INTRAOPERATIVE EMG RESPONSE OF THE MUSCULATURE AFTER STIMULATION OF THE GLENOHUMERAL JOINT CAPSULE

J. JEROSCH[1,2], J. STEINBECK[1], M. SCHRÖDER[1], M. WESTHUES[1], R. REER[2]

In an experimental study we investigated the EMG response in 10 human subjects after intraarticular stimulation of the shoulder joint capsule following arthroscopic insertion of the stimulating electrode in the anterior glenohumeral ligaments. The muscle response was documented by mono- or bipolar electrodes. Reproducible EMG response patterns were present in superficial as well as in deep muscle layers. The response time ranged from 100 to 516 msec. The earliest muscle response was found in the anterior part of the deltoid muscle and the latest one in the supraspinatus muscle and the lateral part of the deltoid muscle.

Clinical relevance : **The results of this study suggest a significant influence of the tension in the joint capsule on the activity of the stabilizing musculature.**

Keywords : shoulder joint ; proprioception ; intraoperative stimulation.

Mots-clés : épaule ; proprioception ; stimulation peropératoire.

INTRODUCTION

The stability of the glenohumeral joint is based on the integrity of the ligamentous structures, the muscular stabilization, and the osseous congruity of the corresponding joint structures. The glenohumeral joint presents a relatively small glenoid fossa facing a large humeral head like a golf ball on the tee. According to Resch *et al.* (33) minimum requirements regarding the diameter, the radius, and the inclination of the glenoid fossa are to be met to provide a stable base for the humeral head. The anterior and posterior glenohumeral ligaments and the coracohumeral ligament, as well as the joint capsule, are considered to be of main importance for passive shoulder stabilization (8, 9, 21, 31, 48). This capsular-ligamentous stabilization ensures the congruity of the corresponding joint structures at rest, and it restricts the range of motion in extreme positions. The muscles support and stabilize the passive structures (22, 31, 35, 38, 39, 47). The recent literature emphasizes mainly the ligamentous stabilization and presents studies of three different types :

1. Anatomic studies with selective preparation of the glenohumeral ligaments (9, 11, 12, 14, 38, 40, 47).
2. Clinical studies with description of the intra-articular pathology (3, 4, 7, 18, 35, 37, 38).
3. Biomechanical studies based on selective section of ligaments or direct measurements of the strain on the ligaments in different positions (15, 19, 20, 22, 43, 48).

These studies demonstrated the strain on different capsule-ligament structures in different functional positions. However, the small diameter of different ligaments found in anatomical preparations or arthroscopic interventions is striking to the critical observer. In contrast to other major joints, for example the knee joint, where the cruciate ligaments make up a strong central column and the collateral ligaments facilitate an efficient lateral stabilization, the glenohumeral joint ligaments are rather weak structures.

[1] Orthopedic Clinic Harlaching, Harlachinger Str. 51, 81547 Munich, Germany.

[2] Institute of Sports Medicine, Westfälische Wilhelms-University Münster, 48149 Münster, Germany.

Correspondence and reprints : J. Jerosch.

On the other hand, it is well known that an injury to the anterior capsule-ligament complex is associated with a high risk of recurrent shoulder instability. Despite their relative weakness, the capsular structures seem to be of importance for joint stability. The purpose of this study was to evaluate the proprioceptive importance of the glenohumeral joint capsule.

MATERIAL AND METHODS

Subjects : Intraoperative EMG responses were measured experimentally in 10 patients with subacromial pathology. The patients' ages ranged from 25 to 67 years ; none suffered from any kind of shoulder instability. Arthroscopy did not reveal any intraarticular pathologic findings indicating an unstable glenohumeral joint.

Anesthesia : In order to exclude possible influences on the EMG response by the narcotic gases, we used a modified neuroleptanalgesia (tranquanalgesia). This was an analgesic-based anesthesia without narcotic gases, based mainly on fentanyl and benzodiazepines. In one subject serving as an internal control we blocked the neural pathway by plexus anesthesia.

Arthroscopy : Arthroscopy was performed in the beachchair position. We first used a dorsal portal to the glenohumeral joint. After complete joint inspection an anterosuperior portal was developed with an outside-in technique. The intraarticular stimulation electrode was inserted through this portal. This electrode was a screw electrode which was placed in the anteroinferior capsule (fig. 1). During the whole procedure the joint was filled with a nonconducting fluid in order to avoid unselected stimulation of glenohumeral structures.

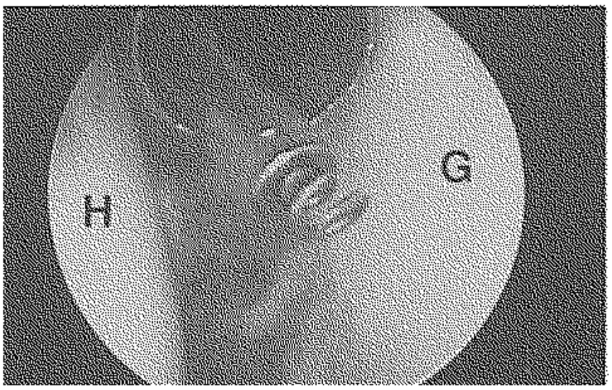

Fig. 1. — Intraoperative placement under arthroscopic control of the stimulation electrode into a right shoulder. The dorsal view shows the stimulation electrode on the top, the glenoid fossa on the right side (G), the humeral head on the left side (H) and the anterior joint capsule.

Intraoperative response : Stimulation current of 100-200 V and stimulation frequency of 1-2 hz were applied (Schwarzer EMG 2002). The value of the electric current was automatically set by the EMG between 100 and 200 V in accordance with the individual needs and reactions of each individual, but was limited to 90 mA. With this stimulation technique adapted to each subject we attempted to generate the minimum receptor potential leading to a muscle response. With this set-up each muscle was tested in every subject. The muscle potentials generated were recorded with bipolar or unipolar needle electrodes (fig. 2). Bipolar electrodes were applied in the superficial muscle groups (trapezius muscle, pectoralis muscle, deltoid muscle with its three parts, biceps brachii muscle) and unipolar needle electrodes in the deep muscle groups (teres minor muscle, subscapularis muscle, supraspinatus muscle, infraspinatus muscle).

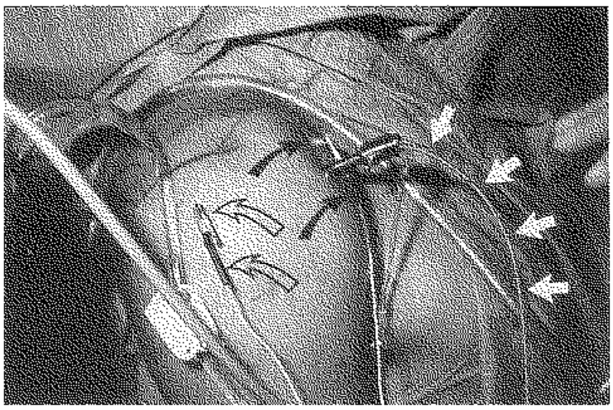

Fig. 2. — Intraoperative set-up and placement of the measuring electrodes in the outside view of a right shoulder (anterior : right ; posterior : left). The intraarticular bipolar stimulation electrode (white arrows) is placed through the superoanterior portal ; the arthroscope is placed through the dorsal portal. On the lateral side a positive electrode is placed in the deltoid muscle (open black arrows), and on the ventral side a negative electrode (closed black arrows) is placed subcutaneously.

Stimulation electrode : A cardiological pacemaker electrode (Modell Y, Biotronics) was used for the intraarticular stimulation. The electrode was screwed into the joint capsule with its helicoidal apex. The head of the screw electrode had a surface area of 12 mm^2, and the ring electrode had a surface area of 48 mm^2. The electric circuit between the stimulation electrode, the patient and the EMG device was established with grounding conduction connecting the EMG-device with the patient, where it was further connected with the forefoot of the contralateral lower extremity. EMG response : the alterations of the membrane potential were recorded by a bipolar response. The positive needle electrodes were placed directly in the bulk of the relevant muscle. The negative electrodes were positioned subcutaneously. The response curves of the muscles were stored, the recorded data were measured and the latency periods were determined by an internal computer and were taken from the impulse to the beginning of the response curve.

RESULTS

The results of EMG recording in the first two subjects tested were too irregular owing to technical difficulties. Except for the one patient with plexus anesthesia, alterations of the membrane potential were detected in all other subjects in the superficial and in the deep muscle groups after intraarticular stimulation (fig. 3).

The EMG response in the different muscle groups occurred with a clearly demonstrable latency period between 100 and 516 msec, ruling out an immediate transmission of the impulse. The shortest latency periods could be demonstrated in the anterior part of the deltoid muscle. In an ascendant sequence the EMG responses of the other muscles were as follows : pectoralis major, posterior part of the deltoid, teres minor, infraspinatus, trapezius, subscapularis, biceps brachii, supraspinatus and the lateral part of the deltoid (table I). No significant differences were noted. We did not perform a quantitative or qualitative differentiation of individual muscle groups.

In the one patient with plexus anesthesia no EMG response after stimulation of the glenohumeral joint capsule was detected. This excluded the direct overflow in this set-up.

Table I. — Latency periods of different muscle groups after intraarticular stimulation of the shoulder joint capsule

	minimum	maximum	mean	standard deviation
trapezius :	286 ms	324 ms	302.0 ms	18.3 ms
delt. ant. :	100 ms	372 ms	215.5 ms	90.0 ms
post. :	232 ms	269 ms	251.6 ms	15.2 ms
lat. :	433 ms	510 ms	470.6 ms	31.5 ms
pect. :	110 ms	353 ms	229.3 ms	88.0 ms
infrasp. :	132 ms	425 ms	287.8 ms	104.3 ms
suprasp. :	377 ms	516 ms	424.5 ms	54.7 ms
subscap.. :	304 ms	377 ms	349.3 ms	28.3 ms
biceps :	356 ms	416 ms	386.0 ms	24.5 ms
ter. min. :	142 ms	352 ms	252.6 ms	86.1 ms

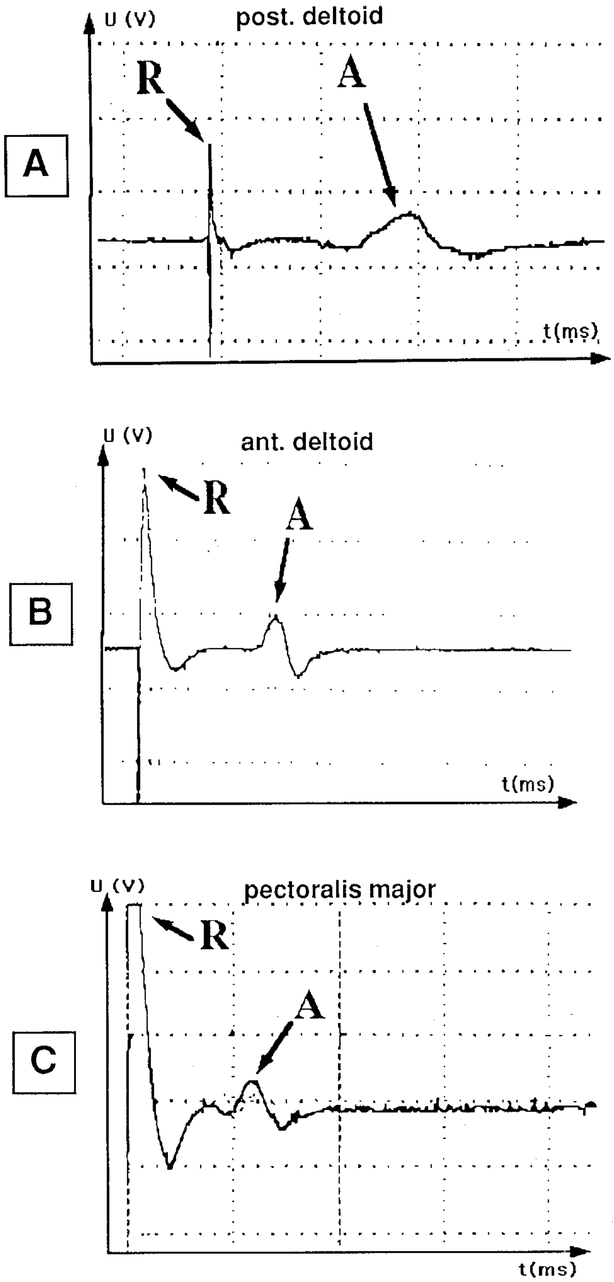

Fig. 3. — EMG signal after intraarticular stimulation (R) of the joint capsule ; posterior deltoid muscle, anterior deltoid muscle, pectoralis muscle.

DISCUSSION

In the 19th century, the neurologist Duchenne stressed the importance of sensory impulses from articular structures (32). Physiologists also considered the sensory information from periarticular structures to be an important source for proprioreceptive and kinesthetic information (2, 44, 45, 49). In 1944 Abbott (1) discovered sensory innervations in knee ligaments. He concluded that signals transferred to the central nervous system regulate the joint-stabilizing muscles.

After cruciate ligament reconstruction Kennedy *et al.* (27) found that good short-term results always deteriorate in the long run. According to their opinion the loss of the feedback mechanism by the mechanoreceptors would explain this phenomenon, rather than reduction of the mechanical stability of the ACL-transplant. Many ultrastructural studies concentrated on the knee joint.

Schultz *et al.* (41) and Schutte *et al.* (42) detected mechanoreceptors in the anterior cruciate ligament. In a light-, scanning electron- and transmission electron microscopic study Haus *et al.* (17) classified 3 types of nerve endings :

1. Pacini's corpuscles transferring fast alterations of forces, showing a fast adaptation and low stimulation threshold.
2. Ruffini's corpuscles signalling slowly changing dimensions of effecting forces and showing a slow adaptation and a low stimulation threshold.
3. Free nerve endings reacting as nociceptors and signalling pain and possibly mechanical and thermal stimuli as well.

Does the shoulder joint follow mechanisms comparable to those in the knee joint ? Injury to the anteroinferior ligament complex is the main predisposing factor for shoulder instability. According to the literature the incidence of accompanying Bankart lesions ranges from 27% to 100% (36). Baker *et al.* arthroscopically examined patients after traumatic shoulder dislocation within 10 days after the initial injury (3). Besides different intraarticular injury patterns they found the most unstable shoulder joints in patients with a complete avulsion of the anterior labrum complex (Bankart lesion) (4). Wheeler *et al.* (50) found a redislocation rate of 92% after a traumatic anterior shoulder dislocation in young athletes. After arthroscopic labrum fixation in comparable subjects the redislocation rate could be reduced to 22%. These clinical observations of Baker and Wheeler emphasize the clinical relevance of the traumatic disruption of the anterior capsule-labrum complex in the pathogenesis of the posttraumatic shoulder instability.

The neurological structures in the joint capsule detected by Jerosch *et al.* (23, 25) seem to be of clinical relevance. These histological studies demonstrated mechanoreceptors (Pacini's corpuscles) in the glenohumeral ligaments (23, 25). The receptors are considered to belong to the fast adapting type (5, 13, 51) called "acceleration receptor" (44). Other authors pointed out that these mechanoreceptors are activated by each movement regardless of the starting position of the joint and they found out that the answer of the receptors was a function of the motion velocity (6, 10). Other authors also reported on the presence of mechanoreceptors in the glenohumeral joint capsule (16, 34) or in para-articular structures (20, 30). Furthermore, there are clinical studies on proprioreception (24, 28, 29).

The present findings suggest that the joint capsule contains probably so-called PD-receptors which are a combination of proportional (intensity detectors) and differential (velocity detectors) receptors. An electrical stimulation will depolarize all receptor structures of the joint capsule. A receptor potential will be generated since an electrical stimulus adequately addresses each type of receptor. This may be a reason for the response of almost all muscles of the shoulder girdle.

The different response time in different shoulder muscles is also not surprising, taking into account that, during shoulder motion, different EMG-patterns of the surrounding musculature can be obtained. This shows that each muscle has its own function in different shoulder positions.

The long latency reflexes of the EMG-response corresponds to similar findings in the knee joint. Johansson *et al.* (26) stated that the long latency in response excludes a direct protective reflex at the knee joint. They postulated an indirect in-

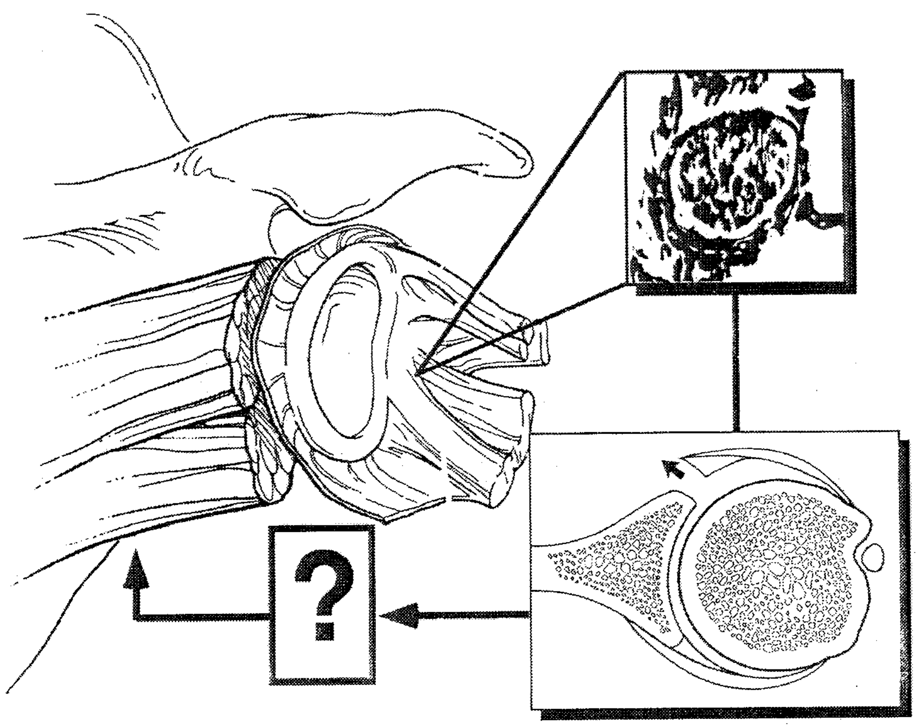

Fig. 4. — Possible feedback mechanism for coordinating muscle function around the shoulder joint.

fluence on the discharge of the alpha-motoneurons via the gamma-spindle system by alteration of the sensitivity of the muscle spindles. By this mechanism the mechanoreceptors cause a certain pretension of the musculature and therefore an increase in joint stability. A direct muscle reflex can no longer be supported.

Therefore, many factors point to a kind of sensory function (biological strain gauge). Through this mechanism the shoulder stabilizing musculature may be partially regulated. A traumatic disruption of the capsule-labrum-structure may lead to a decrease of this feedback mechanism causing a deterioration of the active muscular stabilization which is of such great importance especially for the glenohumeral joint. The increased translation strain on the hyaline cartilage and the repetitive micro- and macro-trauma to the joint lead to early joint degeneration and to further decompensation of the passive stabilizers (fig. 4).

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SAMENVATTING

J. JEROSCH, J. STEINBECK, M. SCHRÖDER, M. WESTHUES, R. REER. Intraoperatief EMG-antwoord van de musculatuur na stimulatie van het gleno humeraal gewricht.

In een experimenteel onderzoek werd het EMG-patroon bij 10 patiënten na intraarticulaire stimulatie van de kapsel van het schoudergewricht geanalyseerd. De intraoperatieve stimulatie werd verricht nadat arthroskopisch de stimulatiecatheter in de voorste glenohumerale ligamenten geplaatst was. De reactie van de spier werd m.b.v. mono- of bipolaire elektroden gedokumenteerd.
Resultaten : er werd een reproduceerbare EMG-spierreaktie in de oppervlakkige en de diepe spierlagen geregistreerd. De reactie tijd varieerde van 100 tot 516 ms. De vroegste spierreactie werd in het voorste gedeelte van de m. deltoideus en de laatste in de supraspinatus spier en het laterale gedeelte van de m. deltoideus gezien.

RÉSUMÉ

J. JEROSCH, J. STEINBECK, M. SCHRÖDER, M. WESTHUES, R. REER. EMG peropératoire des muscles de l'épaule après stimulation de la capsule gléno-humérale.

Les auteurs rapportent les résultats d'un travail expérimental qui a étudié chez dix individus la réponse EMG à une stimulation intra-articulaire de la capsule articulaire de l'épaule après insertion arthroscopique d'une électrode de stimulation dans le ligament gléno-huméral antérieur. La réponse a été enregistrée grâce à des électrodes mono- ou bipolaires. Des types reproductibles de réponses EMG ont été relevées dans les couches musculaires superficielles et profondes. Le temps de latence variait de 100 à 516 msec. La réponse la plus précoce a été observée dans la partie antérieure du deltoïde et la plus tardive dans le sus-épineux et la partie latérale du deltoïde. Les résultats de cette étude suggèrent que la tension de la capsule articulaire exerce une influence significative sur l'activité des muscles stabilisateurs.