THE INNERVATION OF THE SHOULDER JOINT[1]

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TWO FIGURES

INTRODUCTION

Certain features of the gross pattern of the nerve supply of the shoulder joint have been known since the last century. Nevertheless the innervation has been studied less than that for the hip, knee and elbow, and there have been no investigations of the distribution of nerves after they enter the capsule.

Rüdinger (1857) carried out the first systematic study of the nerve supply of this joint. He found it to be derived from the axillary and suprascapular nerves. One branch of the former arose in the axilla and descended to the anteroinferior region of the capsule. Another branch arose from the axillary nerve as it began its circumflex course and supplied the posteroinferior region of the capsule. The latter distribution was especially pronounced when the inferior branch of the suprascapular nerve was lacking. He observed one case in which a muscle bundle arose from the coracoid process and anterior aspect of the capsule. A branch from the brachial plexus supplied this muscle and also gave a twig to the superior region of the capsule. He described superior and inferior branches from the suprascapular nerve. The superior one coursed laterally in the supraspinous fossa, gave a twig to the coracoromial ligament and then split into 3

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2. The presence of anterior or posterior plexuses on the stomach.

3. Whether or not the posterior trunk is distributed to all or to only a part of the posterior surface of the stomach. Table 1 summarizes the statements of the different anatomists.

Agreement is shown in the following:

1. The anterior gastric vagal trunk and the posterior trunk each contain fibers from both the right and left vagus nerves.

2. Branches leave the anterior trunk just below the diaphragm and pass through the gastrohepatic omentum to the liver.

3. Gastric branches of both the anterior and the posterior trunks are distributed mainly along the lesser curvature of the stomach.

METHODS

In this study the vagus nerves were first dissected above the diaphragm in 50 cadavers, starting just below the pulmonary plexus and following them to the diaphragm. The specimens used were those being dissected by freshman medical and postgraduate students. In every case the dissection was done before the student reached the area in his dissection, the nerves were charted and, after the heart had been removed and the student was ready for the dissection of the esophageal plexus, they were checked again to be sure that no branches had been missed. After the student had studied the nerves, a number of dissections were photographed to show the disposition of the main trunks and branches. In some instances branches recorded in the original diagram were broken by the students in their examinations and therefore do not appear in the photographs, but do appear in the drawing beside the photograph. The photographs show the size of the trunks and their approximate location on the esophagus. Only the main trunks and divisions, the communicating branches and the larger esophageal branches were charted: the pericardial, the diaphragmatic and the aortic branches

from the subscapular nerves are mentioned as an additional source. In Cunningham's Text-Book of Anatomy ('43), in the section on joints, the nerve supply is said to arise from the suprascapular, subscapular and axillary nerves, but in the section on the nervous system there is nothing regarding articular filaments from the subscapular nerves.

The most recent investigation appears to be that of Arkhangelsky ('31) who dissected 40 shoulder joints. According to him, the nerve supply is derived from the axillary, suprascapular and anterior thoracic nerves. He states that the axillary nerve always gives a branch about 3 cm cranial to the inferior border of the subscapularis muscle which descends to the inferior border of this muscle and there divides into twigs which are given to the anteroinferior region of the capsule. In about half the cases, he found thin branches which approached the inferolateral region of the capsule near the surgical neck of the humerus. A branch to the bicipital sulcus, as described by Rauber, was much less common. Periosteal and articular branches arise from the suprascapular nerves in both supraspinous and infraspinous fossae. Arkhangelsky dwelt at some length on the articular branches of the anterior thoracic nerves. One of these supplies the acromial process and probably gives fine twigs to the shoulder joint as well. Another branch, which occurred in about 40% of the dissections, ascends in the bicipital sulcus.

So far as could be determined, there have been no complete studies of the nerve supply of this joint in lower animals. Ghetie ('29) mentions an articular branch of the axillary nerve to the shoulder joint of the horse. Sasaoka ('38–'39) mentions a similar branch in the cat.

MATERIALS AND METHODS

Nerves were dissected in 7 adult shoulder joints so as to establish the general pattern of distribution. Four other joints were partially dissected to confirm points brought out by study of fetal joints. Four fetal joints were sectioned

serially at 10 μ and stained by a modified Masson's method.[2] Two were from a 11-week fetus and two from a 12-week fetus. All were left attached to the trunk and sectioned in a plane transverse to the trunk. The ages given are only approximate since they were determined on the basis of crown-rump measurements of fixed specimens. While the material was not satisfactory for the study of nerve endings, it was excellent for tracing nerve fibers, since even in very small bundles there were usually a few large fibers which were easily distinguished.

Diagrammatic sketches were made of representative dissections, and projection tracings were made of fetal sections which showed characteristic features of the nerve supply.

OBSERVATIONS

The major features of existing descriptions were confirmed and, in addition, branches hitherto undescribed were found. The nerve supply is derived from the suprascapular, axillary and anterior thoracic nerves, from the posterior cord of the brachial plexus, directly from the stellate and perhaps other sympathetic ganglia and possibly from the radial nerve.

In the illustrations, both of gross and microscopic material, branches are named according to their most specific origin. Thus, "suprascapular" (fig. 2a) indicates articular twigs from the suprascapular nerve.

The articular branches of the axillary nerve

Shortly after the origin of the axillary nerve from the posterior cord of the brachial plexus a small branch arises which descends laterally across the subscapularis muscle, turns around the lower edge of the muscle and divides into twigs which enter the inferior region of the capsule (fig. 1, a.a.). Some of the terminal ramifications of these twigs were

[2] The first 6 dissections were done while the author was in the Department of Anatomy, Stanford University, California, 1940–1941. The fetal material was obtained through the courtesy of Prof. C. H. Danforth, Department of Anatomy, Stanford University, California.

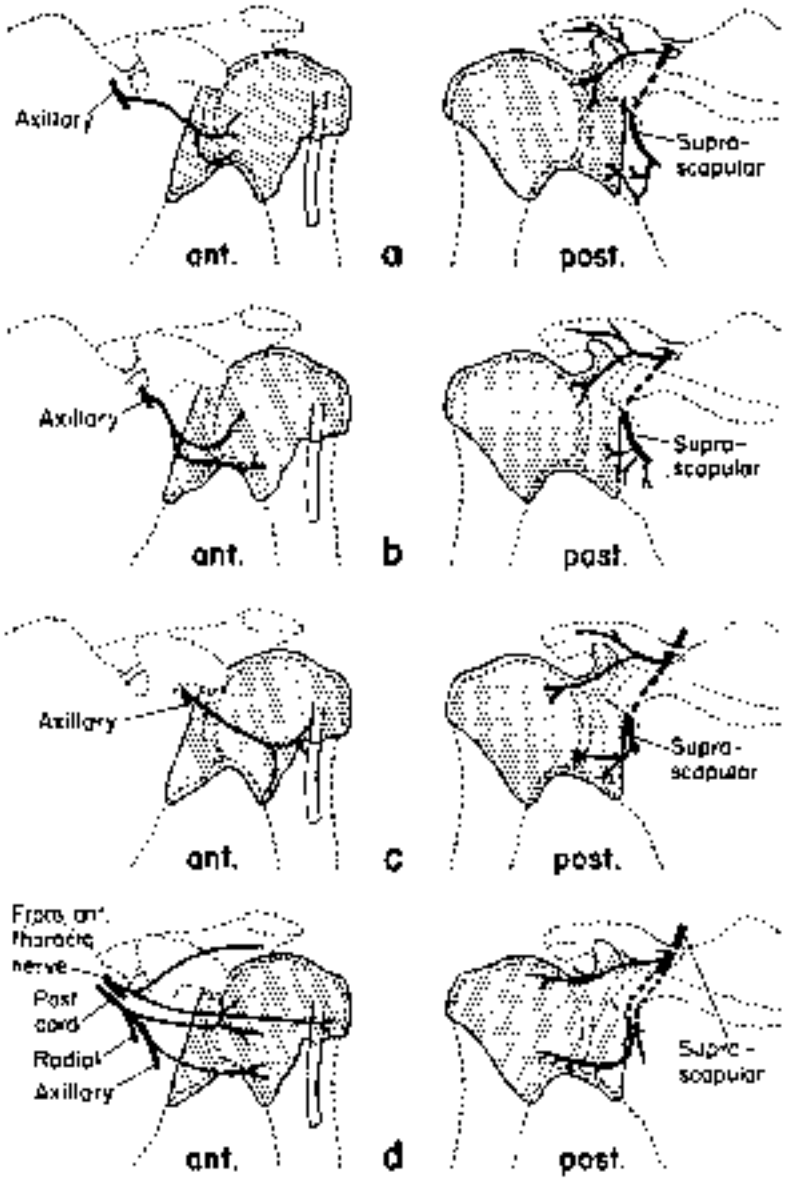

Fig. 1, a-d Anterior and posterior views of different types of distribution of nerves to the shoulder joint. The articular capsule is represented by stippling. c, axil, shows the articular branch of the lateral anterior thoracic nerve and from the posterior cord.

traced superiorly into the anterior and posterior regions of the capsule. In one case a tiny filament was found which accompanied a branch of the anterior circumflex artery into the bicipital sulcus (fig. 1e, ant.).

In the fetal joints, the articular branch of the axillary nerve has a similar course. It gives a twig which accompanies the anterior circumflex humeral artery into the bicipital sulcus and ascends until branches of this vessel enter the head of the humerus (fig. 2c-h). Beyond this point the nerve fibers could not be traced. During the initial part of its course, the bicipital branch anastomoses with a bundle of fibers derived from the posterior cord, and possibly with still another bundle derived from the radial nerve (fig. 2j). Numerous twigs from the main articular branch of the axillary nerve ramify in the inferior region of the capsule (fig. 2i-k) and, in addition, give small branches to the inferior edge of the subscapularis muscle. Still other twigs from this articular nerve ascend in the anterior and posterior regions of the capsule, adjacent to their humeral attachments (fig. 2g-i). These accompany blood vessels and both vessels and nerves give branches which penetrate the fibrous layer of the capsule and enter the synovial layer and adjacent portions of the humerus. The fibers which ascend posteriorly reach the area of distribution of the lower articular branch of the suprascapular nerve. The fibers which ascend anteriorly overlap the area supplied by the branch from the posterior cord.

Many of the small nerve bundles which enter the inferior and anteroinferior regions of the capsule course in the fibrous layer where they appear to terminate. These bundles are numerous in comparison with those which accompany blood vessels into synovial tissue. The arrangement is thus similar to that found in the posterior region of the capsule of the knee joint (Gardner, '48) and in the anteromedial region of the hip joint (Gardner, '49). The articular twigs from the posterior cord also contribute to this arrangement (see below).

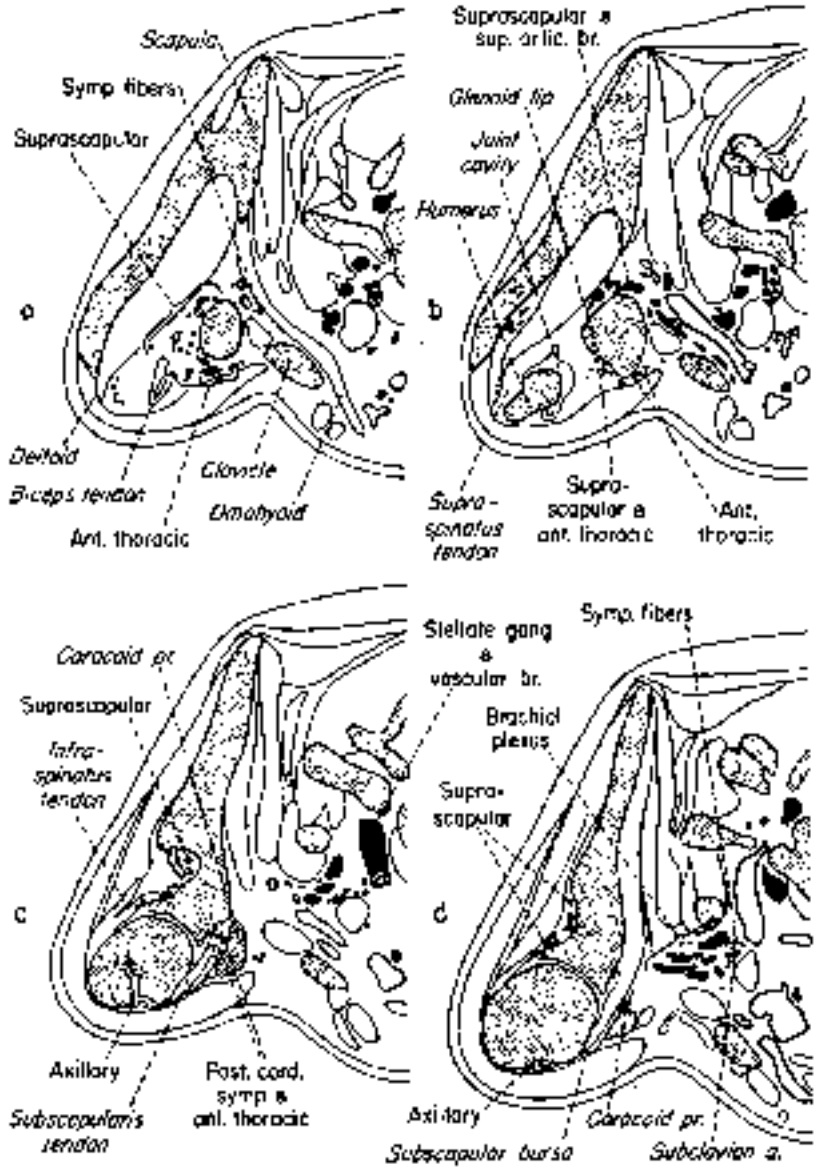

Fig. 2, a-d Projection tracings of a frontal joint (sectioned in a plane transverse to the trunk). Nerves are shown in axial block. The sections go from cranial to caudal levels.

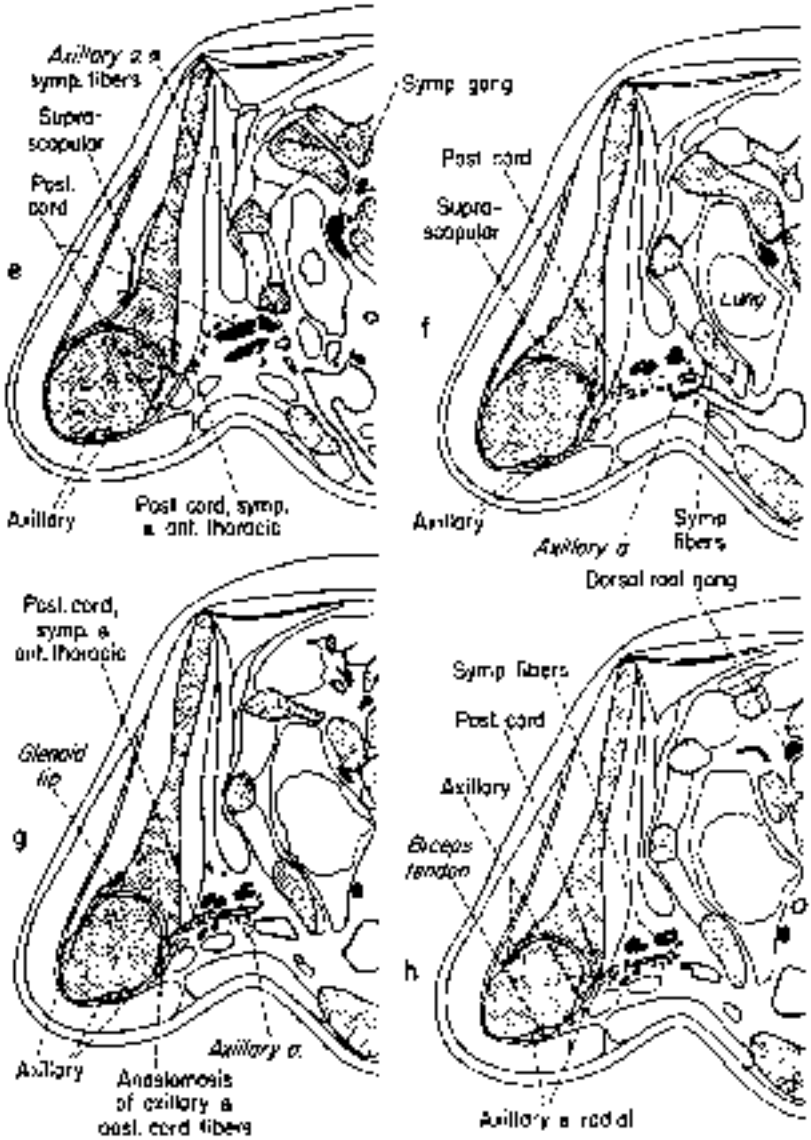

Fig. 2, e-h Continuation of the fetal series.

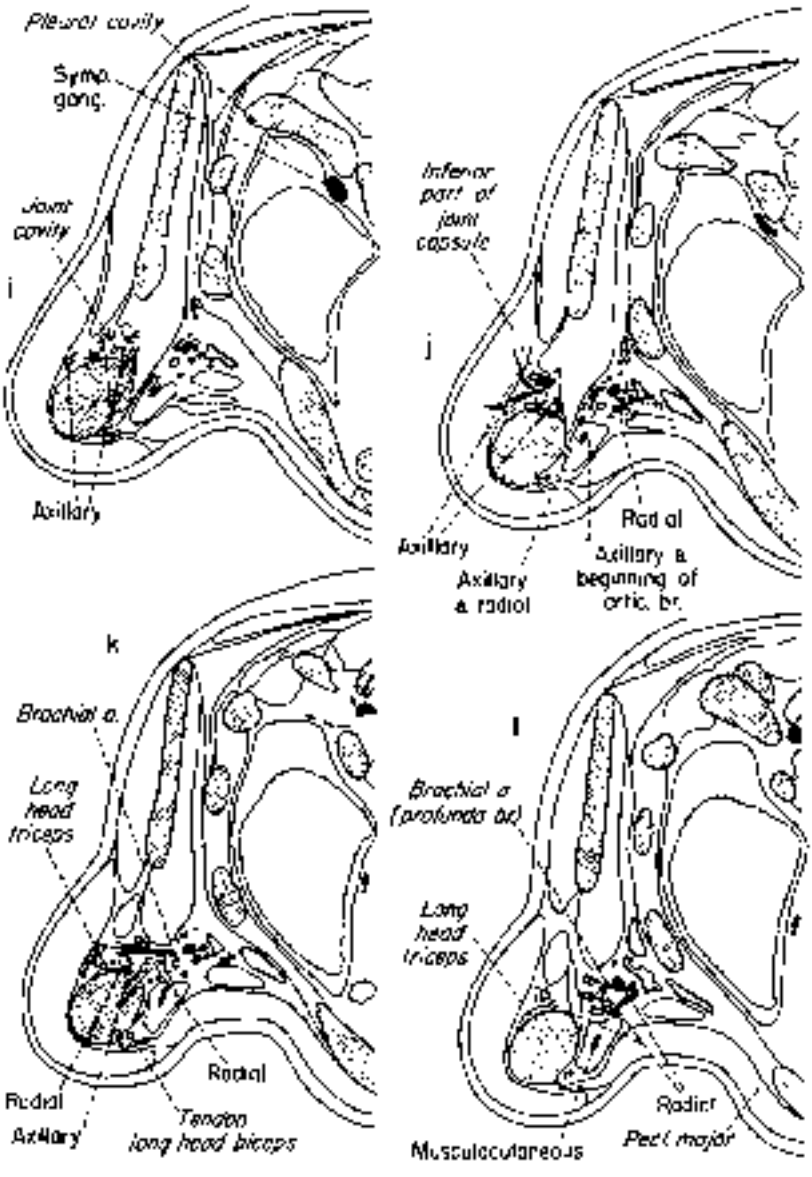

Fig. 2, i–l Continuation of the first sections.

The possible articular branches of the radial nerve

In one fetal joint a small twig arose from the radial nerve near the origin of the profunda branch of the brachial artery. In another joint a similar branch arose somewhat more superiorly. In both cases, the nerves ascended in the adventitia of the brachial artery to the origin of the anterior circumflex humeral artery (fig. 2j-l). Here each seemed to anastomose with the bicipital branch of the axillary nerve. It was difficult to determine the ultimate distribution of the fibers from the radial nerve and to be certain that they entered the bicipital sulcus.

In the same two fetal joints, a twig of the radial nerve ascended in the long head of the triceps brachii, together with an ascending branch of the profunda artery. It reached the junction of the tendon of the long head and the capsule of the shoulder joint and disappeared just as the capsule was definitely reached (fig. 2k-l). Whether or not the fibers actually entered the capsule could not be determined in this material.

The articular branch of the posterior cord of the brachial plexus

This was initially discovered in fetal material. Its articular distribution had been overlooked in the first dissections since it appeared to supply the subscapularis muscle and its tendon. In the fetal material it arises from the posterior cord, just proximal to its termination and apparently from the portion giving rise to the axillary nerve. It descends obliquely across the ventral surface of the subscapularis muscle (fig. 2f). When it reaches the tendon of this muscle it divides into a number of twigs. One or two of the twigs anastomose with the bicipital filament of the articular branch from the axillary nerve (fig. 2g). A few others pierce the tendon of the subscapularis muscle and enter the anterior region of the capsule. This area is also reached by fibers ascending from the articular branch of the axillary nerve. Fibers from both

nerves ramify mainly in the fibrous layer of the capsule, but some of them penetrate deeply to the synovial layer in company with blood vessels. In the region of division of the articular branch of the posterior cord, a small group of fibers detaches itself and anastomoses with a group of fibers whose origin is discussed below. The combined bundle of fibers ascends in company with blood vessels to the joint capsule superior to the tendon of the subscapularis muscle and posterior to the coracoid process (fig. 2c-h). Here it ramifies in an area characterized by a rather extensive vascular network. The same area is also reached by fibers from the suprascapular and anterior thoracic nerves.

The articular distribution of this branch of the posterior cord was later confirmed in dissections. It corresponds in most respects to the upper branch of the axillary nerve described by Rüdinger (1857). It is not unlikely that a larger series would show it arising from the axillary nerve as well as from the posterior cord. Only figure 1d, ant. shows the articular branch from the posterior cord in its gross relationships. The other dissections illustrated were done before the existence of this branch was realized.

The articular branches of the anterior thoracic nerves

An articular branch of the lateral anterior thoracic nerve was first noted in fetal joints and subsequently confirmed in dissections. In its gross distribution it accompanies a branch of the thoracoacromial artery, crosses the coracoid process superiorly and reaches the acromioclavicular joint (fig. 1d, ant.). During the terminal part of its course it gives a twig to the anterosuperior region of the joint capsule. In one instance, a very slender filament arose from the main articular branch soon after its origin and ran laterally, anterior to the coracoid process, and entered the bicipital sulcus (fig. 1d, ant.). The other dissections illustrated in figure 1 were done before the existence of the articular branch of the lateral anterior thoracic nerve was realized.

The distribution described above is similar to that found in fetal joints in which it was observed that the fibers enter the anterosuperior region of the capsule. Here they form a number of small bundles, some of which ramify in the fibrous layer where they overlap the area of distribution of the upper articular branch of the suprascapular nerve. The ramification is similar in arrangement to that formed by the axillary nerve and posterior cord in the anteroinferior region of the capsule, although the numbers of nerve bundles are not as great. Other fibers from the articular nerve penetrate deeper into the capsule and become closely associated with the vascular network in the synovial tissue posterior to the coracoid process. This region is also reached by fibers whose origin is as follows.

In one of the fetal joints an additional articular twig of the lateral anterior thoracic nerve was found. This twig, which was not found in any of the dissections, accompanied small blood vessels across the subscapularis muscle and anastomosed with sympathetic fibers descending in the adventitia of the axillary artery. The combined trunk anastomosed with a twig from the articular branch of the posterior cord and the bundle of fibers resulting from this union ascended to the vascular area posterior to the coracoid process (fig. 2c-5). The contribution of the posterior cord was present in all the fetal joints, while that of sympathetic fibers was found in two fetal joints.

Sympathetic fibers

In two of the fetuses sympathetic fibers were traced into the shoulder joint. In one, they arose from the stellate ganglion; in the other from the sympathetic trunk just superior to the stellate ganglion. In both, the fibers descended in the adventitia of the subclavian and axillary arteries to the origin of vessels ascending to the vascular area of the joint. Here they entered into the formation of the ascending nerve bundle described above. In one joint the sympathetic fibers anastomosed with a twig from the lateral anterior thoracic nerve.

Thus there is a direct path for sympathetic fibers to the shoulder joint. Whether this is a fairly constant feature cannot be stated at this time. In the other two fetal joints, fibers of similar origin were found, but they were not as well stained and were lost in the adventitia of the axillary artery.

The articular branches of the suprascapular nerve

As this nerve enters the supraspinous fossa it gives a branch which runs laterally, deep to the tendon of the supraspinatus muscle. During its course it gives a twig to the periosteum of the coracoid process and frequently one to the coracoacromial ligament (fig. 1, post.). It ends as fine rami in the superior region of the capsule, near the cartilaginous glenoid lip. In the fetal joints, this nerve accompanies branches of the transverse scapular artery into the fibrous layer of the capsule near its fusion with the tendon of the supraspinatus muscle (fig. 2a-b). It ramifies in this area and reaches anteriorly into the distribution of the articular branch of the anterior thoracic nerve, and probably into the vascular area as well. The number of nerve fibers in the superior region of the capsule is exceeded only by those in the anteroinferior area. The articular branch also gives a twig to the acromioclavicular joint. The fibers from the suprascapular nerve to the supraspinatus muscle reach as far as its tendinous insertion but it was not possible to determine whether any of them continued into the capsule. Sympathetic fibers were observed accompanying the transverse scapular artery but it was not possible to trace them to the point of origin of articular vessels.

Just before entering the infraspinous fossa, the suprascapular nerve gives a twig to the neighboring periosteum and one or more filaments which run laterally and enter the capsule deep to the tendons of the infraspinatus and teres minor muscles (fig. 1, post.). In the fetal joints, these fibers, together with the blood vessels which they accompany, ramify in the capsule adjacent to the glenoid lip (fig. 2c-f). Small bundles

of fibers occasionally enter the synovial tissue. The lowermost bundles overlap the area reached by fibers ascending from the articular branch of the axillary nerve.

DISCUSSION

There are certain features of the nerve supply of the shoulder joint which in many respects are similar to those of the knee and hip. The nerve supply is characterized by variation in gross distribution of nerves, by regional differences in intra-articular distribution and by a certain amount of overlap of articular nerves.

Variation in distribution of articular nerves is evident mainly in the manner in which they reach the joint. Once within the joint there is a basic pattern of distribution in that each nerve usually supplies a specific region of the joint. The absence of certain articular branches, as determined by dissection, is more apparent than real since many of these are small and easily overlooked in dissection. For example, the bicipital branch of the axillary nerve was found in but one of the dissections, yet was present in all of the fetal joints. The bicipital branch of the lateral anterior thoracic nerve is less constant. According to Arkhangelsky ('31) it is present in 40% of the cases. In this series it was found in but one of the dissections. Also according to Arkhangelsky, at least one branch from the lateral anterior thoracic nerve supplies the superior region of the shoulder joint. In the present study it was found in both gross and microscopic material, so there is little doubt that it is usually present. The other articular branch of the lateral anterior thoracic nerve, that anastomosing with sympathetic fibers and fibers from the posterior cord, was present in but one of the fetal joints and is undoubtedly quite inconstant.

Rüdinger (1857) described an upper branch from the axillary nerve to the anterior region of the capsule. In the present study the branch which corresponds in distribution to Rüdinger's description arose from the posterior cord, although from that portion of the cord giving rise to the axillary

nerve. Arkhangelsky did not mention such a branch, either from the axillary nerve or from the posterior cord. In gross material, this branch appears to supply the subscapularis muscle and its tendon. The fetal material, however, showed that it either pierces the tendon or courses below it to reach the capsule. It may be, therefore, that he assumed it to be a muscular branch. It is quite likely that a series larger than the present one would show it arising either from the posterior cord or the axillary nerve.

Each nerve entering the shoulder joint supplies a definite region, but there is a certain amount of overlap with other nerves, so that each region is supplied by more than one nerve. Thus, the anteroinferior region of the joint is supplied by the axillary nerve, by the posterior cord and possibly by the radial nerve. The anteroposterior region is supplied by the posterior cord, the lateral anterior thoracic nerve and the suprascapular nerve.

Many of the articular nerve fibers undoubtedly supply blood vessels in the capsule and neighboring bone, since they form bundles which are closely associated with the vessels and decrease in size as the vessels decrease. A number of the fibers are undoubtedly vasomotor. This is borne out by the presence of a direct path from sympathetic ganglia to articular vessels. A similar direct path probably exists for the hip joint (Gardner, '48). Fibers from lumbar ganglia reach the femoral artery but their ultimate distribution is uncertain since the artery receives fibers directly from the femoral nerve. The resulting mixture of fibers does, however, contribute to articular vessels. In none of the fetuses could sympathetic fibers descending in vascular adventitia be traced more distally than the hip or shoulder.

A number of bundles of nerve fibers ramified mainly within the fibrous layer of the capsule. This arrangement was particularly striking in the anteroinferior and anterosuperior regions of the capsule. These regions would be most subject to compression or change of some sort during movement. Thus, a situation similar to that in the knee and hip joints

is present. In these joints, the fibrous layer of the capsule in the posterior region of the knee joint and the anteromedial region of the hip joint contains many small bundles of nerve fibers. In the knee joint of the cat, the posterior region of the capsule contains Ruffini-type nerve endings (Gardner, '44).

The functional implications of articular nerve supply were discussed in more detail in the study of the nerve supply of the knee joint (Gardner, '48).

SUMMARY

The nerve supply of the human shoulder joint was studied in dissections and in serial sections of fetal joints. The articular nerves arise from the axillary, suprascapular and lateral anterior thoracic nerves, from the posterior cord, from sympathetic ganglia and possibly from the radial nerve.

The articular branch of the axillary nerve enters the inferior region of the capsule where it ramifies and from which fibers extend laterally into the bicipital sulcus and superiorly in the anterior and posterior regions of the capsule. Recurrent branches from the radial nerve possibly reach both the bicipital sulcus and the inferior region of the capsule.

The articular branch from the posterior cord supplies mainly the anterior region of the capsule, extending both superiorly and inferiorly. It anastomoses with the bicipital branch of the axillary nerve, and also with sympathetic fibers and occasionally a twig from the lateral anterior thoracic nerve. The bundle of fibers resulting from union with the latter two groups ascends to the anterosuperior region of the capsule, especially to the vascular synovial tissue posterior to the coracoid process.

A branch of the lateral anterior thoracic nerve supplies the acromioclavicular joint and during its course gives a twig to the anterosuperior region of the capsule. In one dissection, this nerve sent a branch to the bicipital sulcus.

In two of the fetal joints, fibers from the stellate ganglion and sympathetic trunk coursed in the adventitia of the sub-

clavian and axillary arteries, anastomosed with the branch from the posterior cord, and eventually reached the vascular area posterior to the coracoid process.

The suprascapular nerve gives an upper branch to the periosteum of the coracoid process, the coracoacromial ligament and the superior region of the capsule. A lower branch of the suprascapular nerve supplies the posteroinferior region of the capsule.

Most of the articular fibers probably supply blood vessels in the capsule and neighboring bone. The fibrous layer of the anteroinferior and anterosuperior regions of the capsule contain numerous small bundles of nerve fibers.

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