

Neural Anatomy of the Glenohumeral Ligaments, Labrum, and Subacromial Bursa

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Summary: The neural histology of the human shoulder ligaments, glenoid labrum, and subacromial bursae were studied using a modified gold chloride stain. Two morphological types of mechanoreceptors and free nerve endings were found in the ligaments. Slow adapting Ruffini end organs and rapidly adapting Pacinian corpuscles were identified in the superior, middle, inferior, and the posterior glenohumeral ligaments. These specialized proprioceptive nerve endings were also found in the coracoclavicular, and coracoacromial ligaments. Only free nerve endings were found in the glenoid labrum and these were located in the peripheral half. Scattered free nerve endings were found throughout the subacromial bursae. This is the first histological evidence of neural receptors in the human shoulder ligaments, glenoid labrum, and the subacromial bursae. Any disruption of the labrum or these ligaments by trauma or surgery can deprive the shoulder of mechanical stability, and may cause a decrease in proprioception because of the loss of these afferent neural receptors. Removal of symptomatic, inflamed bursae may decrease pain signals from this area of the shoulder. **Key Words:** Labrum—Bursae—Ligaments—Shoulder—Neuroanatomy.

There has been no extensive neurological study of the human shoulder joint. The neural input of the shoulder ligaments, glenoid labrum, and subacromial bursae has never been directly investigated histologically. Gardner,¹ in 1948, reported on the gross neural anatomy of the shoulder capsule describing its nerve supply from the suprascapular, axillary, and anterior thoracic nerves. He also traced nerves from the capsule originating from the posterior cord of the brachial plexus, the stellate ganglia, and branches from the radial nerve. He alluded to nerve endings in the capsule

similar to those in the cat knee joint and mentions tracing these nerves as fibers. Neural receptors in the capsule, labrum, ligaments, or subacromial bursae of the shoulder have not been directly observed or classified.

Many studies involving neural receptors in joints have been carried out on the knee joints of cats.²⁻⁸ Recent studies have identified and classified the afferent neural end organs of the human knee joint⁹ and the anterior cruciate ligament.^{10,11}

The purpose of this article is to describe the sensory innervation of the glenohumeral ligaments, glenoid labrum, and subacromial bursa of the human shoulder.

MATERIALS AND METHODS

The coracoclavicular, coracoacromial, and acromioclavicular ligaments along with the superior, middle, inferior, and posterior glenohumeral ligaments were obtained at autopsy from eight fresh (<72 hours since death), unembalmed cadavers aged 24 to 46 years.

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These ligaments were placed in normal saline, cut into segments 1.0 to 1.5 cm long, and stained in bulk using a gold chloride stain modified by Zimny et al¹² for showing nerve endings in frozen sections. After staining, the segments were frozen and sectioned on a sliding microtome at a thicknesses of 25 μ m. The sections were then dehydrated and mounted on glass. Consecutive serial sections were observed under light microscopy and neural receptors were identified and photographed. Analysis of consecutive sections permitted an estimate of the quantity and types of neural receptors in these ligaments.

Four macroscopically intact labrum were cut from the glenoid at autopsy and processed as above in a further modification of the Zimny technique.¹³ Frozen sections of a 25- μ m thickness were dehydrated and mounted on glass. Serial sections of the anterior, posterior, superior, and inferior zones of the labrum were examined under light microscopy. The identification and classification of the types of receptors were based on the studies of Halata,⁸ Skogland,¹⁴ Zimny et al.,^{12,13} and through personal communication with Zimny.

Five subacromial bursae were removed, placed in 10% formalin, and processed with the gold chloride stain to investigate the presence of neuroreceptors and free nerve endings. Consecutive 25- μ m frozen sections of bursal tissue were prepared and stained before light microscopy evaluation.

RESULTS

Neural end organs existed in all ligaments of the shoulder that this study addressed. Pacinian corpuscles, two types of Ruffini end organs, and free nerve endings were found within the collagenous structure of the ligaments as well as in the surrounding connective tissue. No difference in distribution was noted by age.

The most abundant neural mechanoreceptor found in the shoulder ligaments was the classic Ruffini end organ (Fig 1). The Pacinian corpuscles were less abundant overall (Fig 2), but more commonly seen in the glenohumeral ligaments than in the accessory ligament studies. The Ruffini end organ described by Halata was rarely found in the glenohumeral ligaments. Its presence in the other ligaments was more common, yet less than the other two types of mechanoreceptors. The distribution of the neural end organs appeared to be equal among all the coraco-clavicular ligaments and the acromial-clavicular joint ligaments.

The glenoid labrum showed no evidence of any mechanoreceptors. Free nerve endings were noted in the surrounding connective tissue. Occasional free

nerve endings were noted in the fibro-cartilage tissue of the labrum and these appeared only in the peripheral half.

The subacromial bursae showed only diffuse copious free nerve endings (Fig 3). Larger, more complex mechanoreceptors were not seen in the bursal tissue.

DISCUSSION

The neural receptors found in the shoulder joint are specialized afferent end organs broadly classified as mechanoreceptors. Mechanoreceptors act as transducers converting mechanical energy of physical formation into electrical energy of a nerve action potential.^{2,5,8} The greater the stimulus the more rapid the rate of neural firing from the receptor. The central nervous system uses the rate and frequency of the receptor's impulses to analyze the position of the joint.^{3,4}

Mechanoreceptors also possess the property of adaptability, the intrinsic ability of the receptor to decrease the frequency of impulses with a continued unchanging stimulus. A rapidly adapting receptor can identify the change in tension of the ligament, but quickly decreases its impulses once the tension becomes constant. In this way, these receptors can monitor acceleration or deceleration of a ligament's tension. Slow adapting receptors have the ability to continuously respond to tension in the ligament. They identify motion and position of the ligament and allow the central nervous system to interpret the motion and position of the joint.^{5,7,10,11}

The authors observed three types of mechanoreceptors in this study. All three have been described in previous studies, but they have never been observed around the shoulder. Two types of slow adapting Ruffini end organs were identified. The first type, or classical Ruffini receptor has a low threshold and responds to slight changes in tension in the ligament.⁴ Its slow adaptability allows constant input from the ligament.

A second type of Ruffini end organ, best described by Halata,⁸ was also identified. Although these receptors resemble small Golgi tendon organs, the ultrastructure and function of these receptors is similar to a Ruffini receptor with the additional capacity of slow adaptation. The fast adapting Pacinian corpuscle, found in abundance in the anterior cruciate ligament,^{10,11} was not as common in the shoulder ligaments.

The shoulder has a wide range of motion, and the proprioceptive neural input from the shoulder requires more receptors that sense position (slow adapting). Knee motion is primarily limited to one plane and there is not an excessive need for large numbers of receptors to iden-

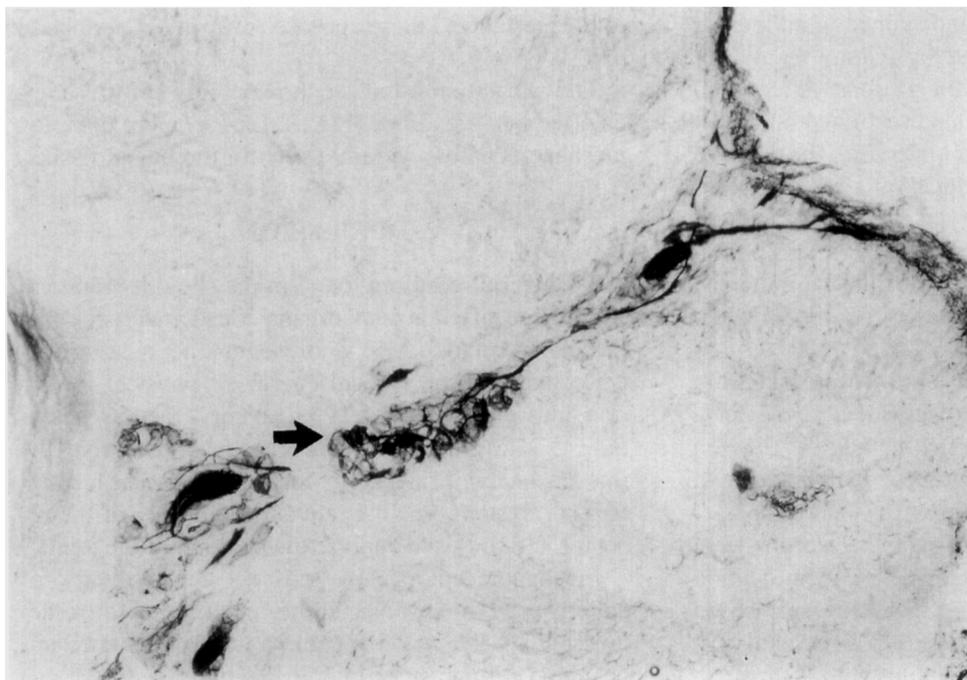


FIG 1. Ruffini end organ in inferior glenohumeral ligament (original magnification $\times 100$).

tify position and angle. In the anterior cruciate ligament, the slow adapting Ruffini end organs were not as common as the Pacinian corpuscles.^{10,11} The perceived sensation of the position and movement of the shoulder joint

plays an important role in coordinating muscular tone and control. Injury to these afferent fibers from dislocation, fracture, or surgery may result in a decrease in proprioception ability or a decrease in muscle coordination.



FIG 2. Pacinian corpuscle in coraco-humeral ligament (original magnification $\times 200$).

FIG 3. Free nerve endings in subacromial bursa (original magnification $\times 200$).



Many authors have postulated that functional instability of a joint after injury results from the decrease in intrinsic protective muscular tone and coordination that the joint derives from its afferent proprioceptive reflex.⁹⁻¹¹ This is particularly true in chronic ankle sprains.⁶ It has been shown that shoulders after glenohumeral joint dislocation have a proprioceptive deficit when compared with the normal shoulder.¹⁵ Joint instability from trauma may be related to a decrease in proprioceptive reflexes, and this instability can subsequently lead to reinjury. Recurrence rates of glenohumeral joint dislocation is high and is higher in younger patients.

This study did not specifically quantitate these neural receptors because estimates of receptors were obtained through examination of consecutive sections. Therefore, these neural findings are descriptive and more qualitative than quantitative as presented in other ligament studies.^{2,10,11} Further work with computerized optical scanning would further differentiate exact nerve ending densities.

Removal of the coracoacromial ligament in conjunction with excision of the subdeltoid bursae during an open or arthroscopic subacromial decompression makes physiological sense. Excision of these tissues may decrease the painful stimuli and allow more joint movement, strength, and shoulder function.¹⁶⁻¹⁸

CONCLUSION

The authors have provided what they feel is the first description of neural tissue in the glenohumeral joint, coracoacromial ligament, subdeltoid bursa, and coracoclavicular ligaments. Pacinian corpuscles were the most abundant in the glenohumeral ligaments with Raffini endings seen in some density. The subdeltoid free nerve endings were primarily noted in the subdeltoid bursa. Identification of these neural endings lend support to theories of proprioception and proprioceptive deficit resulting in joint instability. Further study will be needed.

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