Influences of neck afferents on sympathetic and respiratory nerve activity

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P. S. Bolton, I. A. Kerman, S. F. Woodring and B. J. Yates

FROM ABSTRACT

It is well established that the vestibular system influences the sympathetic nervous system and the respiratory system; presumably, vestibulosympathetic and vestibulorespiratory responses participate in maintaining stable blood pressure and blood oxygenation during movement and changes in posture.

Many brainstem neurons that generate vestibulospinal reflexes integrate signals from the labyrinth and neck muscles to distinguish between head movements on a stable body and whole body movements.

In the present study, responses were recorded from the splanchnic (sympathetic), hypoglossal (inspiratory) and abdominal (expiratory) nerves during stimulation of the C2 dorsal root ganglion or C2 or C3 nerve branches innervating dorsal neck muscles.

Stimulation of neck afferents using low current intensities, in many cases less than twice the threshold for producing an afferent volley recordable from the cord dorsum, elicited changes in sympathetic and respiratory nerve activity.

These data suggest that head rotation on a stable body would elicit both cervical and vestibular inputs to respiratory motoneurons and sympathetic preganglionic neurons.

The effects of cervical afferent stimulation on abdominal, splanchnic and hypoglossal nerve activity were not abolished by transection of the brainstem caudal to the vestibular nuclei; thus, pathways in addition to those involving the vestibular nuclei are involved in relaying cervical inputs to sympathetic preganglionic neurons and respiratory motoneurons.

Transection of the C1-3 dorsal roots enhanced responses of the splanchnic and abdominal nerves to pitch head rotations on a fixed body but diminished responses of the hypoglossal nerve.

Thus, neck and vestibular afferent influences on activity of respiratory pump muscles and sympathetic outflow appear to be antagonistic, so that responses will occur during whole body movements but not head movements on a stationary trunk.
In contrast, neck and vestibular influences on tongue musculature are complementary, presumably to produce tongue protrusion either during movements of the head alone or of the whole body.

THESE AUTHORS ALSO NOTE:

There is considerable evidence to suggest that the vestibular system influences activity of both sympathetic and respiratory nerves.

“Electrical stimulation of the vestibular nerve results in changes in activity of a number of sympathetic nerves, as well as nerves innervating the diaphragm, intercostal muscles and abdominal muscles, and nerves innervating muscles regulating upper airway resistance.”

Natural stimulation of vestibular receptors produced by head rotations (on a fixed body) have prominent effects on the cardiovascular and respiratory systems in animals if the normal inhibitory influences are removed by transections of cervical dorsal roots and the IXth and Xth cranial nerves. Without the normal inhibitory influences from the cervical roots and cranial nerves IX and X, natural stimulation of vestibular receptors produced by head rotations will cause the following:

1) Increase in sympathetic nerve activity.
2) An increase in blood pressure of approximately 20 mm Hg.
3) Large increases in activity of nerves innervating abdominal muscles.
4) Large increases in activity of nerves innervating the tongue musculature.
5) Increased discharges in the phrenic nerve, which innervates the diaphragm.

Vestibular influences (increases) on the sympathetic nervous system offset orthostatic hypotension.

“Vestibulospinal reflexes presumably contribute to adjustments in breathing and airway patency during changes in posture and also could be directly involved in producing movement and postural change.”

“Vestibular inputs to the brainstem are elicited whenever the head changes position in space, either when the head is turned on a stationary body or when a whole body movement occurs.”

Many reflexes elicited by vestibular stimulation include:

1) There are vestibulospinal reflexes that act on the limbs during whole body movements, as when the body changes position in space during falling.
2) Importantly, the vestibulospinal reflexes do not influence the limbs when the head is turned on the body.
3) Therefore, the central nervous system must distinguish between whole body movements and head movements with the trunk fixed in space to generate appropriate compensatory reflex responses.
4) Therefore, vestibular nucleus neurons receive signals from neck receptors.
5) Vestibulosympathetic reflexes are well documented. This study and others document cervical afferents to the vestibular nucleus, creating cervical-vestibular-sympathetic reflexes. [Very Important]

Vestibulocollic reflexes are vestibular reflexes acting on neck muscles.

Cervicocollic reflexes are reflex contractions of neck muscles elicited by stimulation of neck proprioceptors.

Vestibulocollic and cervicocollic reflexes cause stability of head position.

This study (on animals) investigates the prospect that inputs from the neck might influence brainstem systems that control respiration and circulation.

An important component of this study was to determine if the removal of cervical inputs to the vestibular nuclei could alter the vestibulosympathetic and vestibulorespiratory reflexes. This analysis would also help to determine the strength of the cervicosympathetic and cervicorespiratory reflexes.

RESULTS

"In all cases, [afferent] stimulation of cervical afferents [C2 and C3] produced a change in splanchnic [abdominal sympathetic] nerve activity." The effect was bilateral.

The hypoglossal nerve also responded to C2 root afferent stimulation, but the response was less than the splanchnic nerve. The effect was also bilateral.

The abdominal nerves also responded to C2 and C3 root afferent stimulation, and again the response was less than the splanchnic nerve. The effect was again bilateral.

The ability of afferent stimulation of C2 or C3 roots to stimulate responses in the splanchnic, hypoglossal or abdominal nerves was still present but reduced after transection of the brainstem. "These findings suggest that whereas neck afferent inputs can reach sympathetic preganglionic neurons through pathways in addition to those involving the vestibular nuclei, neurons located in the rostral medulla or pons are critical for producing long-latency components of cervico-sympathetic responses."

Also, "the vestibular nuclei are not an essential part of the neural pathway relaying cervical inputs to hypoglossal motoneurons."

The effects of brainstem transection on cervicoabdominal responses showed a pronounced increase in nerve amplitude, indication that the transmission of cervical inputs to abdominal motoneurons is inhibited by the vestibular nuclei neurons.
Responses of the hypoglossal, abdominal and splanchnic nerves to head rotations were essentially normal only if the upper cervical nerve roots were intact; additionally:

1) If the upper cervical roots were transected, however, there was a 453 ± 247% increase in sympathetic activity (during head rotation). [This is quite important because it indicates that the vestibular nucleus excites the sympathetic nervous system while the cervical afferents inhibit the sympathetic nervous system].

2) If the upper cervical roots were transected, however, there was a 463 ± 349% increase in abdominal motor nerve activity (during head rotation). [This is quite important because it indicates that the vestibular nucleus excites abdominal motor nerve activity while the cervical afferents inhibit abdominal motor nerve activity].

3) If the upper cervical roots were transected, there was a 36.4 ± 19.8% reduction of the hypoglossal nerve responses. [This indicates that cervical afferents excite the hypoglossal nerve].

DISCUSSION

“The present study shows that cervical afferents, including those from dorsal neck muscles, influence activity of sympathetic preganglionic neurons, abdominal motoneurons and hypoglossal motoneurons.”

The cervical afferents produce changes in sympathetic and respiratory outflow.

This study showed that stimulation of muscle branches of cervical posterior primary rami “produced changes in sympathetic and respiratory nerve activity.”

These authors suggest that the cervical influence on the sympathetic nervous system is initiated by excited muscle spindle and Golgi tendon organ afferents.

“It is well established that stimulation of the vestibular system can affect activity in sympathetic and respiratory nerves; these responses are mediated by neurons in the medial and inferior vestibular nuclei.”

Afferent “inputs from the neck to sympathetic preganglionic neurons and respiratory neurons are relayed in part through cells in the vestibular nuclei with convergent neck and vestibular signals.”

“These experiments showed that neck inputs are also relayed to sympathetic and respiratory neurons through circuits that do not involve the vestibular nuclei.”
KEY POINTS FROM DAN MURPHY

1) The vestibular system influences the sympathetic nervous system and the respiratory system.

2) Vestibulosympathetic and vestibulorespiratory responses help maintain stable blood pressure and blood oxygenation during movement and changes in posture.

3) In this study, stimulation of the C2 dorsal root ganglion or C2 or C3 nerve branches innervating dorsal neck muscles elicited changes in abdominal (splanchnic [T5–T10]) sympathetic and respiratory nerve activity.

4) Cutting the C1-3 roots increases the activity of the splanchnic (abdominal sympathetic) and abdominal (diaphragm somatic motor) nerves to head rotations. [An important clinical application is that properly functioning upper cervical afferent nerves inhibit the abdominal sympathetic nerves].

5) Stimulation of vestibular receptors by head rotations will cause the following:
   A)) Increase in sympathetic nerve activity.
   B)) An increase in blood pressure of approximately 20 mm Hg.
   C)) Large increases in activity of nerves innervating abdominal muscles.
   D)) Large increases in activity of nerves innervating the tongue musculature.
   E)) Increased discharges in the phrenic nerve, which innervates the diaphragm. [Importantly, these effects are inhibited by well functioning upper cervical afferent neurons].

6) The vestibular nucleus receives afferent signals from neck receptors. [Very Important]

7) Vestibulosympathetic reflexes are well documented. This study and others document cervical afferents to the vestibular nucleus, creating cervical-vestibular-sympathetic reflexes. [Very Important]

8) “In all cases, [afferent] stimulation of cervical afferents [C2 and C3] produced a change in splanchnic [abdominal sympathetic] nerve activity.” The effect was bilateral.

9) Both neck afferent and vestibular efferents reach sympathetic preganglionic neurons, but do so through separate pathways.

10) Responses of the hypoglossal, abdominal and splanchnic (sympathetic) nerves to head rotations were essentially normal only if the upper cervical nerve roots were intact. [An important clinical application includes that if the upper cervical afferents were not functioning properly (subluxation), it would alter the function of the hypoglossal, abdominal and splanchnic nerves].
11) The vestibular nucleus excites the sympathetic nervous system while the cervical afferents inhibit the sympathetic nervous system.

12) The vestibular nucleus excites abdominal motor nerve activity while the cervical afferents inhibit abdominal motor nerve activity.

13) Cervical afferents excite the hypoglossal nerve.

14) The cervical afferents produce changes in sympathetic and respiratory outflow.

15) These authors suggest that the cervical influence on the sympathetic nervous system is initiated by excited muscle spindle and Golgi tendon organ afferents.

16) Afferent “inputs from the neck to sympathetic preganglionic neurons and respiratory neurons are relayed in part through cells in the vestibular nuclei with convergent neck and vestibular signals.”

17) “These experiments showed that neck inputs are also relayed to sympathetic and respiratory neurons through circuits that do not involve the vestibular nuclei.”

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The most important point of this article is that it adds to the evidence that upper cervical afferents inhibit visceral sympathetic efferent nerve activity.