River, 1977; Moodie, Brisbin, & Morgan, 1986; Williams et al., 1988). Use of neuromuscular electrical stimulation has also lead to substantial reductions in subluxation (Baker & Parker, 1986; Faghri et al., 1994). To deliver appropriate clinical interventions, however, the clinician must have an accurate and practical means of identifying the presence of subluxation, its characteristic pattern, and its severity.

Decisions about the sensitivity of the instruments used to measure subluxation can be based on the goals of measurement. For example, it may be sufficient to use palpation to determine if the patient's subluxation is serious enough to require devices such as slings and lap trays. On the other hand, if the patient has only a small degree of subluxation, a more sensitive instrument would be desirable to assure that further damage does not occur from overcorrecting the subluxation with support devices. Brooke, de Lateur, Diana-Rigby, and Questad (1991) recently reported that radiographs of 10 patients with subluxation showed a mean overcorrection of subluxation of 7.8 mm compared with the unimpaired shoulder, when the patients were positioned in an arm trough or used a wheelchair lap tray. Despite the weaknesses inherent in measuring subluxation over surface anatomy, use of arm length discrepancy measurement by tape measure or measuring jig could be more useful than palpation alone in identifying the influence of clinical interventions such as arm troughs or lap trays. Overcorrection of subluxation is very difficult to determine by palpation. Although arm length measures would likely provide some gauge of the problem of overcorrection, current methods of clinical evaluation need further development.

Therapists who treat subluxation should also include detection and treatment of other patterns of subluxation (anterior, superior). At present, radiographic techniques such as a single A-P view may be inadequate in identifying variations from inferior subluxation. In the present study, 7 of the 20 patients had some clinical evidence of anterior subluxation that could not be detected on A-P X ray. Current clinical techniques for measuring subluxation may need to be modified to address the altered relationship between the acromion and the humerus when anterior subluxation is present. The clinical measures of subluxation did not distinguish between inferior and anterior subluxation unless the examiner was specifically looking for this clinical presentation. Examiners reported that anterior subluxation was more difficult to measure. In fact, several clinical measurements were opposite those
expected for inferior subluxation (e.g., joint space was narrower on the hemiplegic side). The presence of shoulder-hand syndrome coincided with greater subluxation and an increase in muscle tone that in some cases led to an anterior subluxation pattern (Ryerson & Levis, 1988). A correlation between clinical palpation of anterior subluxation and a higher risk for development of painful poststroke complications is implied by our findings.

Further study focusing on establishing higher validity of the three clinical measures of subluxation would be useful in order to use these measures in practical and cost-effective clinical research. In addition, studies emphasizing detection of different patterns of subluxation and assessment of fluctuations in subluxation during activity would provide the therapist with better information regarding intervention. Until subluxation can be completely ruled out as a complicating factor in poststroke recovery, its management should be addressed as part of a comprehensive rehabilitation program. Therapists may be optimistic about identifying the presence of inferior subluxation; however, development and use of clinical techniques to monitor the type and severity of subluxation and to judge the effectiveness of its treatment need further attention.

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References


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