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Biomechanical properties of the glenohumeral joint capsule in hemiplegic shoulder pain

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ABSTRACT

Background: Although many hemiplegic shoulder patients have been suffering from limited range of motion, it is not fully established whether the pathologic biomechanics are same in hemiplegic shoulder pain and adhesive capsulitis. Therefore we aimed to investigate biomechanical properties of glenohumeral joint capsules of hemiplegic shoulder pain with limited range of motions.
Methods: Participants were 14 patients with hemiplegic shoulder pain, 10 controls, and 42 adhesive capsulitis patients matched with the hemiplegic shoulder pain group for sex, age, and range of motion. Demographic data, clinical variables, and sonographic findings were comparable between hemiplegic shoulder pain and adhesive capsulitis groups. We compared capsular capacity, maximal pressure, and capsular stiffness of glenohumeral joint capsule among the 3 groups.
Findings: Hemiplegic shoulder pain and adhesive capsulitis groups had smaller capsular capacity and higher maximal pressure than controls. The capsular stiffness of hemiplegic shoulder pain group was higher than that of controls ($P = 0.001$) but lower than that of adhesive capsulitis group ($P < 0.001$).
Interpretation: The stiffness of glenohumeral joint capsules in hemiplegic shoulder pain and adhesive capsulitis patients was substantially higher than that in controls, suggesting that hemiplegic shoulder pain patients had stiffer capsules as adhesive capsulitis patients did although the severities were different. This finding implicates that hemiplegic shoulder pain may share common pathologic properties of tighter capsules with adhesive capsulitis. However, there may be additional mechanisms contributing to range of motion limitation in hemiplegic shoulder pain because capsular stiffness in those patients was not as severe as that in adhesive capsulitis patients with similar range of motion limitation.

1. Introduction

Hemiplegic shoulder pain (HSP) is one of the most common complications in stroke patients (Lo et al., 2003; Roy et al., 1994; Van Ouwenaller et al., 1986): its prevalence in this population is 38% to 84% (Joynt, 1992; McKenna, 2001). HSP is reported to be strongly related to the increase in hospitalization of these patients and their prognosis with respect to upper-extremity function (Lindgren et al., 2007; Roy et al., 1994). Many HSP patients have limited range of motion (ROM) in multiple directions (Bohannon et al., 1986; Lo et al., 2003), and they are commonly treated with injections, exercises, or other therapies (Partridge et al., 1990; Snels et al., 2000). A highly effective treatment option has not yet been developed, perhaps because the pathological mechanism has not been clearly identified.

Several causes may contribute to HSP: complex regional pain syndrome type 1 (Lo et al., 2003), rotator cuff tear (Cailliet, 1980; Najenson et al., 1971), shoulder subluxation (Roy et al., 1994), and adhesive capsulitis (AC) (Lo et al., 2003; Rizk et al., 1994). AC has been reported as one of the most important factors contributing to HSP (Hakuno et al., 1984; Lo et al., 2003). It is of note that HSP had a significant association with limited range of external rotation, which is thought to be distinctive of AC in the general population (Bohannon et al., 1986; Zorowitz et al., 1996). However, no published research indicates whether the pathological condition of the joint capsule is the same in HSP and AC.

Although the pathology of AC is known as fibrous dysplasia accompanied with inflammation of the glenohumeral joint (GHJ) capsule (Hand et al., 2007; Noel et al., 2000; Uhthoff and Boileau, 2007), pathological diagnosis of this relatively benign disease is impractical. A recent development in a real-time pressure–volume monitoring technique for

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intraarticular hydraulic distension (IHD) (Chung et al., 2009; Kim et al., 2009, 2011; Lee et al., 2008) circumvents this problem by providing information about biomechanical properties of GHJ capsules. Researchers who used this technique have documented significantly increased capsular stiffness in AC (Chung et al., 2009), close associations between limited ROM and capsular stiffness (Lee et al., 2008), and superior short-term outcomes of capsular preservation compared to conventional capsule-rupturing IHD (Kim et al., 2011).

Since the introduction of the monitoring technique in clinical settings, many AC and a few HSP patients have been treated, and quantitative data characterizing the biomechanical properties of their GHJ capsules are now available. Comparing these biomechanical data between control (CON) subjects without limited ROM, AC subjects with limited ROM, and HSP patients may elucidate the underlying mechanisms of HSP with multidirectional ROM limitations. To our knowledge, such a study has not yet been reported.

We aimed to characterize the GHJ capsular properties, specifically capsular capacity, maximal pressure, and capsular stiffness, of patients with HSP by comparing the pressure–volume (PV) profiles of HSP, CON, and AC subjects.

Table 1
Demographic and clinical variables, and sonographic findings.

	CON (n = 10)	HSP (n = 14)	AC (n = 42)	*P*
Demographic variables				
Sex ratio, male:female	6:4	7:7	16:26	.737
Age, mean (SD), years	53.6 (12.8)	59.3 (14.3)	63.2 (9.5)	.137
Height, mean (SD), cm	168.1 (9.8)	164.5 (10.0)	161.1 (7.4)	.090
Weight, mean (SD), kg	74.9 (16.0)	59.8 (10.8)	60.1 (10.9)	.019
Involved side, right (%)	9 (90)	6 (42.9)	23 (54.8)	.061
Symptom duration, months	NA	5.3 (3.8)	8.8 (8.9)	.249
Sonographic findings				
LBT sheath swelling, n (%)	1 (10.0)	7 (50.0)	27 (64.3)	.007
Rotator cuff partial tear, n (%)	4 (40.0)	5 (35.7)	19 (45.2)	.878
Calcification, n (%)	2 (20.0)	2 (14.3)	9 (21.4)	.905
SASD bursa swelling, n (%)	1 (10.0)	3 (21.4)	12 (28.6)	.545
Range of motions				
Abduction, mean (SD), °	105.1 (15.6)	57.3 (15.0)	62.1 (15.9)	<.0001
Forward flexion, mean (SD), °	161.4 (11.8)	95.4 (17.1)	94.5 (22.0)	<.0001
External rotation, mean (SD), °	58.0 (19.8)	27.1 (14.8)	30.3 (13.1)	<.001
Sum of ROM, mean (SD), °	324.5 (40.3)	179.8 (32.7)	187.0 (35.1)	<.0001

CON, control; HSP, hemiplegic shoulder pain; AC, adhesive capsulitis; SD, standard deviation; NA, not applicable; LBT, long biceps tendon; SASD, subacromial subdeltoid; ROM, range of motion.

2. Methods

2.1. Subject selection

We screened medical records of all patients who underwent IHD procedures for the first time to treat limited ROM of the shoulder in at least 2 directions from December 2006 to March 2012 at a special outpatient clinic dedicated to IHD (N = 606). Limited ROM was defined as <80° abduction, <130° flexion, or <30° external rotation as determined by goniometric measurement or reaching C7 or higher (external rotation) and L1 or lower (internal rotation) vertebrae in scratch test (Chung et al., 2009; Kim et al., 2011; Lee et al., 2008). Patients with any structural or systemic disorders that might result in pain or limited ROM, such as full-thickness rotator cuff tear, history of major trauma or surgery in the shoulder, inflammatory joint disease, or osteoarthritis, were excluded. The remaining patients (N = 592) had ROM limitations in 2 or more directions and considered to have features of AC. Among them, 14 had HSP, all of whom were included in the HSP group.

AC patients without neurologic problems were selected by propensity-score matching. A logistic regression model was created to derive a propensity score with sex, age, and ROMs of abduction, forward flexion, and external rotation as independent variables. Each HSP patient was matched with 3 AC patients. The matching process was supported by Medical Research Collaborating Center of Seoul National University Hospital.

Finally, we retrieved clinical and biomechanical data of 10 non-AC subjects without limited ROM; these subjects made up the CON group. These subjects had volunteered to participate in our previous prospective study (Chung et al., 2009). The CON group comprised 3 shoulders with partial tears of the supraspinatus tendon, 1 with mild shoulder pain and subtle shoulder laxity, 1 with calcific tendinitis, 3 with cervical radiculopathy, and 2 healthy shoulders. Written, informed consent was obtained from each CON subject.

The institutional review board of Seoul National University Hospital approved the use of patient data.

2.2. Patients' demographic and clinical parameters

Sex, age, height, and the involved side were not significantly different among groups (Table 1). The mean weight of the CON group was different from that of the other 2 groups, because both shoulders of a volunteer weighing 99 kg were included in the CON-group data. Symptom duration, ROMs, and sum of ROM were comparable between the HSP and AC groups, and this was as expected because subjects in the AC group were selected by matching the age, sex, and ranges of motion of each HSP subject. However, the CON group had significantly larger ROMs than the HSP group ($P < 0.0001$, 0.0001, 0.0005, and 0.0001, respectively) and AC group (all $P < 0.0001$).

The prevalence of rotator cuff partial tear, calcific nodules, and subacromial subdeltoid bursa swelling was comparable among the 3 groups (Table 1). However, the prevalence of long biceps tendon sheath swelling was higher in the AC group than in the CON group ($P = 0.003$). Otherwise, no statistically significant differences were found.

For the HSP group, we additionally reviewed the chart retrospectively to obtain clinical information. The time after stroke was 15 months (range 2–96). Of the 14 patients, 8 (57%) had left hemiplegia and 6 (43%) had right hemiplegia. Among them, 3 patients had grade 1 shoulder subluxation by de Bats Subluxation Scale (Chantraine et al., 1999). There was no patient who had shoulder–hand syndrome, which is diagnosed, in our department, when a patient complains aching pain, skin sensitivity, and swelling on his or her hand and increased uptake around the hand in a triphasic bone scan shows. Muscle power of shoulder abductor was measured by manual muscle test following the Medical Research Council scale (Paternostro-Sluga et al., 2008). We found that 3 patients had almost normal muscle power, 8 patients had grade 3 muscle power, 1 had grade 4 and 1 had grade 2; there was no record on muscle power for 1 patient.

2.3. Routine evaluation prior to IHD

Patient eligibility for the invasive IHD procedure was assessed by means of routine clinical and sonographic evaluations. Passive ROM was measured using a goniometer while the patient sat on a stool. Abduction and forward flexion of the GHJ were measured when the examiner elevated the patient's upper arm in the coronal and sagittal planes of the trunk, respectively. To eliminate the contribution of scapular movement, the subject was asked to relax as much as possible while the examiner pressed down on the clavicle and scapula with one hand. External rotation was measured with the shoulder adducted and elbow flexed to 90°. Because there is no practical way to measure internal rotation with a goniometer, we used a scratch test. External and internal ranges of rotation were recorded as the lowest and highest anatomical structure reached by the middle and first finger, respectively. After evaluation of ROM, a sonographic study of the affected shoulder was performed (Accuvix V20, Medison; Seoul, Korea). We documented long biceps tendon sheath swelling, rotator cuff tear, calcification, subacromial subdeltoid bursa swelling, and any other noteworthy findings.