ORIGINAL ARTICLE

Comparative Effectiveness of the GivMohr Sling in Subjects With Flaccid Upper Limbs on Subluxation Through Radiologic Analysis

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ABSTRACT. Dieruf K, Poole JL, Gregory C, Rodriguez EJ, Spizman C. Comparative effectiveness of the GivMohr sling in subjects with flaccid upper limbs on subluxation through radiologic analysis. Arch Phys Med Rehabil 2005;86:2324-9.

Objective: To test the effectiveness of the GivMohr sling in reducing subluxation while providing joint compression through a flaccid limb, using the criterion standard of radiography for measuring subluxation.

Design: Anteroposterior 0° radiographs were taken of each subject: 1 of the unaffected shoulder and 3 of the affected shoulder; 1 without a sling, 1 with the GivMohr sling, and 1 with the Rolyan humeral cuff sling.

Setting: Two large rehabilitation centers.

Participants: Twenty-five adult volunteers with a flaccid upper limb (UL) secondary to cerebrovascular accident or other pathology.

Interventions: Not applicable.

Main Outcome Measures: Vertical and horizontal subluxation were measured in millimeters on each of the 4 radiographs for each subject.

Results: A 1-way analysis of variance revealed a significant main effect for vertical but not horizontal subluxation. Post hoc tests showed that the GivMohr sling measures were similar to measures for the uninvolved shoulder, but significantly different from measures for the Rolyan and the involved shoulder.

Conclusions: These results show that a properly fitted GivMohr sling reduces subluxation without overcorrecting. This new sling provides an alternative treatment option for persons with flaccid ULs that may prevent secondary complications and improve outcomes.

Key Words: Hemiplegia; Orthotic devices; Radiography; Rehabilitation; Shoulder.

STROKE AND OTHER central nervous system insults can result in a completely flaccid upper limb (UL), which, in turn, can lead to shoulder subluxation, a difficult and sometimes painful manifestation.[1] Subluxation is an increase in the space between the humerus and acromion, altering the mechanics and alignment of the joint, which allows the weight of gravity to pull caudally on the flaccid arm.[2,3]

Subluxation of the shoulder has been associated with numerous negative outcomes including electromyographic findings consistent with denervation in the affected UL.[4] Chino[5] reported delayed latency times, with the most notable slowing being in the suprascapular and axillary nerves. In addition, the musculocutaneous and radial nerves also showed abnormal conduction values despite the fact that these nerves are less involved in the suspension of the humeral head in the glenoid fossa. This early traction neuropathy can result in a transient nerve injury that delays rehabilitative and functional progress by months[4] or can become a long-term injury that is resistant to treatment.[6] The subluxated position of the humerus may also contribute to the pathogenesis of other conditions by stretching neurovascular and musculoskeletal tissues around the shoulder joint.[7] These conditions include limited range of motion, pain, brachial plexus injury, reflex sympathetic dystrophy, adhesive changes, and subacromial impingement among others.[8,9] In addition, subluxation is related to poorer motor return in the UL.[9] All of these conditions can significantly affect a patient's physical, functional, and psychosocial rehabilitation.[10]

Alternatively, as subluxation decreases, nerve latencies appear to improve.[11] If the UL is properly positioned during the flaccid stage, many people develop sufficient muscular activity to maintain the alignment of the glenohumeral joint.[6] Early intensive therapy including repetition and functional activity has been shown to lead to better return of arm function. However, this type of therapy should be delayed past the first 7 days after injury to avoid enlarging the area of the primary lesion.[12,13] The flaccid period of the shoulder appears to represent a critical time for preventing soft tissue damage of the shoulder girdle, while correctly timing interventions to increase arm function. During this time the paralyzed flaccid arm should be carefully protected, positioned, and supported.[2,5,6,14]

Supports and Slings

A variety of modalities and slings have been used to reduce subluxation and prevent secondary complications of the flaccid UL. Although many studies have examined the supports over the years, there is no consensus as to which provides the best treatment, including the consistent reduction of the subluxation. In fact, much controversy continues to exist over the use and effectiveness of these devices.[1,15-19] Despite a significant amount of research and development in this area, little change has occurred in the clinical setting. A follow-up survey by Boyd et al[20] indicates that management of the shoulder following stroke was unchanged in 10 years. Three of the 4 supports

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most frequently chosen by therapists in 1984 were still used 10 years later, with the same defined goals.

Slings included in research over the years include the single strap hemisling,[19] Harris hemisling,[21] Bobath shoulder roll,[18,19,21] Henderson shoulder ring,[18] and the Rolyan humeral cuff sling.[19] Modalities used with the flaccid UL include strapping or taping,[3] electric stimulation,[22-24] and wheelchair positioning.[21,25] All supports vary with regard to position and forces acting on selective parts of the subluxated limb, as they attempt to avoid the gravitational pull of the humerus and maintain correct anatomic alignment.[4]

Zorowitz et al[19] noted that 3 slings (Bobath shoulder roll, Rolyan humeral cuff, single strap hemisling) tested in subjects less than 6 weeks poststroke reduced the vertical asymmetry of glenohumeral subluxation, but only the single strap hemisling corrected vertical asymmetry to any significant degree. In addition, total asymmetry (combined vertical and horizontal subluxation) was significantly reduced, but not fully corrected with use of the Rolyan humeral cuff. This study also concluded that lateral displacement of the humeral head does not appear to result from the subluxation itself but may be caused by application of the supports. Williams et al[18] noted no difference between 2 slings (Bobath shoulder roll, Henderson shoulder ring) in reducing the amount of subluxation in the affected shoulder, but found statistically significant differences among measurements of the unsupported affected shoulder, the supported affected shoulder, and the unaffected shoulder. This study concluded that either of the 2 shoulder supports was better than no support in reducing shoulder subluxation.

The use of modalities for the treatment of subluxation is equally controversial. Faghri et al[26] reported that electric stimulation reduces subluxation, but Yu et al[27] did not find a significant relation between the use of intramuscular electric stimulation and subluxation. Linn et al[28] noted a decrease in the reduction of subluxation when the electric stimulation is removed and Ada and Foongchomcheay[22] reported a relation between acute subluxation but not in those with chronic subluxation. Strapping or taping is a new modality used in treatment of subluxation, also with conflicting results. Hanger et al[3] reported no evidence that strapping reduced the prevalence of subluxation, whereas Morin and Bravo[29] found that strapping in conjunction with a conventional sling significantly reduced subluxation greater than either condition individually. Lap boards and arm troughs provide reasonable approximation of the glenohumeral joint when the subject is seated in a wheelchair, but the seated position must be monitored constantly because overcorrection may occur and the lap board may cause skin breakdown on the forearm or near the olecranon process.[21,25]

Smith and Okamoto[17] examined the utility of 22 slings available in the early 1980s and provided a checklist of desirable and undesirable features based on a review of the literature at that time and clinical expertise. The checklist provided guidelines for clinicians to consider in prescribing slings (eg, protection of limb and ease of application). Of these features, positioning of the humeral head in the glenoid fossa was the most frequently cited desirable sling design feature. Other desirable positioning included humeral abduction, external rotation, and elbow extension. The criteria in this checklist continue to be supported by a wide range of authors.[30,31] Many of these criteria, including correction of subluxation, proper positioning, and protection of the affected UL, are used currently to evaluate the effectiveness of different kinds of slings.

A new sling, the GivMohr sling,[a] was originally designed to properly position the flaccid UL while providing joint compression through the UL. This joint compression provides sensory feedback and is intended to increase tone or muscle activity in the flaccid limb.[32,33] Although the sling has been used for that purpose, it also appears to have a positive effect on reducing shoulder subluxation. The sling holds the arm in a functional position (shoulder slightly abducted and externally rotated and elbow in extension) and provides protection of the vulnerable limb from injury. This leaves the limb free to provide counterbalance weight shifting in ambulation as well as providing dynamic joint compression through the UL joints during standing and ambulation (fig 1).

The sling holds the arm in a functional position (shoulder slightly abducted and externally rotated and elbow in extension) with a modified figure-of-8 strap of nonelastic webbing that loops around the anterior aspect of the unaffected shoulder and axilla and crosses between the scapulae. These straps are adjustable with buckles to modify the fit. The 2 elastic straps travel anteriorly and posteriorly down the affected arm and cross again to terminate in a palmar roll. A short perpendicular adjustable elastic strap at the lateral epicondyle joins the 2 longitudinal straps and provides support to the elbow in extension. The nonelastic webbing provides the support for the sling and the UL, and the elastic straps provide compression through the UL from the hand to the shoulder. Proper fit of the GivMohr sling is described elsewhere (*http://www.givmohrsling.com*) and includes the following: the cross of the figure-of-8 strap should be centered over the spine and low between the scapulae; the hand piece should accommodate the contour of the hand; the wrist cross should be centered over the wrist; the wrist should be in 30° of extension; the elbow should be in 30° of flexion or less; the elbow strap should be approximately 5cm (2in) distal to the olecranon process; and the shoulder should be in a neutral position. A final check should include finger palpation and clinical observation to ensure reduction of humeral subluxation.

Measurement of Subluxation

There are a number of ways subluxation has been measured, including palpation,[1,34] calipers,[35] Plexiglas jig,[10] and radiography.[35-37] Radiography has been considered the criterion standard for determining the amount of subluxation present. Different radiologic methods have been examined to find which is most effective and necessary. The methods most frequently investigated were: 0° anteroposterior (AP) view, 45° angle for articular configuration of the shoulder, and a complex tridimensional approach. According to Arsenault et al,[38] although the 45° angle approach may be more sensitive than the 0° AP approach, the difference in magnitude is clinically unimportant for the purposes of measuring subluxation. The complex tridimensional approach evaluated by Prevost et al[35] does yield a high level of precision, yet this approach was found to be far from necessary; the 0° AP was sufficient for pursuing a clinical study of subluxation. Studies by Brooke[21] and Zorowitz[19] and colleagues used the 0° AP view and were able to find significant differences in subluxation when comparing 3 and 4 different supports, respectively.

Summary

Subluxation is a common problem. Therefore preventative measures and appropriate treatment of glenohumeral joint subluxation should be performed as early and as vigorously as possible to decrease possible complications.[4,14,39] The purpose of this study was to determine if the GivMohr sling is effective in reducing shoulder subluxation in subjects with flaccid ULs. In addition, this study compared the GivMohr sling with the Rolyan humeral cuff,[b] which has been shown to decrease total joint asymmetry around the shoulder.

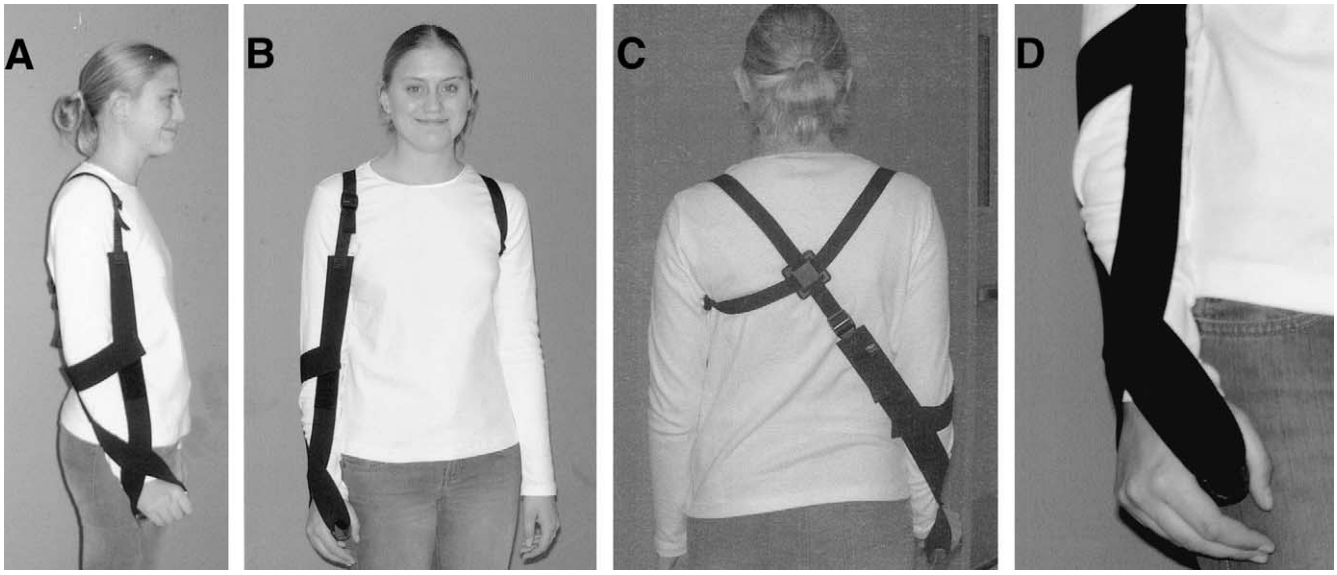

Fig 1. An unimpaired subject demonstrating the GivMohr sling. (A) From the side showing the elastic straps crossing at the wrist and the horizontal elbow strap distal to the olecranon. The horizontal elbow strap is attached with self-adhesive and can be adjusted higher or lower. (B) From the front showing the anterior elastic strap on the UL and the webbing straps in front of the shoulders with the buckle for adjustment. (C) From the back showing the webbing crossing between the scapulae and the adjustment buckle attachment to the elastic posterior strap. (D) Close-up view of the wrist and hand showing the wrist cross over the wrist and the hand piece.

METHODS

Participants

Twenty-five persons (14 men, 11 women) presenting with a flaccid UL were recruited for this study and signed informed consent to participate. The subjects were either current or prior patients at 2 large rehabilitation hospitals. Ages of the subjects ranged from 37 to 79 years (mean, 63.2y). Sixteen of the subjects had right-side flaccidity and 9 had left-side involvement. The majority (n=20) had flaccid upper extremities as a result of stroke; the other 5 had a variety of diagnoses including surgical recovery from epilepsy, brachial plexus syndrome, and traumatic brain injury. Mean time following the insult until time of assessment was 20.45 months (range, 0.5–264mo). The majority were less than 7 months postinsult, while 5 subjects were more than 18 months postinjury. Each subject's unaffected limb acted as his/her own control.

Procedure

This study was approved by the university's human research review committee, and by the research committees at both rehabilitation centers. After the subjects formally consented to participate, they answered a short questionnaire about diagnosis and pain levels. Then 4 standard AP radiographs were taken of each subject sitting in a chair without armrests. The UL was positioned unsupported in a gravity-dependent position at the side of the body. Because the majority of subjects were not able to stand, to standardize the procedures all subjects were radiographed in the sitting position. One radiograph was of the uninvolved shoulder, 1 of the involved shoulder with the GivMohr sling applied, 1 of the involved shoulder with the Rolyan humeral cuff applied, and 1 of the involved shoulder without any sling support. The first sling condition radiographed for each subject was determined by the condition in which the subject arrived at the radiography session; that is, wearing no sling, wearing the GivMohr, or using another support. In these facilities, the Rolyan sling is rarely used and, therefore, subjects who arrived with a different support system were radiographed with the Rolyan sling first. This provided for a natural counterbalance to control for order effects.

The radiographs were taken by a certified radiographer with 2 therapists present to apply and fit the slings according to the written instructions provided with each sling and assure consistent positioning of the subjects. The position of each subject's head and body was standardized as much as possible to decrease any variance in tone that may have affected the amount of subluxation present.

Radiographic Analysis

Radiographs were analyzed and measurements were made on a viewing box. Radiographic measurements were performed by blinded researchers.

Three reference points were marked to measure in millimeters the horizontal and vertical subluxation as selected by previous examiners.[21,35] The points include the central point of the glenoid fossa, the central point of the humeral head, and the most inferior and lateral point on the acromial surface of the acromioclavicular joint. First, the central point of the glenoid fossa is identified by marking vertical and horizontal edges. The bisection of these height and width measurements defines the central point of the glenoid fossa. To obtain the reference point on the humeral head, one must measure the greatest width horizontally across the head and bisect the line. The vertical component (V on figs 2–5) of glenohumeral subluxation was determined by measuring from the third point, the most inferior and lateral point on the acromion surface of the acromioclavicular joint, to the central point of the humeral head. The horizontal component (H on figs 2–5) was measured by the horizontal distance between the reference points of the glenoid fossa and humeral head (see figs 2–5).

RESULTS

Means and standard deviations (SDs) for each condition were calculated for the vertical and horizontal subluxation

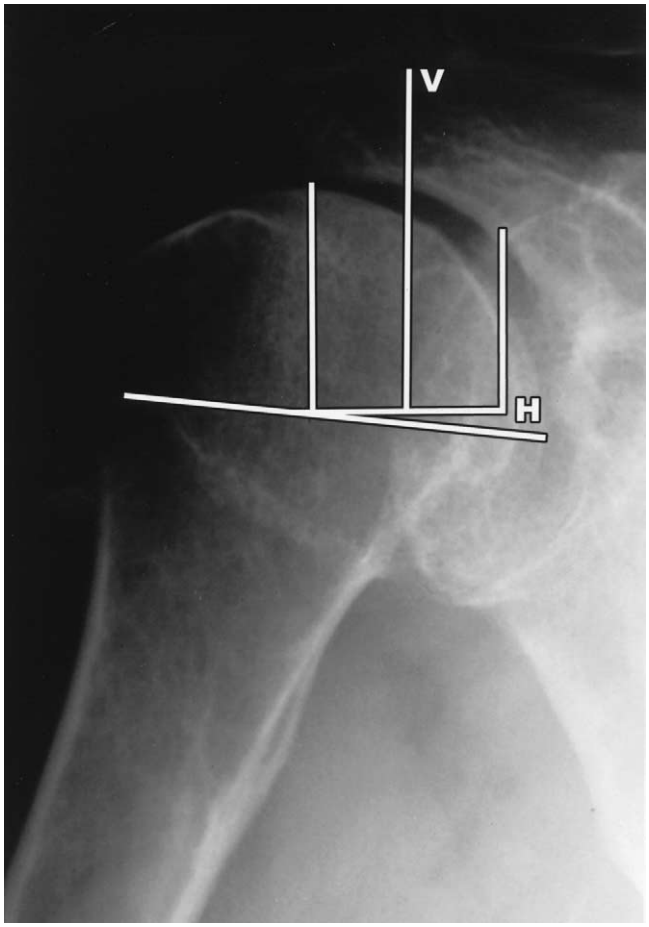

Fig 2. Radiograph of uninvolved shoulder. H indicates the horizontal component of the subluxation measured by the horizontal distance between the center points of the glenoid fossa and humeral head. V indicates the vertical component of the glenohumeral subluxation determined by measuring from the most inferior and lateral point on the acromion surface of the acromioclavicular joint, to the central point of the humeral head.

(tables 1, 2). As might be expected, the uninvolved shoulder displayed the least amount of vertical subluxation.

The means for the 4 sling conditions were compared using general linear model repeated-measures analyses. A significant main effect was found for vertical subluxation ($F_{3,22}=15.09$, $P<.001$) but not for horizontal subluxation ($F_{3,22}=1.38$, $P=.27$). Post hoc pairwise comparisons showed that the GivMohr sling vertical measures did not differ significantly from the uninvolved normal shoulder, but were significantly less than for the Rolyan ($P<.001$) and the unsupported involved shoulder ($P<.001$). The vertical subluxation for the Rolyan humeral cuff did not differ significantly from the unsupported involved shoulder, both of which were significantly greater than the uninvolved normal shoulder ($P<.001$) and the GivMohr on the involved arm ($P<.001$).

DISCUSSION

The results of this study indicate that the GivMohr sling significantly reduces vertical subluxation without overcorrecting in either vertical or horizontal positions. The Rolyan humeral cuff, which has been reported[19] to be the best sling to correct overall asymmetry of the affected shoulder, did not significantly reduce vertical subluxation. In fact, the measurements of the Rolyan were closest to the unsupported involved arm.

Neither the GivMohr sling nor the Rolyan humeral cuff significantly changed the horizontal subluxation. This was not a surprising finding because the amount of horizontal subluxation in a flaccid limb was minimal with no difference in horizontal subluxation between the uninvolved shoulder and the unsupported involved shoulder. According to previous research,[19] horizontal subluxation is often caused by a shoulder support rather than by pathologic mechanisms within the shoulder.

This study seems to validate the GivMohr sling's static qualities, specifically that it mechanically holds the humeral head in a physiologically sound position during rest. Future research should elaborate on the sling's dynamic qualities. Because of the design of the sling, the arm is less encumbered than with most other slings and it allows and even encourages movement within the realm of normal postural reactions. Based on this theory, future research may include an electromyographic study examining muscle firing of shoulder and elbow muscles in response to voluntary and involuntary stimuli, such as balance challenges and arm swing during gait.

There are several limitations in this study. First, the size of the sample selected was limited by funding to 25 subjects. Obtaining this number of subjects with a flaccid UL took more than 2 years and required volunteers from 2 different institutions. Second, only 1 radiograph of each condition was taken due to concern for

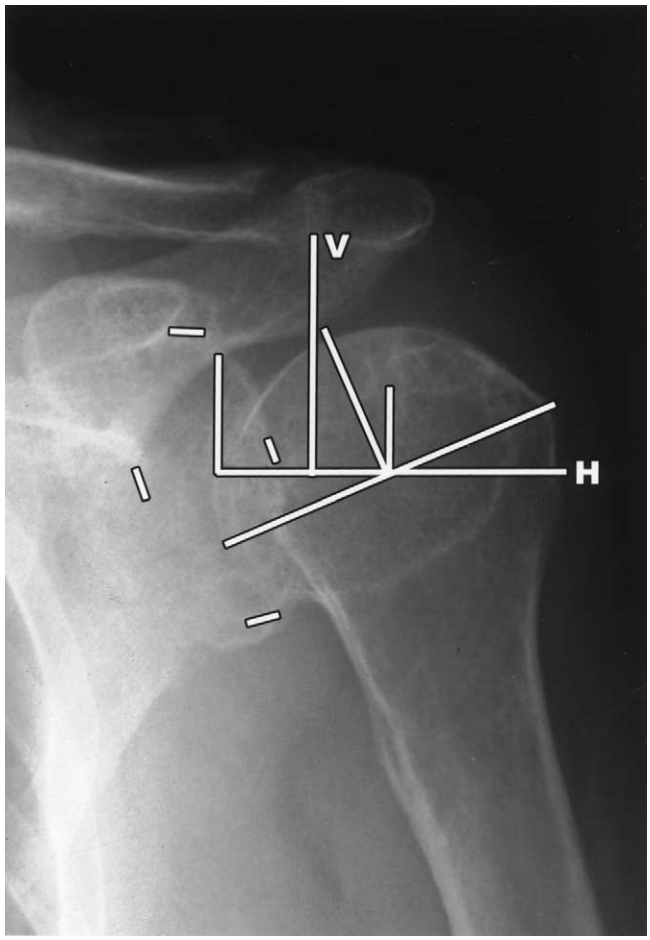

Fig 3. Radiograph of the vertical and horizontal components of subluxation in the involved shoulder with the GivMohr sling.

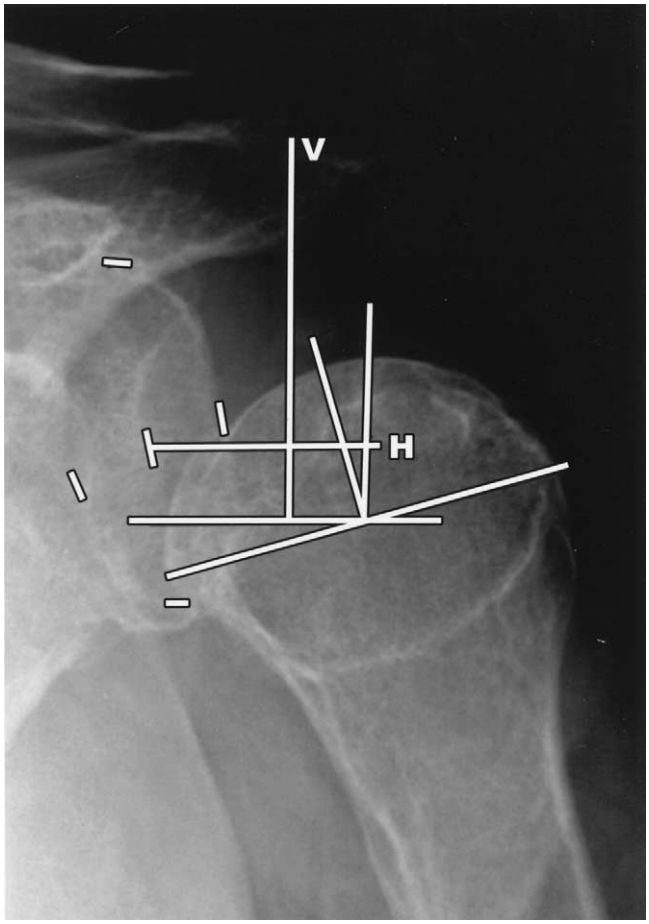

Fig 4. Radiograph of the vertical and horizontal components of subluxation in the involved shoulder with the Rolyan humeral cuff.

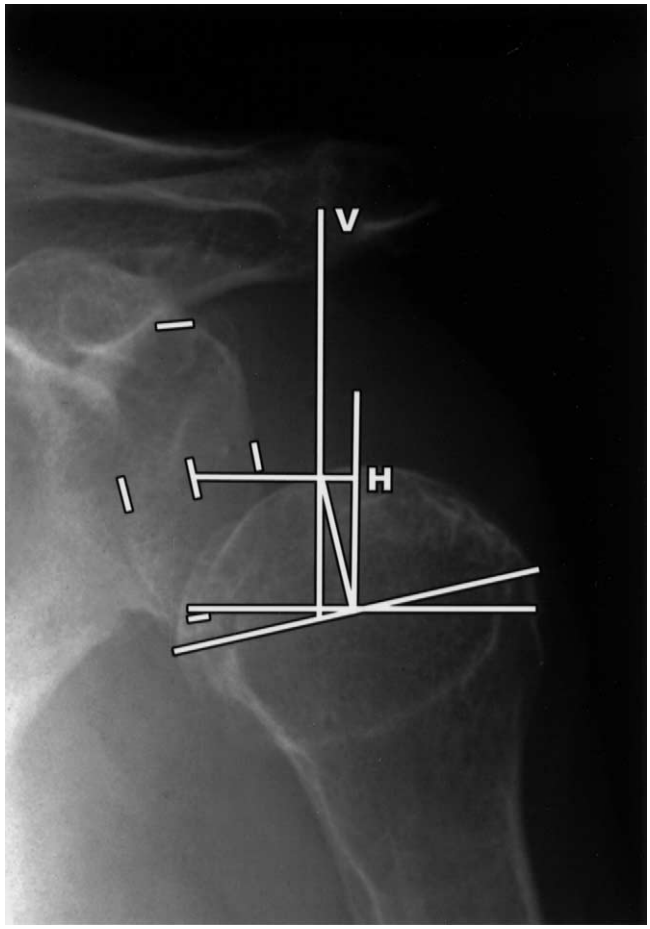

Fig 5. Radiograph of the vertical and horizontal components of subluxation in the involved shoulder without support.

exposure to multiple radiographs. When taking the radiographs, although a 0° standardized position was used, potential variation still occurred because of distance of the radiography equipment from the subject and any slight position variations of the slings. Third, although manufacturers' guidelines were followed to apply and fit the slings, the fit criteria are vague, especially for the Rolyan, and thus proper fit may be a confounding variable of the study. Fourth, it was not possible for the researchers to be blinded to the study because they were directly involved with all parts of the research, including recruiting subjects and scheduling radiographs. To counter the possibility of researcher effects, 2 therapists were always present during testing to verify proper sling placement, proper fit, and subject position. In addition, different radiologists were involved and the measurements were calculated by blinded researchers. It should be also noted that this research only measured the short-term effectiveness of the shoulder supports on subluxation. Long-term results will be the subject of a future study.

Use of an arm sling has been shown to improve gait in patients with hemiplegia.[40] Future studies with the GivMohr sling should explore the effect of the sling on gait, balance, and function. In addition, the effectiveness of the GivMohr sling on the reduction of pain or in the increase of functional movement of the limb over time would be a fruitful area of future study. Whereas this study used a variable range in time between insult/injury and assessment ranging from 2 weeks to 22 years, a future study with a larger sample might standardize the time span postinjury. Most of the subjects' flaccid ULs were caused by cerebrovascular insult, but several were not. Future research with a larger sample would allow subgroup analysis comparing acute with chronic subluxations within different diagnoses.

CONCLUSIONS

According to Morley et al,[30] there continues to be a lack of reliable and valid research evidence on which to base conclusions about any currently available methods to realign the low-toned and subluxated glenohumeral joint. Management of the flaccid UL continues to be a challenging issue. Based on the results of this study, the GivMohr sling provides an appropriate option for treatment. The sling's design is focused on proper anatomic alignment with emphasis on quality of movement and

Table 1: Vertical Subluxation

Sling Conditions	Mean ± SD (mm)
Uninvolved shoulder	39.70±5.81
GivMohr sling	40.24±7.49
Rolyan humeral cuff	47.86±9.35
Unsupported	47.70±8.85

Abbreviation: Unsupported, involved shoulder unsupported.

Table 2: Horizontal Subluxation

Sling Conditions	Mean ± SD (mm)
Uninvolved shoulder	26.46±4.35
GivMohr sling	27.16±4.63
Rolyan humeral cuff	25.58±6.17
Unsupported	26.42±4.79

function, in addition to decreasing subluxation and preventing secondary complications. Although further research is necessary, the GivMohr sling can be used during the critical acute period of the flaccid UL and also for the long term in those persons who continue with the flaccid state. In either case, the debilitating complications associated with subluxation can be avoided and the potential for functional recovery increased.

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Suppliers

a. GivMohr Sling, 10,000 Rio Grande Blvd NW, Albuquerque, NM 87114.

b. Sammons Preston Rolyan, 270 Remington Blvd, Ste C, Bolingbrook, IL 60440-3593.