Arterial Baroreceptor Fibers from the Aortic Region of the Dog in the Cervical Vagus Nerve

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ABSTRACT

The neural pathways followed by sensory fibers from arterial baroreceptors in the aortic region of the dog were investigated with neurophysiological recording. Systemic arterial baroreceptor fibers separate from the depressor nerve were found in the left cervical vagus in each of five dogs investigated; at most two fibers were isolated from each dog due to the difficulty of the dissection. These fibers originated from or above the aortic arch region. One baroreceptor fiber had its arterial sensory ending below the fifth rib. In the right cervical vagus in six dogs, visual evidence of fiber activity from systemic arterial baroreceptors could not be produced; only subjective (auditory) evidence for the presence of systemic arterial baroreceptor fibers was obtained. The number of these arterial baroreceptor fibers, which run in the vagus nerve but are not part of the depressor nerve, appeared to be smaller than the number of arterial baroreceptor fibers in the depressor nerve.

KEY WORDS

aortic depressor nerve baroreceptor fiber pathways vagal afferent fibers
aortic arch deafferentation neurogenic hypertension low-pressure baroreceptors

The various receptor fibers that run in the vagus nerve and the depressor nerve have been investigated for many years with both anatomical (1-3) and physiological techniques (1, 4, 5). Such investigations, however, are not complete. For instance, it is not clear whether the depressor nerve contains all or most of the baroreceptor fibers from the aortic and the subclavian regions in the dog or the cat. Nevertheless, in several studies, the denervation of these baroreceptors has been considered to be complete or virtually complete following bilateral section of the depressor nerves (6-8), and all arterial baroreceptors have been presumed eliminated by the additional section of the carotid sinus nerves (9-13).

Two major types of studies would be facilitated by elimination of the sinoaortic baroreceptor fibers. The first is the study of the reflex effects arising from receptors in the low-pressure portions of the cardiovascular system (atria [14], pulmonary artery [15, 16], and lung [17-20]). The second is the study of neurogenic hypertension following denervation of arterial baroreceptors (10, 11, 13).

In studying the low-pressure baroreceptors, several investigators have maintained constant pressure in the sinoaortic region (17-20) so that reflex effects from these receptors could be considered nonexistent. Edis and Shepherd (21) denervated the sinoaortic region by cutting the carotid sinus and the depressor nerves in the neck.

Conclusions about reflexes seen after selective sensory denervation (7, 8, 12) may be invalid if all the arterial baroreceptors are not cut, particularly when the stimulus produces arterial blood pressure changes. Considerations of neurogenic hypertension may also be influenced by the assumption of total denervation, and contradictory results have been reported following sinoaortic denervation (6, 10, 11, 13).

Systemic arterial baroreceptor fibers reach the central nervous system via the vagus, the recurrent laryngeal nerves, and the depressor nerve in the rat (4, 5, 22). O'Leary et al. (3) concluded that in the rabbit the vagus nerve serves as an additional pathway for the depressor nerve. Whether all arterial baroreceptor fibers join the depressor nerve in the neck is not known with certainty for other species. Since the dog is frequently used in studies of neurogenic hypertension and low-pressure baroreceptors, we conducted experiments to determine if some systemic arterial pressure fibers, running parallel to those in the depressor nerve, lie in the cervical vagus nerve of the dog.
Methods

Any aortic arch baroreceptor fibers which do not join the depressor nerve in the neck but remain in the cervical vagal trunk would be found in the vagal trunk cranial to the point at which the depressor nerve appears as a separate branch (Fig. 1). Location of baroreceptors in the arterial system can be determined by occluding vessels at several sites while recording the firing activity of the baroreceptors. If the pressure in the entire aorta is decreased by occlusion of the aorta at its origin, all systemic arterial baroreceptors will decrease their firing level, and low-pressure baroreceptors may increase their firing level. If the arterial baroreceptors are at the arch of the aorta, occlusion of the descending aorta will raise the arterial blood pressure and cause these baroreceptors to increase their firing rate. Baroreceptors on the pulmonary artery will be affected only as pulmonary arterial blood pressure changes.

Eleven dogs of both sexes (4-12 kg) were studied; studies were conducted on the left side in five dogs and on the right side in six dogs. The dogs were medicated with ketamine hydrochloride (35 mg/kg) and anesthetized with sodium pentobarbital (30 mg/kg), supplemented as needed. A long midline incision was made in the neck, and the trachea and the left common carotid artery were cannulated low in the neck. The tip of the arterial cannula was secured at the root of the brachiocephalic artery. With a stereomicroscope (10x magnification), the vagosympathetic bundle was carefully dissected free from the level of the thyroid artery up to the cranial pole of the nodose ganglion and to the middle of the superior cervical ganglion. The cranial end of the vagosympathetic bundle was freed by transecting the superior cervical ganglion and cutting the nodose ganglion above the root of the superior laryngeal nerve. The depressor nerve was then located anatomically and physiologically identified by dissecting free a short length of the nerve and placing it on a pair of platinum electrodes; the oscilloscope record and the sound pattern produced by the action potentials are distinct and synchronous with the cardiac cycle. Although in about half of the dogs the depressor nerve was visible in situ after little or no dissection of the vagosympathetic sheath, the two cranial ganglia of the vagosympathetic bundle were always sectioned so that a workable length of the vagal trunk was available.

Positive-pressure respiration was started and the left side of the chest was entered between the fourth and the fifth ribs. A length of ½-inch umbilical tape was looped around the ascending aorta at the heart and around the descending aorta at the level of the fifth rib. The ends of the umbilical tape were passed through 4-inch lengths of polyethylene tubing to form occluding nooses.

Next, the vagal trunk was sectioned immediately below the root of the superior laryngeal nerve and desheathed for about 1 cm or up to the point where the depressor nerve left the main vagal trunk. The desheathed vagal trunk was placed on a small dissecting platform inserted into the cavity in the neck formed by retracting the skin and the larynx. The nerve and the dissecting platform were then covered with warm mineral oil. Using a technique similar to that of Coleridge et al. (1), the vagal trunk was divided lengthwise into four large branches and then methodically reduced to about 100 single-fiber preparations under 16-25x magnification. Because of the large number of pulmonary stretch receptor fibers in the vagus, nerve fibers from cardiovascular receptors were further isolated during recording by turning off the respiratory pump after hyperventilating the dog. Whenever a cardiac frequency was discerned in a nerve slip, the ascending aorta and the descending aorta were occluded consecutively.

After all the vaginal fiber recordings were completed, the depressor nerve activity was again recorded. This step ensured that the depressor nerve was still intact and that all recordings were from fibers which remained in the vagal trunk.

Action potentials were measured with a pair of platinum electrodes, amplified by a Tektronix 122 amplifier, visualized on one beam of a Tektronix 502A oscilloscope, and simultaneously monitored with a loudspeaker. Both differential and single-ended recordings were used. A notch filter was used to attenuate 60-cycle noise when recording in the single-ended mode. The electrocardiogram was monitored on the second beam of the oscilloscope and used to trigger the oscilloscope sweep. Aortic arch pressure and respiration were measured with Statham pressure transducers. The latter two signals were displayed on a Beckman recorder and were simultaneously passed through Vetter FM adapters for recording on two tracks of a TEAC four-track tape recorder. Nerve activity and electrocardiogram signals from the oscilloscope were recorded.

**FIGURE 1**

Diagrammatic representation of the anatomical arrangement of the depressor nerve in the neck of the dog on the right side. Variations in anatomical arrangements are frequent. For a detailed study of variations in depressor nerve anatomy in the dog, see Hasimoto and Hirohata (25) and Edis and Shepherd (21).
directly on the other two tracks. The tape recordings were played back on a Honeywell visicorder for later inspection and study.

Results

In each dog a large number of nerve fibers in the cervical vagus displayed nerve activity with a cardiac rhythm. Nearly all of these fibers, numbering well over 50 separate fibers per side in each dog, were carrying information about blood pressure upstream from the ascending aortic loop and were presumed to be low-pressure baroreceptor fibers.

Unequivocal evidence of systemic arterial baroreceptor fibers could not be obtained in the right cervical vagus nerve in any of the six dogs studied. In a few instances systemic arterial baroreceptor activity was barely discernible by ear in relatively large vagal slips, but the fibers responsible apparently were destroyed in the process of dividing the larger slips into smaller branches.

However, records from vagal fibers showing systemic arterial baroreceptor activity were obtained from the left cervical vagus in all five dogs tested. At most two fibers were isolated from a given dog. Very likely there were more fibers, since recording from single-fiber preparations required more than 10 hours in some dogs. Like Coleridge et al. (1), we found that a nerve can continue to conduct action potentials for a very limited time after it is desheathed—the smaller the nerve slip, the shorter the available time. As indicated earlier, the vagus nerve was divided into four branches before it was examined electrophysiologically. The branch examined first invariably contained the largest number of active fibers. Furthermore, as in the right vagus nerve, activity of arterial baroreceptor fibers discernible by ear (but not seen as a single-fiber record) was encountered more frequently (up to six instances in one dog) in the left vagus. Unfortunately, no systematic tabulation of these findings was made. In fact once a suitable nerve recording was obtained, the search for more arterial baroreceptor fibers was pursued with less diligence and effort; our study was not aimed at determining the total extent of the arterial baroreceptor population in the cervical vagus.

In all but one case, the systemic arterial baroreceptor sensory ending was located somewhere on the arterial tree downstream from the ascending aorta and above the level of the fifth rib. A representative record of the activity of such a systemic arterial baroreceptor is shown in Figure 2. Following the occlusion of the ascending aorta, firing of this fiber ceased but promptly returned following the release of occlusion, thus definitely placing the site of this baroreceptor ending downstream from the ascending aorta. Occlusion of the descending aorta, which raised pressure in the aortic arch region, caused an increase in nerve activity, and placed the site of the receptor ending above or upstream from the level of the fifth rib. The possibility that this receptor is in the aortic arch is highly probable.

In one case a systemic arterial baroreceptor in the left cervical vagus had a receptor ending located below the level of the fifth rib (Fig. 3). In this case, occlusion of either the ascending or the descending aorta caused cessation of the nerve activity. Release of occlusion resulted in the prompt return of nerve activity in both cases.

Discussion

Since in this study the vagus nerve is severed cranially and is dissected free caudal to a point well past the carotid sinus, the possibility that any of
Recording of nerve activity of a baroreceptor whose sensory ending is located on the arterial tree below the level of the fifth rib. See legend to Figure 2 for explanation of abbreviations. The top half of the figure shows the nerve firing response to occlusion and release of the ascending aorta; the bottom half shows the response to occlusion and release of the descending aorta at the level of the fifth rib. These results indicate that the receptor ending is downstream from both occlusion sites.

These baroreceptor fibers could be from the carotid sinus, like those found by Jewett (23), is remote. These baroreceptor fibers are also not from the thyrocarotid arterial junction, since Cann and Bartter (24) found that such fibers coursed centrally in close proximity to the carotid sinus nerve. Our findings establish that the vagal trunk of the dog, at least the left vagus, is an alternate pathway by which fibers from baroreceptors in the aortic arch region pass to the central nervous system, as they do in the rat (4, 5, 22) and the rabbit (3, 9). As a consequence, complete denervation of the aortic arch in the dog cannot be accomplished by sectioning only the depressor nerve in the neck.

Our study suggests that the number of aortic arch fibers remaining in the left cervical vagus is much smaller than the number in the depressor nerve. There appear to be fewer systemic arterial baroreceptor fibers in the right cervical vagus than there are in the left, as manifest by our inability to obtain unequivocal evidence of these fibers in the right vagus. This difference between the left and the right sides agrees with the results of Hasimoto and Hirohata (25) who found that the effect of stimulating the right depressor nerve of the dog on blood pressure and heart rate varied from dog to dog but was always less than half the effect obtained by stimulating the left depressor nerve with the same voltage and frequency. Perhaps there are far fewer baroreceptor fibers from the root of the right subclavian artery than there are from the aortic arch.

The baroreceptor fiber shown in Figure 3 has its nerve ending low on the descending aorta. This receptor is not a pacinian corpuscle, because fibers from pacinian corpuscles travel centrally in the spinal cord (26). These more abdominally situated receptors must be few in number, since we found only one fiber in five dogs.

The significance of these vagal but nondepressor baroreceptor fibers must be questioned. It appears that the number of such vagal fibers is small compared with the number of depressor nerve fibers, and this observation tends to minimize their importance if importance depends only on the number of fibers. After the depressor nerve was sectioned in the neck, Hasimoto and Hirohata (25) reported no change in blood pressure in response to stimulation of the aortic nerve. However, the figure they presented to support this finding shows a small blood pressure response. Their results, furthermore, are open to criticism, because the carotid sinus receptors were intact: the magnitude of the responses they obtained must have been diminished by the buffering activity of the carotid sinus nerves. The results of Edis and Shepherd (21) indicate that these vagal fibers are not important. They reported that, after denervating both carotid sinuses and cutting the depressor nerves in the neck, reflex changes in blood pressure and heart rate in response to a marked increase in aortic arch pressure were abolished in six dogs. However, these investigators tested the reflex responses from the aortic arch but did not test the responses from the root of the right subclavian artery.

Even though reflex effects from vagal arterial baroreceptors may be minimal in acute experiments, these baroreceptors cannot be dismissed. Their effect in dogs made chronically hypertensive by sinoaortic denervation may be important. Some of the puzzling changes in blood pressure observed by Ferrario et al. (10) in their chronically hypertensive dogs may be due to these fibers. Also, the resistance response of the various vascular beds,
especially changes in hind-limb resistance attributed to low-pressure baroreceptors by Pelletier et al. (8), should be accepted with some reservation until more studies confirming the results of Edis and Shepherd (21) are available.

References


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