An Analysis of the Sympathetic Trunk and Rami in the Cervical and Upper Thoracic Regions in Man * †

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THE CERVICAL and upper thoracic sympathetic nerves frequently become involved in diseases in which vascular hypertonus is a factor, such as Raynaud's syndrome and other vascular disorders in the upper extremities, angina pectoris, epilepsy, etc. Cervical and cervicothoracic sympathectomy have become common surgical procedures in the treatment of patients with these and certain other diseases. The relief of vascular hypertonus or spasticity by sympathectomy requires complete sympathetic denervation of the vascular beds involved. Frequently, however, sympathectomy, as it is usually carried out, fails to achieve complete sympathetic denervation of the area in question because not all the sympathetic conduction pathways in the area are interrupted. Failure to interrupt all the sympathetic conduction pathways in the cervical and upper thoracic regions by extirpation of the sympathetic trunk is due in part to the occurrence of sympathetic pathways that do not traverse the sympathetic trunk. Variations in the distribution of sympathetic nerve fibers through the sympathetic trunk and the rami through which it is connected with the spinal nerves are also significant. More complete knowledge of the distribution and the frequency of accessory ganglion cells and the fiber composition of the sympathetic trunk, the rami that connect it with the spinal nerves and the rami that join the vertebral and the carotid plexuses and the variations in these nerves, therefore, would be advantageous.

The anatomical relationships of the sympathetic trunks, the communicating rami and the sympathetic roots in the cervical and the upper thoracic segments have been described by various investigators.[25, 26] The fiber composition of these nerves has also been investigated. The pertinent data have been reviewed particularly by Mitchell[16] and Kuntz.[13] Incomplete data relative to the frequency and the distribution of accessory ganglion cells in these segments are also available (Skoog;[22] Kuntz and Alexander;[14] Ehrlich and Alexander[6]).

Data relative to the rostral limit of the outflow of preganglionic fibers concerned with sympathetic innervation of the upper extremity are inconclusive. The assumption that all preganglionic fibers for the upper extremity traverse nerve roots caudal to the second thoracic has been supported by Gask and Ross,[9] Forster,[8] Sheehan and Marazzi,[20] Geohegan *et al.*[10] and others. According to Ray *et al.*,[19] preganglionic fibers for the hand commonly are present in the second to the fifth thoracic nerves. Kuntz and Dillon[15] demonstrated preganglionic fibers for the upper extremity in the first thoracic nerve in the Rhesus monkey. On the basis of digital vasomotor responses to stimulation of the ventral nerve roots in man, exposed during operative procedures, Bridges and Yahr[3] concluded that in addition to lower thoracic nerve roots, the ventral roots of both the first thoracic and the eighth cervical nerves are traversed

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by preganglionic fibers that are concerned with the vasomotor innervation of the hand.

Significant data relative to the fiber composition of the communicating rami and the sympathetic roots are also available. The communicating rami consist predominantly of myelinated fibers most of which fall within the caliber range of preganglionic fibers. The fiber composition of the sympathetic roots is highly variable. On the basis of studies of these roots in the Rhesus monkey (Sheehan and Pick[21]) and in man (Pick and Sheehan[17]), they have been classified in several categories according to the relative abundance of unmyelinated and myelinated fibers. On the basis of these studies it is apparent that not all the fibers in the cervical and upper thoracic sympathetic roots are postganglionic. Data relative to the fiber composition of the rami that join the carotid and the vertebral plexus are fragmentary.

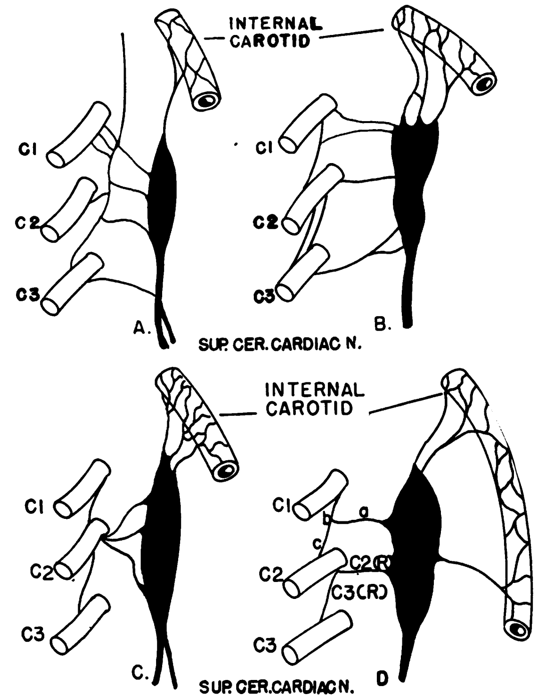

FIG. 1. Diagram illustrating variations in the rami connecting the superior cervical ganglion with the rostral 3 cervical nerves and the internal carotid artery. A. Cadaver 323 (Right). B. Cadaver 323 (Left). C. Cadaver 130 (Right). D. Cadaver 278 (Right).

MATERIALS AND METHODS

Detailed dissections of the cervical and upper thoracic portions of 19 sympathetic trunks with sympathetic roots and rami have been carried out in 11 cadavers. Diagrams of the nerves were made and compared with those of previous investigators to determine the most common patterns. Thirteen of the sympathetic trunks and their connecting rami were selected as suitable for histologic study. Some of the material was prepared by the silver technics of Holmes and of Bielschowsky. Other stains used were osmic acid, Luxol blue, and Sudan black B.[4] Myelinated fiber counts were made in sections taken at various levels of the sympathetic trunk and of every ramus. The fibers were divided into two categories; those under four microns and those four microns or over in diameter. No attempt was made to determine the ratio of preganglionic to postganglionic fibers.

ANATOMICAL DATA

Sympathetic Trunk: The *superior cervical ganglion* usually is fusiform and extends from near the base of the skull to the upper, or sometimes the lower, border of the second cervical vertebra. The most constant nerve related to it is the internal carotid. This nerve is usually composed of one to four slender rami and can be traced to the internal carotid artery (Fig. 1). It sometimes loses its identity in the adventitia before the artery enters the internal carotid canal. The superior cervical ganglion is connected with the nodose ganglion of the vagus nerve by one or more rami. Several small rami also extend into the fascial layers of the carotid sheath. The superior cervical cardiac nerve usually arises from the inferior pole of the ganglion (Fig. 1C), but in some instances from the sympathetic trunk a centimeter or more below the ganglion (Fig. 1A). The connections of the superior cervical ganglion with the anterior primary rami of the cervical nerves vary. Some of the variations are illustrated in Figure 1. In all the bodies examined it was connected with the first three cervical nerves by rami that could be demonstrated grossly, but no direct connection with the fourth cervical nerve was observed. Some rami derived from the superior cervical ganglion do not join the anterior primary rami of the nerves directly, but join interconnecting rami between two or more cervical nerves.

A *middle cervical ganglion* was grossly demonstrable in only three of the sympathetic trunks dissected. Of these only on (cadaver 585, right) was immediately apparent. Three small rami ex-

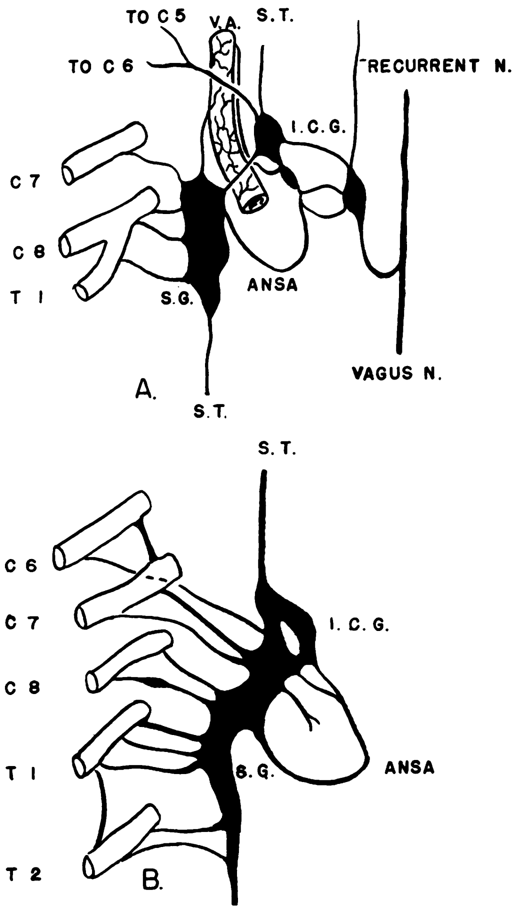

FIG. 2. Diagrams illustrating variations at the levels of the stellate and the intermediate ganglia. A. Cadaver 130 (Right). The ganglia of the sympathetic trunk are connected with a ganglion in the recurrent laryngeal nerve. B. Cadaver 42 (Left). The intermediate cervical ganglion (I C A) is fused with the stellate ganglion (S. G.).

tended from this ganglion mediad into the fascia of the carotid sheath. One small ramus joined the fourth cervical and a somewhat larger one the fifth cervical nerve. In cadaver 952 (left), one ramus from the middle cervical ganglion was identified as the middle cervical cardiac nerve. A second ramus extended to the common carotid artery and a third to the sixth cervical nerve. In cadaver 691 (left) rami to the fifth and sixth cervical nerves, the middle cervical cardiac nerve and small laryngeal rami could be traced from the middle cervical ganglion. The ansa subclavia formed its only connection with the stellate ganglion. The ansa was considerably larger than usual in this instance.

An *intermediate,* or "low type" middle cervical, ganglion was identified in all but two of the dissections. In cadaver 585 (right) both a middle and an intermediate cervical ganglion were present. The intermediate ganglion is commonly connected with the inferior cervical or the stellate ganglion through the ansa subclavia (Fig. 2A) and another strand of fibers that may pass on either side of the vertebral artery and vein or form an ansa vertebrae. In cadaver 42 (left) the intermediate ganglion was fused on either side of the vertebral vessels with an unusually large stellate ganglion (Fig. 2B). In this instance no direct connections of the intermediate ganglion with cervical nerves were observed. Usually, however, rami extend from the intermediate ganglion to the fifth and sixth cervical nerves (Fig. 2A) and occasionally to the seventh. In three instances a slender ramus from this ganglion joined the plexus on the vertebral artery. In cadaver 130 (right) an unusual connection occurred with a small ganglion in the recurrent laryngeal nerve. A ganglion was grossly visible in the ansa subclavia at the inferior pole of the intermediate ganglion and three slender rami connected it to the ganglion in the recurrent nerve. Another ramus extended from the ganglion in the ansa subclavia rostrad along the vertebral artery (Fig. 2A).

A *stellate ganglion* was present in all of the sympathetic trunks dissected. In one instance (cadaver 42 left) (Fig. 2B) the second thoracic and the intermediate ganglion were fused with the stellate forming an unusually large ganglionic mass. In this cadaver a ganglion was grossly visible in one of the rami to the eighth cervical nerve (Fig. 2B). The seventh and eighth cervical and the first thoracic nerves always received at least one ramus each from the stellate ganglion and in numerous instances two or three rami. The vertebral nerve constantly arises from the stellate ganglion, usually from its rostral pole, and extends rostrad to the verterbral foramen with the vertebral vessels. It commonly gives off rami to the seventh and eighth cervical nerves. In cadaver 278 (right) it also gave off a ramus to the sixth cervical nerve.

Microscopic examination of the cervical sympathetic trunk shows considerable variation in the numbers of myelinated fibers at different levels, and at the same level in different cadavers. Between the superior cervical and the intermediate cervical ganglion, the trunk appears grossly as a single nerve, but microscopically it was found to be composed of 1 to 12 bundles. Trunks made up of 10 or 12 bundles commonly exhibited 2 large ones. The remaining ones include relatively few fibers. Those in which the bundles were fairly uniform in size consisted of only 4 or 5 bundles. Two trunks in this series (323, left, and 952, right) were each composed of a single bundle of fibers.

In both trunks ganglion cells were present in all the sections examined between the intermediate and superior cervical ganglia. A total myelinated fiber count in sections of trunk 323 (left) showed 3,050 fibers just rostral to the intermediate ganglion and 1,553 at the caudal pole of the superior cervical ganglion. Of these, 21 fibers were over four microns in diameter. Since the preganglionic fibers are predominantly myelinated and less than four microns in diameter, these counts indicate a reduction of nearly 50 per cent in the number of preganglionic fibers from the rostral pole of the intermediate ganglion to the caudal pole of the superior cervical ganglion. This obviously is correlated with the abundance of ganglion cells throughout the cervical portion of the sympathetic trunk. Other trunks in this series showed only small differences in the numbers of myelinated fibers at the two levels indicated. Different sympathetic trunks, however, show considerable variation in this respect. The myelinated fibers less than four microns in diameter at the caudal pole of the superior cervical ganglion showed a range of variation from 4,615 in cadaver 278 (left) to 1,532 in cadaver 323 (left). Counts of the small myelinated fibers at the same levels in both sympathetic trunks also vary. In cadaver 278 the right trunk included 1,897 and the left 4,615 fibers in this category at the caudal pole of the superior cervical ganglion, a difference of 2,718 fibers. Counts of the fibers over four microns in diameter in the same sections revealed 244 in the left and 82 in the right trunk. Most of the myelinated fibers less than four microns in diameter in these sections fell within the diameter range of 1.5 to 3.5 microns, which is the range that includes most preganglionic fibers.

The rami that extend from the superior cervical ganglion rostrad along the internal carotid artery include both myelinated and unmyelinated fibers, but the unmyelinated ones predominate. In cadaver 278 (right) these rami contained 103 myelinated fibers less than four microns and eight that were four microns or more in diameter. Two clumps of ganglion cells were observed in transverse sections just proximal to the point of juncture with the plexus on the internal carotid artery (Fig. 3A and B). In only one instance (cadaver 323, left) could a ramus be traced directly to the first cervical nerve (Fig. 1B). It included 38 myelinated fibers over four microns in diameter. This ramus was composed of four small bundles in which the myelinated fibers were evenly dispersed among the unmyelinated ones. A ramus was traced directly to the second cervical nerve in three cadavers. The cadaver numbers, myelinated fiber counts and the numbers of bundles in the rami are shown in Table I.

TABLE 1. *Ramus to Second Cervical Nerve*

Cadaver Number	Under 4 Microns	Over 4 Microns	Bundles
278 (right)	21	13	4
323 (left)	9	17	1
82 (right)	52	27	4

The third cervical nerve received a direct ramus from the sympathetic trunk in four cadavers and from the superior cervical ganglion in two. In all the other bodies dissected it was interconnected with the first and second cervical nerves. The myelinated fibers in the direct rami ranged from 97 less than 4 microns and 61 more than 4 microns in diameter in cadaver 585 (right) to complete absence of myelinated fibers less than 4 microns in diameter and only 7 larger ones in cadaver 42 (left). The small myelinated fibers are uniformly scattered throughout the rami, but in several instances the larger ones occur in definite aggregates wtihin the rami. In other instances they are incorporated in a separate bundle.

The clearest macroscopic picture of the complex interconnections of the rostral three cervical nerves and the superior cervical ganglion was observed in cadaver 278 (right) (Fig. 1D). Ramus "a" (Fig. 1D) is composed of ten microscopic bundles including 37 myelinated fibers less than 4 microns and 49 over 4 microns in diameter. The intercommunicating rami "b" and "c" are composed predominantly of myelinated fibers over 10 microns in diameter and bundles of unmyelinated fibers interspersed among them. Two small bundles including only 16 myelinated fibers are found between four large ones in ramus "b" (Fig. 1D). Ramus C2 (R) is a typical sympathetic root including 21 myelinated fibers under 4 microns and 13 over 4 microns in diameter. It joins the anterior primary ramus of the second cervical nerve and forms a part of ramus C3 (R). The latter ramus includes 117 myelinated fibers less than 4 microns and 174 over 4 microns in diameter. Most of the latter are over 10 microns in diameter.

In three instances the fourth, and in two instances the fifth, cervical nerve was not directly connected with the sympathetic trunk. In all other instances each of these nerves received a sympathetic root either from the middle cervical portion of the sympathetic trunk or from the middle cervical ganglion. In two instances the fifth cervical nerve received a sympathetic root from the intermediate ganglion. In none of the bodies dissected

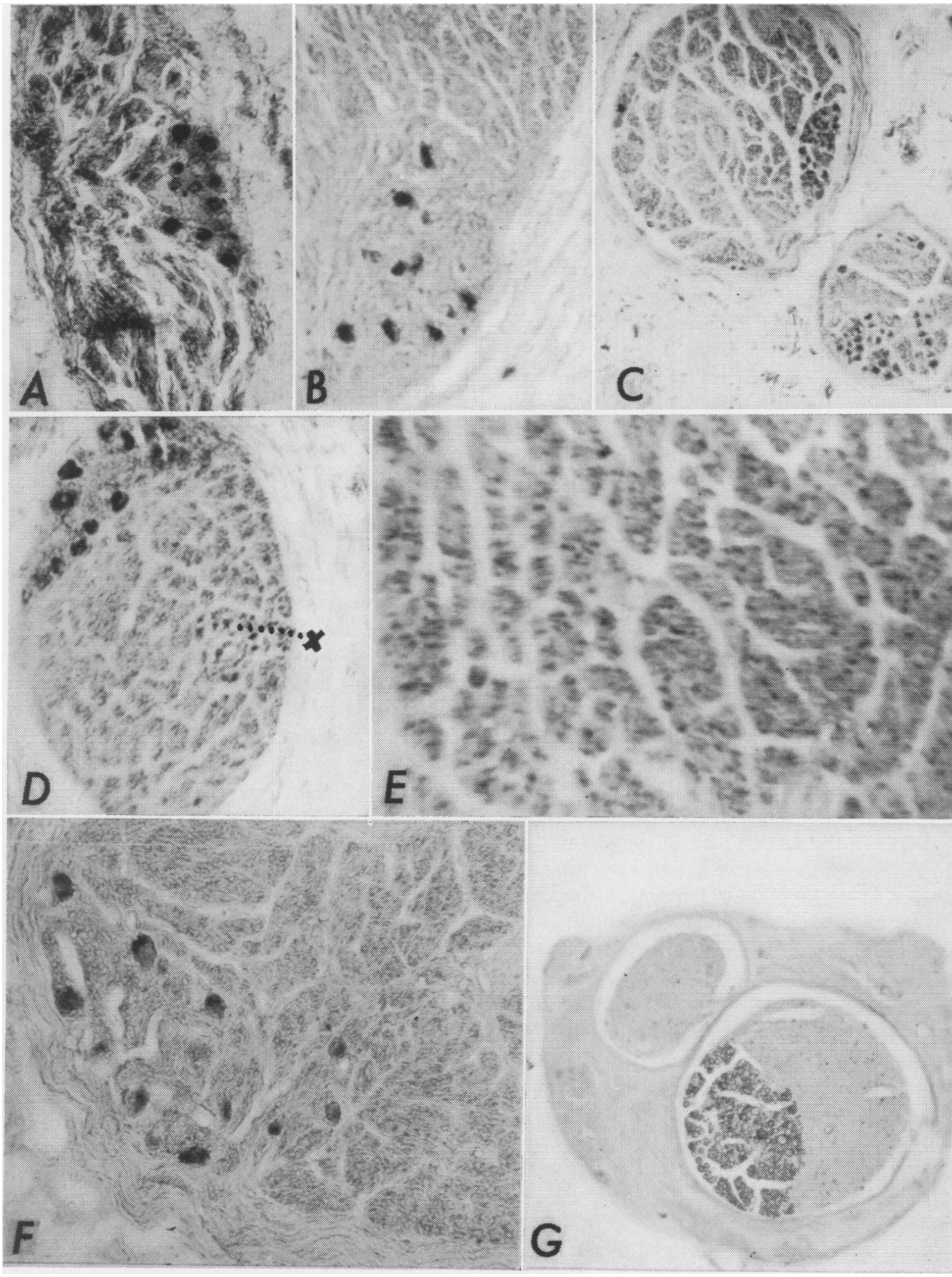

FIG. 3. Photomicrographs of representative cervical rami. All sections were cut at 10 microns. A and B. Aggregates of ganglion cells observed in the internal carotid nerves just proximal to the point of juncture with the plexus on the internal carotid artery (D, Fig. 1). C. Clumps of large somatic fibers within the sympathetic root of the fifth cervical nerve (Cadaver 323, Right). D. Scattered ganglion cells in the sympathetic root of the eighth cervical nerve. (x)—Aggregate of large myelinated fibers (B, Fig. 2). E. A portion of a section of the vertebral nerve (Cadaver 278, Right) showing large numbers of myelinated fibers less than 4 microns in diameter. F. Scattered ganglion cells in the vertebral nerve (Cadaver 278, Right). G. Aggregate of large fibers in a cervical sympathetic root of a cat.

did the fourth cervical nerve receive a root from the superior cervical ganglion. In cadaver 585 (left) a joint sympathetic root arose from the middle cervical portion of the sympathetic trunk which included 131 myelinated fibers less than 4 microns and 49 over four microns in diameter. By contrast a joint ramus arose from the same portion of the trunk in cadaver 42 (left) that was devoid of small myelinated fibers and contained only 16 fibers over four microns in diameter. Bundles of large somatic fibers, as described by Pick and Sheehan,[17] occur frequently in the sympathetic roots of the fourth and fifth cervical nerves or closely associated with them (Fig. 3C).

The sympathetic root of the sixth cervical nerve, in many instances, includes a relatively large number of myelinated fibers. Those less than 4 microns in diameter showed a range of 47 in cadaver 278 (right) to 507 in cadaver 42 (right). Fibers 4 microns and over in diameter ranged from 6 in cadaver 585 (right) to 151 in a sympathetic root that gave off a twig to the fifth cervical nerve. In most instances the sympathetic root of the sixth cervical nerve arises directly from the intermediate ganglion or, less frequently, from the stellate ganglion. When it arises from the stellate ganglion it usually does so in common with a sympathetic root of the seventh and occasionally the eighth cervical nerve. Scattered accessory ganglion cells were observed quite consistently in sections of the sympathetic roots of the fifth and sixth cervical nerves. In cadaver 130 (left) a ganglion was grossly visible close to the junction of the sympathetic root with the sixth cervical nerve. This was verified by microscopic examination.

The sympathetic root of the seventh cervical nerve, in nearly all instances, included myelinated fibers in relatively large numbers scattered among the unmyelinated ones, but the myelinated fibers vary in numbers within a wide range. In cadaver 42 (right) this root included 1772 myelinated fibers less than 4 microns in diameter contrasted with 423 fibers in this category in cadaver 278 (left). The fibers 4 microns or over in diameter vary from 185 in cadaver 782 (right) to 16 in cadaver 585 (right). One to three rami may be traced to this nerve in gross dissection, but 2 to 10 or more additional very slender ones may be observed microscopically. The small myelinated fibers tend to be uniformly scattered throughout the bundles while the large ones frequently are aggregated. In some instances a sympathetic root of this nerve arises in common with that of the sixth (cadaver 323, right) cervical nerve and in other instances in common with the sympathetic roots of both the sixth and the eighth cervical nerves. This common root may also include the fibers of a ramus that extends rostrad along the vertebral artery. More commonly, the latter raums arises independently.

The sympathetic roots of the eighth cervical nerve are by far larger and more numerous than those of any other cervical nerve. Three or more separate rami can usually be observed macroscopically. When examined microscopically these rami appear to be made up of a dozen or more fiber bundles. Frequently one or two bundles are relatively large as compared with the remaining small ones. Scattered ganglion cells occur frequently in these roots (Fig. 3D). They also include myelinated fibers in large numbers. The highest total number was 3,642 (cadaver 323, right) of which only 53 were 4 microns or over in diameter. The smallest number of myelinated fibers counted was 1,668 (cadaver 278, left) of which 201 were 4 microns or over in diameter. The major portion of the small myelinated fibers ranged from 1.5 to 3.5 microns in diameter and were usually uniformly scattered among the unmyelinated fibers. Aggregation of the larger fibers occurred frequently. In some instances they were located within a large bundle, but more frequently they were segregated in small bundles lying close to the periphery of a larger bundle (Fig. 3D).

The first thoracic nerve is very closely related to the eighth cervical and is usually connected with the sympathetic trunk by at least two rami. No distinct first thoracic ganglion was observed. In three of the bodies dissected, at least one ramus connecting the eighth cervical nerve with the stellate ganglion included ganglion cells throughout nearly its entire length. In only one instance (cadaver 952, left) was a typical white communicating ramus found at this level, but in the second thoracic segment the white ramus was consistently separate from the sympathetic root.

The nerve that accompanies the vertebral artery was especially prominent in 6 instances. When observed microscopically it was usually found to include large numbers of myelinated fibers scattered among the unmyelinated ones (Fig. 3E). The counts of myelinated fibers in this nerve vary more widely than those of any of the cervical sympathetic roots. In cadaver 278 (right) it included 3,461 myelinated fibers of which only 21 were 4 microns or over in diameter. The sections in which the fiber counts were made also revealed a few scattered ganglion cells (Fig. 3F). In cadaver 323 (right) two distinct rami were observed at dissection. Microscopic examination of these rami revealed only two small nerve bundles including 363 myelinated fibers of which 23 were 4 microns or over in diameter. In all instances in which the total myelinated fiber count in this ramus was large the total number of myelinated fibers in the cervical sympathetic trunk was relatively small.

DISCUSSION

The data obtained in this investigation relative to the superior cervical ganglion in general corroborate the findings of earlier investigators. Those relative to the middle cervical ganglion support the assumption that, in the absence of a grossly demonstrable ganglion in the middle cervical region, ganglion cells usually are present in variable numbers in the middle cervical portion of the sympathetic trunk. The intermediate cervical ganglion, designated by some investigators as a "low" middle cervical ganglion, was observed macroscopically in all but two of the bodies examined. Since this ganglion is never located midway between the superior and inferior cervical ganglia, the term "intermediate cervical ganglion" appears to be a more appropriate designation for it than the term "middle cervical ganglion."

A stellate ganglion was present in every sympathetic trunk examined. In some instances it extended caudad to include the second thoracic ganglion. In cadaver 42 (left) (Fig. 2B) the intermediate cervical ganglion was intimately fused with it, forming a ganglionic mass that completely encircled the vertebral vessels. Harman,[11] Potts,[18] Axford,[2] and others have described variations in the form of this ganglion, but this particular variation is not illustrated in any of their diagrams. The finding that all 19 sympathetic trunks examined in this series included a stellate ganglion corroborates the finding of Jamieson *et al.*[12] that fusion of the inferior cervical and first thoracic ganglia occurs in at least 82 per cent of all sympathetic trunks in man.

The presence of accessory ganglia in many of the cervical sympathetic roots, as reported by Skoog,[22] is corroborated. Accessory ganglia also occur, in some instances, in relation to the primary ventral and communicating rami of the eighth cervical and the rostral 2 or 3 thoracic spinal nerves. No attempt was made in this investigation to determine the frequency of accessory ganglia in the segments in question, but it is significant that such ganglia were observed frequently in sections in which fiber counts were carried out even though only a few selected transverse sections of each ramus or sympathetic root were examined. The occurrence of ganglion cells throughout the entire cervical sympathetic trunk, as observed in cadavers 323 (left) and 952 (right), has not been previously reported. In instances in which many ganglion cells occur in the cervical portion of the sympathetic trunk the superior cervical ganglion is smaller than average and the rostral portion of the sympathetic trunk includes less than the average number of myelinated fibers, since many preganglionic fibers terminate in relation to the scattered ganglion cells.

The presence of large numbers of myelinated fibers that do not exceed 3.5 microns in diameter, i.e., fibers that fall within the diameter range of preganglionic fibers, in the vertebral nerve supports the conclusion of some investigators that this nerve represents an accessory sympathetic trunk. In cadaver 278 (right) it included 3,340 myelinated fibers less than four microns in diameter while the sympathetic trunk at the caudal pole of the superior cervical ganglion included only 1,897 myelinated fibers in the same diameter range. A lesser excess of myelinated fibers not over 3.5 microns in diameter in the vertebral nerve over those in the same diameter range in the cervical sympathetic trunk was also observed in other cadavers. Accessory ganglia are known to occur along the vertebral artery and its branches. Such ganglia were observed in the vertebral nerve particularly in cadaver 278 (right) (Fig. 3F). The large number of myelinated fibers in the diameter range of preganglionic fibers suggests that ganglion cells must be present in considerable abundance. As observed by Christensen *et al.*,[5] the vertebral nerve in the cat gives off sympathetic rami to cervical nerves from the eighth to the third. Its extirpation, however, resulted in no marked alteration in the vertebral plexus. In a series of human dissections, Alexander[1] consistently traced the vertebral nerve from the stellate ganglion and found that it gives off rami to cervical nerves from the eighth to the third or more rostral ones. Extension of the vertebral nerve onto the basilar artery could not be demonstrated. It conveys postganglionic fibers to the cervical nerves and is traversed by small afferent components of these nerves.

The internal carotid nerve has generally been regarded as devoid of preganglionic components, although it includes some myelinated fibers. Every internal carotid nerve examined in the present investigation included 100 or more myelinated fibers. Aggregates of ganglion cells have been observed in 2 of the internal carotid nerves examined (Fig. 3A and B) just proximal to the point of juncture of the nerve with the plexus on the artery. Since the ganglion cells in the internal carotid nerve and those adjacent to the internal carotid artery must be synaptically related to preganglionic fibers, it appears highly probable that many of the myelinated fibers in the internal carotid nerve are preganglionic.

The data obtained relative to the cervical and rostral thoracic sympathetic roots indicate that, with possible exceptions, they include myelinated fibers. In only one instance (second cervical, cadaver 323, right) was a sympathetic root found to be devoid of myelinated fibers. All other sympathetic roots examined included some myelinated fibers less than 4 microns in diameter and, in most instances, at least a few 4 microns or more in diameter. The fibers in the former category can be traced directly to small mixed bundles arising from the sympathetic trunk. Some of those in the latter category are afferent spinal nerve fibers that traverse the sympathetic trunk. The large myelinated fibers that occur in compact bundles in the cervical sympathetic roots, as described by Pick and Sheehan,[17] are somatic fibers that innervate prevertebral muscles. Fibers in this category also traverse some cervical sympathetic roots in the cat (Fig. 3G) and the dog.

Counts of the myelinated fibers in the sympathetic roots of the three rostral cervical nerves vary widely. Most commonly those less than 4 microns in diameter are more numerous than those over four microns. The large myelinated fibers in these sympathetic roots probably are afferent. The origins of the small ones as yet are not fully known. Some undoubtedly are preganglionic fibers that make synaptic connections with accessory ganglion cells in the rostral cervical segments. Some probably are afferent cervical nerve components.

The rostral limit of the preganglionic outflow in man appears to be in the eighth cervical segment. The outflow of preganglionic fibers concerned with the sympathetic innervation of the upper extremity has long been a controversial issue. The assumption that no preganglionic fibers for the upper extremity traverse nerve roots more rostral than the second thoracic has been supported by Gask and Ross,[9] Foerster,[8] Sheehan and Marazzi,[20] Geohegen *et al.*[10] and others. Ray *et al.*[19] advanced the opinion that the rostral limit of the outflow for the hand is at the second thoracic level. On the basis of a recent study involving anterior root stimulation during surgical exposure, Bridges and Yahr[3] advanced data that support the assumption that the rostral limit of the preganglionic outflow for the upper extremity is at least as high as the eighth cervical segment. The emergence of preganglionic fibers in the ventral root of the eighth cervical nerve is also indicated by anatomical data obtained in this investigation.

The occurrence of preganglionic fibers in the ventral root of the eighth cervical nerve may now be regarded as amply demonstrated. Most of these fibers probably enter the stellate ganglion. In some instances some of them enter the intermediate ganglion. The cervical sympathetic roots that arise from the stellate and intermediate ganglia also include myelinated fibers in the preganglionic diameter range. Some of these undoubtedly are preganglionic fibers that make synaptic connections with accessory ganglion cells. In view of the experimental demonstration by Bridges and Yahr[3] that preganglionic components of the eighth cervical nerve are concerned in the sympathetic innervation of the upper extremity, complete surgical sympathetic denervation of the upper extremity obviously cannot be achieved without interruption of these fibers. In at least some instances this would require section of the communicating ramus of the eighth cervical nerve or extirpation of the intermediate ganglion in addition to section of lower communicating rami or extirpation of the corresponding sympathetic trunk ganglia. In the presence of accessory ganglion cells located in relation to the ventral primary rami of the nerves in question, complete sympathetic denervation also requires interruption of the pathways of which these ganglion cells constitute the distal elements, but which do not traverse the sympathetic trunk. This has been accomplished in the second, third and fourth thoracic segments by resection of the spinal nerve roots (Smithwick[23, 24]). No practical technic for the interruption of such pathways in the first thoracic and the eighth cervical nerve has as yet been devised. Accessory ganglion cells located in sympathetic roots in general are synaptically related to preganglionic fibers that traverse these roots. These pathways, therefore, are interrupted by sympathetic trunk extirpation or sections of the communicating rami.

Since the vertebral nerve includes preganglionic fibers and gives off rami to cervical nerves, it may be of surgical interest under certain conditions. This pathway probably is effectively interrupted by extirpation of the stellate and intermediate cervical ganglia.

Accessory sympathetic ganglion cells located in the internal carotid nerve and plexus undoubtedly are synaptically related to preganglionic fibers most of which traverse the internal carotid nerve. Others probably reach the internal carotid plexus through the nerves that accompany the common carotid artery. Those in the internal carotid nerve probably are interrupted by superior cervical sympathetic ganglionectomy. Complete surgical sympathetic denervation of the head and face, however, probably requires extirpation of several rostral thoracic segments of the sympathetic trunk and the intermediate cervical ganglion or section of the corresponding communicating rami.

SUMMARY

The cervical and upper thoracic portions of the sympathetic trunks and the sympathetic roots and rami connected with them have been studied in 11 human cadavers by means of dissections and microscopic analysis. The gross anatomical data in general corroborate the findings of earlier investigators. In instances in which a middle cervical ganglion cannot be detected grossly, it usually can be detected microscopically. An intermediate cervical ganglion was present in all but two and a stellate ganglion was present in all the sympathetic trunks examined.

Ganglion cells were present in all sections examined between the stellate and superior cervical ganglia in two sympathetic trunks. The frequent occurrence of accessory ganglia in the cervical sympathetic roots, as reported by Skoog,[22] is corroborated. Ganglion cells also occur in the internal carotid and the vertebral nerves.

The presence of ganglion cells and large numbers of myelinated fibers that do not exceed 3.5 microns in diameter in the vertebral nerve supports the conclusion of some investigators that this nerve represents an accessory sympathetic trunk. Every internal carotid nerve examined included 100 or more myelinated fibers, most of which are probably preganglionic fibers that are syn-

aptically related to ganglion cells in the nerve.

The cervical and rostral thoracic sympathetic roots include myelinated fibers most of which are less than 4 microns in diameter. Such fibers are particularly abundant in the sympathetic roots of the sixth, seventh and eighth cervical nerves. The observation of Pick and Sheehan[17] that myelinated fibers 4 microns or more in diameter frequently occur in compact bundles in cervical sympathetic roots is corroborated.

The requirements for complete surgical sympathetic denervation of the upper extremity and the head are considered.

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