Vagal Reflexes

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Many body reflexes are not clearly understood and have been given various theoretical explanations. Observations and the response to drugs have led to some of our present day theories, whereas the pathways of some reflexes have been proved by extensive research in the laboratory. I have tried to compose a brief review of the work of many authors to place the vagus nerve in its proper perspective.

The central nervous system is composed of brain and spinal cord. Nerves going toward or from the brain are called the cranial nerves of which there are 12 pairs. Those going toward or from the spinal cord comprise the 31 pairs of spinal nerves. The cranial and spinal nerves are classified as the peripheral nervous system.

FUNCTION OF THE NERVOUS SYSTEM

The function of the entire nervous system is adjustment to the external and internal environment. This may be summed briefly as follows:

I. Function: environmental adjustment
   A. External environment: Voluntary Nervous System
      1. Afferent (sensory) — gives us sensory awareness
      2. Efferent (motor) — conscious movement of somatic muscle
   B. Internal environment: Involuntary or autonomic nervous system
      1. Afferent (visceral)—usually without sensation
      2. Efferent (visceral)—alterations in movement of smooth muscle or myocardium. In some instances promotes or inhibits secretions.

From the outline below one can infer that some functions of the nervous system are at the level of consciousness or awareness, but many are below the level of consciousness.

Those reflexes dealing with external environment are anesthetized with ease and rapidity according to the particular drug used. Most signs of the level of anesthesia deal with the degree of anesthesia to the voluntary nervous system; one should be cognizant of the fact that general anesthesia applies to both the sensory afferent fibers and the motor efferent fibers. The muscle relaxants are not anesthetic drugs. They have no effect on the sensory afferent nerves. Their effect is produced at the junction of the efferent motor nerve and the muscle it innervates.

Desirable general anesthetic drugs will adequately anesthetize the voluntary nervous system but will leave the involuntary or autonomic nervous system to perform its function, namely regulating the internal environment.1

The combination of nerve fibers forming the cranial and spinal nerves are varied. Some are only afferent sensory, such as the optic or 2nd

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cranial nerve, whereas some are a combination of two, three or four of the nerve fibers listed above. The vagus nerve or 10th cranial nerve is one containing all four types of fibers.¹

AUTONOMIC OR VEGETATIVE NERVOUS SYSTEM

Before we become involved in discussion of the reflexes of the vagus nerve, a brief look at the function and distribution of the autonomic nervous system will make the vagal reflexes more readily recalled. There are two divisions: the sympathetic or thoracolumbar and the parasympathetic or craniosacral. One generally thinks of the fibers as being only efferent but this is not totally correct.² However, we will speak primarily of the efferent fibers. In life, as well as during the trauma of surgery, the sympathetic nervous system helps during stress. When the stress situation is removed the parasympathetic system restores the internal environment to normal conditions.

What signs do we observe in sympathetic and parasympathetic stimulation? Using the table in Fig. 1, think of the sympathetic system as a tiger lying under a tree eating his catch. Suddenly he picks up the scent of an approaching lion and he knows he is in immediate danger. Instantaneously the following occur:

- Pupils—dilate to improve vision.
- Salivary glands—flow is inhibited.
- Blood vessels in striated muscle—dilate to give good blood flow.
- Bronchi—dilate to permit more oxygen intake.
- Heart rate—increases to improve circulation.

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<thead>
<tr>
<th>SYMPATHETIC</th>
<th>PARASYMPATHETIC</th>
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<tr>
<td>Dilate</td>
<td>Constrict</td>
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<tr>
<td>Flow inhibited</td>
<td>Flow increased</td>
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<tr>
<td>Dilate</td>
<td>Possible slight constriction</td>
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<tr>
<td>Dilate</td>
<td>Constrict</td>
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<tr>
<td>Increases</td>
<td>Decreases</td>
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<tr>
<td>Dilate</td>
<td>Constrict</td>
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<td>Secrete adrenal</td>
<td>No innervation</td>
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<td>Glycogenolysis</td>
<td>Secretory</td>
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<tr>
<td>Inhibited</td>
<td>Peak performance</td>
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<tr>
<td>Constricted</td>
<td>Dilated</td>
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<tr>
<td>Vasoconstriction</td>
<td>Vasodilatation (slight)</td>
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<tr>
<td>Constricts</td>
<td>Stores RBC</td>
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**Pupils**
- **Salivary glands**
- **Blood vessels (striated muscle)**
- **Bronchi**
- **Heart Rate**
- **Coronary vessels**
- **Adrenal glands**
- **Liver**
- **Digestion**
- **Blood vessels in thorax & abd.**
- **Kidney**
- **Spleen**

Fig. 1. Physiology of sympathetic and parasympathetic nervous systems.
Coronary vessels—dilate to supply more nutrition and oxygen to the myocardium.

Adrenal glands—secrete more adrenalin which in turn keeps stimulating the sympathetic nervous system.

Liver—changes stored glycogen to glucose and ejects it into the blood for quick energy.

Digestion—is inhibited or may even discontinue.

Blood vessels—in the thoracic and abdominal viscera are constricted. Blood is not needed by the digestive system at this time.

Kidney—vasoconstriction so most of the blood will by-pass the kidney.

Spleen—constricts, forcing its stored red blood cells into circulation.

The animal is ready “for fight or flight”!

On the other hand, we have the actions of parasympathetic system. Try to picture a contented cow chewing her cud under a tree. We would observe the following:

Pupils—constrict. She has nothing to look or search for.

Salivary glands—secrete in abundance.

This is necessary for the beginning of digestion.

Blood vessels—in striated muscle will be somewhat constricted due to lack of exercise.

Bronchi—partially constricted. No need for increased respiratory exchange.

Heart rate—normal or somewhat decreased.

Coronaries—normal or constricted for the heart is not being taxed.

Adrenal glands—probably do not have innervation by the parasympathetic nerves.

Liver—collects the excess glucose from the blood (result of digestion) and stores it as glycogen. It also secretes many enzymes necessary for digestion.

Digestion—at its peak performance.

Blood vessels—in the splanchnic bed are engorged with blood. This is necessary for two reasons: supplying the digestive tract with blood and picking up nutrient material from the small intestine.

Kidney—normal blood flow or some vasodilatation.

Spleen—dilates and again stores red blood cells. This system permits restoration and conservation of body energy.

Neurohumoral System: Certain chemicals are necessary for nerve impulses to become effective. Very briefly, one may say acetylcholine is the humoral transmitter for parasympathetic nerves and is readily destroyed or hydrolized by the enzyme acetylcholinesterase to prevent sustained effects. The humoral transmitter for sympathetic nerves is noradrenalin which is quickly oxidized by amine oxidase.

Innervation: Most viscera is innervated by both sympathetic and parasympathetic nerves. One may consider them as being antagonistic to each other. The effects on the physiology will depend upon the degree of stimulation or depression of one system. This is illustrated in Fig. 2. The mid-line indicates the normal balance. Four changes may alter the normal but produce only two responses.

One of two things may give the appearance of sympathetic stimulation. Either the parasympathetic system may be depressed, as by atropine, or the sympathetic system may be stimulated, as in stress. On the other hand, two separate drugs or environmental changes may give the symptoms of an overactive parasympathetic system, e.g., a depressed sympathetic system as may be seen during high spinal anesthesia, or stimulated parasympathetic system produced by reflexes or the administration of physostigmine.

Vagus Nerve and Reflexes

The vagus nerve is the 10th Cranial Nerve. The cell bodies or nuclei of its efferent fibers lie in the medulla oblongata. The vagus is classified as a mixed nerve because it has fibers belonging to all four classifications. Some are afferent sensory, some efferent motor, others afferent visceral and still others, efferent visceral.
word "Vagus" is Latin for "wandering", and the nerve is well named. This is demonstrated by the diagram in Fig. 3, where briefly we show where the receptors are found for the afferent fibers and where the effectors are found for the efferent fibers.

Vagal reflex is an impressive term. When we need an explanation for some otherwise unexplained alteration in physiology, vagal reflex often calms the most arrogant and argumentative individual. Any surgical procedure could cause a vagal reflex. Usually,

![Diagram of the Vagus Nerve]

Fig. 3. Brief distribution of the Vagus Nerve.
when the term is used, we mean that the fiber which is classified as part of the parasympathetic system has been overly stimulated, resulting in bradycardia, hypotension or bronchial spasm. Actually vagal reflexes are numerous and varied. We shall mention only a few of the more common of them encountered during anesthesia.

When we wish to expose the glottis of a conscious patient, we follow the procedure necessary for adequate topical anesthesia of the oral and laryngeal pharynx. Again referring to Fig. 3, we see that if topical anesthesia is inadequate, the receptors of the afferent sensory fibers will receive the stimulus and convey it to the medulla. The efferent motor fiber will probably cause the striated muscle of the larynx and pharynx to respond. Gagging and spasm result. Coughing occurs as well, but this is not accomplished through the vagus nerve. The only part the vagus plays in the cough reflex is the closure of the vocal cords, permitting the muscles of the chest and diaphragm to build up pressure behind them. Closure of the glottis is caused by striated muscle—we can, to an extent, control it. Therefore, good topical anesthesia will not permit this reflex to have a starting point and this is to be desired.

To illustrate another reflex—An endotracheal tube has been inserted with rather inadequate general and topical anesthesia. The trachea is still sensitive. The anesthetist inflates the cuff and bradycardia results. Impulses may traverse either the afferent sensory or afferent visceral fibers (or both), be transmitted to the neuron forming the efferent visceral fiber. This may produce bradycardia and probably hypotension as well. This reflex may be called vago-vagal. This supposedly signifies that both the afferent and efferent neurons causing the reflex are vagal fibers. Do note the word "may". A rather recent study shows that tachycardia and hypertension usually occur. However, bradycardia and hypotension have also been observed. It is also noteworthy to remember that this reflex (parasympathetic stimulation) may cause constriction of the coronary vessels and insult the myocardium further by producing anoxia. The disastrous consequence of an anoxic myocardium might well be ventricular fibrillation.

Bradycardia and hypotension occasionally occur in patients undergoing some type of ocular surgery. The trigeminal (5th cranial) nerve furnishes the afferent fiber and the visceral vagus fiber produces the effect. Pressure of the face mask on the eye, or stimulation of the nasal mucosa under light anesthesia may also produce the same effect. Usually this is not extreme, but could be avoided by topical anesthesia to the eye, effective nerve block, reducing the pressure or stopping the stimulation.

Whenever intentional or inadvertent pressure is applied to carotid sinus in the neck, parasympathetic stimulation usually follows. The degree of hypotension and bradycardia will depend a great deal on the sensitivity of the carotid sinus.

The efferent fibers of the vagus are very numerous in the viscera of the thorax. During intrathoracic surgery these fibers may be stimulated directly, therefore, not requiring an afferent pathway. Stimulation of the vagus just above or at the level of the heart may cause cardiac standstill and absence of blood pressure.
We know that pain can produce shock. Often this picture of shock differs from shock produced by blood loss by bradycardia instead of tachycardia accompanying the hypotension. The skin may be warm and dry; not cold and clammy. One good example of this may be the patient in the recovery room who has had a hemorrhoidectomy under spinal anesthesia. After the effects of the spinal anesthetic drug have worn off, the pain may be intense. The pelvic nerve forms the afferent pathway which gives the patient a sensation of pain but it may stimulate the parasympathetic nerves of the vagus as well. Parasympathetic stimulation may be observed during various pelvic and rectal procedures, particularly if the patient is maintained in a light plane of anesthesia, with or without muscle relaxants. I have witnessed a cardiac arrest during a proctoscopic examination in which no anesthetic had been given and, unfortunately, no premedication had been given either. I am not prepared to say that this was due to vagal reflex, but no better explanation was volunteered. I have also observed sudden and intense bradycardia and hypotension during hysterectomy. Apparently, again, the pelvic nerve produces the afferent pathway and the vagus parasympathetic fiber, the efferent pathway. In almost every instance an intravenous injection of atropine grs. 1/150 gave dramatic improvement.

POSSIBLE PREVENTION AND SUGGESTED TREATMENT

How may one avoid these bothersome reflexes? Adequate oxygenation with proper elimination of carbon dioxide is of paramount importance. Deficient ventilation with a high concentration of oxygen may meet the metabolic needs for oxygen but may not permit elimination of carbon dioxide. This tends to have an acidifying effect, lowering the blood pH. It has been fairly well established that this prolongs the action of parasympathetic stimulation by inhibiting the hydrolysis of acetylcholine by acetylcholinesterase.

Since the advent of muscle relaxants we usually maintain patients in the 1st plane of the surgical stage. This is generally desirable. However, this level of anesthesia is often inadequate to completely block all afferent fibers, neither the afferent sensory or the afferent visceral, and it is possible for some stimuli to initiate the reflex. The efferent visceral pathway is not affected by anesthetic drugs until the 3rd and the 4th planes of the surgical stage are reached. This level of anesthesia the patient cannot tolerate, at least not for any length of time. One very effective method of correction is the use of regional drugs at the receptor cells of the afferent fiber. The reflex does not "get a start" so to speak. Topical, infiltration or nerve blocks are very effective. One might ask for less stimulation to a part, e.g., removal of instruments pressing the carotid sinus, but not all stimulation can be avoided.

Atropine blocks or inhibits muscarinic effects. That is, the effector cells in the viscera which are innervated by the parasympathetic nerves are inhibited. The entire reflex arc is permitted to be formed until it reaches the cells in the viscera where no effect is permitted. The end result gives the appearance of no reflex having ever been started.

One point about atropine needs clarification. For many years the use of atropine before Pentothal Sodium anesthesia was stressed. It was
thought to prevent laryngospasm. Atropine does have a drying effect on the salivary glands, thereby decreasing the possibility of mucous and saliva stimulating the vocal cords, but, atropine probably has no effect on striated muscle. Laryngeal spasm is made possible by the striated muscles of the larynx. The muscle relaxants, which paralyze striated muscle, will prevent or correct laryngospasm, but with our present knowledge of the nervous system and atropine, the usefulness of atropine for this purpose seems doubtful.

One cannot expect the muscle relaxants to prevent vagal reflexes. The curariform drugs may block the vagal reflexes at the autonomic ganglia but dosage must be equivalent to that required to produce respiratory muscle paralysis. However, the synthetic curariform drug, Gallamine (Flaxedil) seems to cause little or no autonomic ganglionic blockade.2

SUMMARY

A brief review of the physiology of the autonomic nervous system has been given emphasizing that the sympathetic system prepares the body for "fight and flight" and the parasympathetic in turn restores and conserves energy.

Various vagal and vago-vagal reflexes have been discussed and the afferent and efferent pathways have been outlined. These reflexes may or may not occur. In the event that they are present they may be recognized by bradycardia (including possible coronary constriction), hypotension and at times bronchiolar constriction.

Suggested prevention and treatment is the use of topical, local infiltration, and nerve block anesthesia; deeper planes of anesthesia, atropine and possibly large doses of the curariform drugs with the exception of Flaxedil.

BIBLIOGRAPHY