

Effects of Total Body Conduction Block

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This lecture will outline some of my opinions concerning symptoms, effects and complications resulting from total body conduction block, and also comparison between regional and general anesthesia.

The local anesthetic property of cocaine was first demonstrated clinically in 1884. In 1899, cocain was the first to be successfully used for clinical local anesthesia and then procaine was discovered as the first synthetic local anesthetic agent in 1904, followed by nupercaine, cinchocaine, dibucaine (1929), tetracaine (1930), lidocaine (1944), mepivacaine (1957), bupivacaine (1963), and lately etidocaine and ropivacaine in order. In 1904, Tuffier first tried cocain intrathecally to relieve the pain of sarcoma of the leg. As the better local anesthetics have been discovered, spinal and epidural analgesia have now been well established for clinical use. In recent decades, the regional anesthesia with local anesthetics became a very important part of all anesthesia.

And pain management also has been greatly improved to become a subspecial field in anesthesia. The main work in pain management is neural conduction block.

The transient neural conduction block is something mysterious in the pain management using local anesthetics, therefore, I will describe some of my opinions about neural conduction block.

The goal of pain management is to block nerve conduction of nociceptive impulses. The mechanism of neural conduction block is to inhibit sodium influx by the cation which plays the major role in conduction block. The local anesthetics have made a great contribution to modern medicine for human welfare.

Total body conduction block

In the early day of anesthesia history, the deliberate total body conduction block was widely carried out for almost all kind of surgeries on the lower body as well as the upper body, i.e., tonsillectomy and mastectomy etc. The total spinal anesthesia in accurate connotation should include blockade of all nerve roots originating from the spinal cord, i.e., all cervical, thoracic, lumbar and sacral nerves.

The conduction block is a term explaining physiological action mechanism of regional blockade. Therefore, conduction

and regional blocks are different in name but same in effectiveness and action mechanism. Total body conduction block is different from total spinal anesthesia. Total spinal anesthesia is blockade of all the spinal nerves originating from the spinal cord, whereas total body conduction block should include all the cranial nerves in addition to all the spinal nerves.

In 1903, Braum introduced the term 'conduction anesthesia' in his textbook for all region of the body.

Lately, the main title of the chapter for regional anesthesia in 'Introduction to Anesthesia' (8th ed. Dripps, 1995) is described as 'CONDUCTION ANESTHESIA' in capital letter. However, this book did not describe conduction block in detail.

The conduction of nervous system is vitally important for the living cell to preserve their body function. The nerve conduction is a basic function of the nervous system to exchange new informations to act and respond to the environment. The conduction block by applying local anesthetics is to stop the function of nerve fibers to transmit afferent impulses from the peripheral nerve ending and efferent impulses from the central nervous system. Here the term, "total body conduction block" implies the total blockade of all the informations transmitting from the environment to the central nervous system during the time while local anesthetic works. This transient conduction block by using the local anesthetics is mysterious and has made tremendous contribution to medical care

for mankind welfare providing several important benefits: 1) regional anesthesia for good surgical condition, 2) differential diagnosis, 3) pain management, and 4) rebalancing body function.

Let us consider whether the brain works or not when there is no information input to the brain, because the brain works only by the informations coming from internal and external environments. As conduction block in the body is widened, the subject receives less information, less alert, more dull and finally unconscious in total block. In total body conduction block, the body may not function except primitive activity such as cardiac autoregulation. Even respiration stops, but only heart beats. Almost all body organs may rest with no information input. Even heartbeats slow down with the block of cardiac accelerator.

Physiology of total body conduction block

The physiological effects of spinal anesthesia is well understood and easily managed. However, if spinal anesthesia extends to the cranial space, dramatic and life-threatening changes can occur. The mechanism of action underlying such changes differ significantly from that of spinal anesthesia predictable dermatomal anesthesia. When the cranial subarachnoid space is invaded, paralysis of the cranial nerves occurs and consciousness may also be affected.

Since, total body conduction block affects the spinal cord, brain and

autonomic nervous system, and causes vast physiological changes encompassing many organ systems, these changes therefore would best be described according to organ systems, the nervous, cardiovascular, gastrointestinal, genitourinary and endocrine systems.

1. Nervous systems

The nervous system can be divided into the central and peripheral nervous systems. The peripheral nervous system in turn can further be divided into the cranial nerves, spinal nerves and autonomic nerves.

1) Central nervous system

The complete pathway by which local anesthesia affects the brain and spinal cord through the subarachnoid space is not yet clearly understood. However, it is known that anesthetics can reach neurons through the pia mater. Measuring neuronal activity through EEG will likely be helpful in delineating this pathway. In actuality, the estimated time for lidocaine to reach neurons through the pia mater after administration into the subarachnoid space is significantly longer than what is observed in clinical practice. I will discuss the issue of consciousness later.

2) Peripheral nervous system

(1) Spinal Nerves: The spinal cord ends at the L2-L4 vertebral area, and the level of spinal anesthesia corresponds to the dermatomal level at which anesthetic is administered, and affects only the corresponding anterior and posterior nerve

roots. Thus, with spinal anesthesia, organs which are innervated by the spinal nerves corresponding to a particular dermatome are affected. In contrast, an anesthetic applied to the subarchnoid space would have direct access to all the brain, since the subarchnoid space contains the cerebrospinal fluid which flows freely to the central nervous system. In clinical practice, the level of spinal anesthesia can be determined by the clinical symptoms following anesthesia and accordingly adjusted. The sacral, lumbar, thoracic and cervical nerves can carefully and systematically be anesthetized in a predictable and dermatomal manner.

(2) Cranial nerves: Since the spinal and cranial subarachnoid spaces are contiguous, a drug administered in the spinal subarachnoid space would easily gain access to the cranial subarachnoid space. Once an anesthetic is administered into the spinal subarachnoid space, one can observe a gradual anesthesia upward from the level administered affecting the cranial nerves from caudal to cephalad.

The most obvious clinical features are observed in cranial nerves V, VII, IX and X. When the trigeminal nerve is blocked, the muscles of mastication relax, the jaw drops, and the tongue is paralyzed, allowing easier insertion of a laryngoscope and subsequent tracheal intubation. However, auditory and ophthalmic functions are also affected with time, and the response to auditory stimuli is lost and the pupils are fixed. Ultimately consciousness is lost. Thus, the effect of total body conduction block on the central

nervous system correlates with our anatomic understanding, with the auditory and ophthalmic functions affected last.

3) Autonomic nervous system

(1) Sympathetic nervous system: The sympathetic nervous system emerges from the T1-L2 nerve roots and synapse onto the sympathetic ganglia, located on various organs. Thus, this is the first to be affected following spinal anesthesia.

In the commonly used high spinal anesthesia, T1-T4 levels are involved, and the corresponding sympathetic nerves are completely anesthetized. The sympathetic nerves at this level innervate the heart and lungs, and through the stellate ganglia, they also innervate the upper extremities, pupils, auditory organs and brain. Thus, the high spinal anesthesia up to T1 level blocks total body sympathetic function. The specific effects on individual organ will be discussed below when reviewing according to organ systems.

(2) Parasympathetic nervous system: The anatomic location of the parasympathetic nervous system differs from the sympathetic nervous system. It emerges from the cranial nerves and S2-S4 spinal levels, and is composed of the cranial outflow and sacral outflow. The parasympathetic nerve fibers from the vagus nerve innervate the heart, lungs and abdominal organs. The sacral parasympathetic nerves innervate the colon and genital organs.

2. Cardiovascular system

The cardiovascular system is regulated by the sympathetic and parasympathetic nervous systems. The cardiac and vascular effects will be described separately.

1) Cardiac system

Parasympathetic nerve fibers innervate the sinus and atrial nodes of the heart through the vagus nerve. The sympathetic nervous innervation to the heart is provided by the cardio-accelerator fibers originating from T1-T4 spinal nerves and distributes throughout the entire heart. Generally, when blood pressure decreases, heart rate increases as a result of the feedback system through the baroreceptors. However, when total spinal anesthesia involves T4 or higher level, the cardio-accelerator fibers are affected, and bradycardia rather than tachycardia can occur causing subsequent hypotension.

Although one would expect a change in blood pressure following spinal anesthesia, since the sympathetic tone of peripheral vessels and cardiac output also affect blood pressure, spinal anesthesia has little effect on blood pressure when there is adequate effective circulating volume. However, when the anesthesia is up to the T4 or higher spinal level, cardiac-accelerator fibers become anesthetized and blood pressure drops precipitously.

My own observation is that blood pressure is usually well maintained with total spinal anesthesia, however hypotension is dramatic when blood

pressure is once affected. This may be due to the combined effect of the parasympathetic vagal stimulation to the sinoatrial node and the inhibited sympathetic tone of the cardio-accelerator fibers. However, the exact mechanism remains unclear.

2) Vascular system

With the exception of capillaries, precapillary sphincters and metarterioles, the arterial system is innervated with vasoconstrictor and vasodilator fibers, which are regulated by the impulses propagated by the sympathetic nervous system, thereby controlling the sympathetic tone. Therefore, when the sympathetic nerves are activated, small arteries and arterioles which are rich with the sympathetic nerve fibers constrict, resulting in increased vascular resistance and blood pressure. The regulation of peripheral circulation, however, involves not only the sympathetic nervous control, but also humoral regulation and local autoregulation. Local regulation of capillary blood flow undergoes autoregulation and is affected by tissue oxygen need and arterial blood flow, as well as humoral factors such as adenosine, histamine, hydrogen ion and potassium, thus involving a complex interplay between these multiple influences.

The way in which spinal anesthesia can affect the vascular system is by regulating the contractility of blood vessels through the sympathetic nervous system. Thus, hypotension following spinal anesthesia can be due to multifactorial pathways. The sympathetic fibers originate from the

T1-L2 nerve roots, then travel along the vertebral column, enter and synapse in the paravertebral ganglia and distribute to blood vessels. Since spinal anesthesia involves the anterior nerve roots, which passes through the subarachnoid space and anesthetizes below that particular spinal level, the entire sympathetic nervous system will be affected if the level reaches T1. Nevertheless, when high spinal anesthesia is clinically applied, vascular tone is retained, arguing that regulatory mechanisms other than the sympathetic nervous system is involved in maintaining vascular homeostasis. The degree of hypotension following total spinal anesthesia is less than what one would anticipate, were this the only regulatory mechanism of blood pressure. However, when hypotension occurs bradycardia is usually accompanied rapidly, the use of vasopressors is helpful. Vasopressors under these circumstances have a heightened response, and hypotension can be corrected with small doses of ephedrine.

3. Respiratory system

Respiration is regulated by the respiratory center and nerve fibers distributed. In higher spinal anesthesia, abdominal muscles are paralysed and respiration becomes calm and depressed. However, even when the spinal anesthesia level is quite high, the minute ventilatory volume and arterial oxygen exchange are not affected and, only when blood pressure drops, does the alveolar dead space increase.

Although respiratory arrest can be observed in total spinal anesthesia, respiration is intact even when spinal anesthesia involves the central nervous system, and diaphragm is not easily completely paralyzed. In my opinion, respiratory arrest can occur when an ample amount of anesthetic is administered above the C2-3 region. When the position of spinal anesthesia is higher, the central nervous system is affected, and simultaneous involvement of the vagus nerves causes vocal cord paralysis, resulting in respiratory compromise with respiratory distress. Paralysis of abdominal muscles inhibits the patient's cough reflex, and the only way to detect distress may be in the patient's facial expression. At this point, oxygen can be administered through a mask, and the patient can be oxygenated comfortably. Even if the central nervous system is involved, the anesthetic is diluted in the cerebrospinal fluid and respiration generally continues. If respiratory compromise occurs, it would occur at approximately 15 minutes following anesthesia. When the patient displays residual respiration, an application of 50-100 mg of pentothal sodium can completely abolish this, so that mechanical ventilation can be readily applied. There are usually no complications under the management of an experienced anesthesiologist.

4. Gastrointestinal system

The intestines are innervated by the sympathetic and parasympathetic nerves.

The parasympathetic stimulation allows contraction of the intestines and increases peristalsis, whereas the sympathetic stimulation does the opposite.

The sympathetic fibers all arise from the T5-L1 nerve roots and innervate the abdominal organs. The parasympathetic innervation to the stomach, small intestine and most part of the colon arise from the central nervous system through the vagus nerve, and the remaining parasympathetic fibers arise from the S2-S4 nerve roots to innervate the large intestine below the splenic flexure. Therefore, the usual spinal anesthesia below T5 level affects only the sympathetic and parasympathetic fibers below that level and does not involve the area of the vagal innervation. That is, the activity of the intestines increases, but the sphincter of Oddi, biliary and gastric motility persist, allowing nausea and vomiting to occur. Therefore, spinal anesthesia is relatively contraindicated in bowel surgery but indicated for paralytic ileus to restore peristalsis. In contrast, total spinal anesthesia would involve the vagus nerve and would have a different effect on the gastrointestinal system.

Although our observations have not focussed on the effect of total spinal anesthesia on the gastrointestinal tract, our initial observations point toward decreased gastrointestinal motility, when vagus nerve is paralyzed through total spinal anesthesia.

It is well known that the anesthesia of the sympathetic nerve fibers results in two-fold enlargement of the spleen and,

therefore thus, spinal anesthesia is contraindicated in internal bleeding and uncontrolled defecation can occur because the anal sphincter relaxes.

5. Genitourinary system

The kidney is innervated through the T11-L1 nerve roots, whereas the blood vessels supplying the kidney are not similarly innervated. Blood supply to the bladder is controlled by local autoregulation and diminishes as blood pressure decreases. Bladder function is regulated by the sympathetic and parasympathetic nerves and, when the sympathetic nerves are paralyzed, bladder function is compromised. Unlike renal function, bladder function is affected by spinal anesthesia. According to our observations and experiments, urinary retention occurs following spinal anesthesia. I have shown that this is especially prominent with total spinal anesthesia.

Since bladder function is regulated by the S2-S3 parasympathetic nerve fibers, the bladder muscles are paralyzed and the urinary sphincter remains constricted following spinal anesthesia, resulting in urinary retention. Penile erection is also controlled by the sacral parasympathetic nerve and, therefore is obliterated following spinal anesthesia, but flaccid engorgement occurs due to the dilated blood vessels.

6. Endocrine system

The adrenal glands receive the sympathetic innervation from the T11-L2 spinal levels through the preganglionic

cholinergic fibers, and there is no parasympathetic input. However, the pancreas receives both the sympathetic input from the T8-T9 spinal levels and the parasympathetic input from the vagus nerve. Anatomically, it is easy to understand it because most of the sympathetic nerve fibers are paralyzed when spinal anesthesia is applied, and the amount of epinephrine and norepinephrine released by the adrenal medulla decrease. Moreover, since nociceptive fibers are also affected by spinal anesthesia, norepinephrine released from the sympathetic nervous system further decreases, resulting in a decrease in total plasma catecholamines.

The adrenal cortex normally increases its steroid production following stress, and, therefore, blood 17-hydroxycortisone increases under the stress such as surgery and anesthesia. However, the stimulation to the adrenal cortex is blunted in total spinal anesthesia and steroid production decreases.

The innervation to the pancreatic islets of Langerhans is not well understood. The effect of spinal anesthesia on the endocrine system has not yet been well explored, and our understanding is rudimentary. The only well established effect is that the stress-response diminishes the function of the endocrine system.

7. Vision and hearing

Depending on the level of spinal anesthesia various sensory perception decrease and, in the case of total spinal anesthesia by which the central nervous

system is involved, the trigeminal and vagus nerves are affected. Initially, the ocular reflex remains intact, and the patient can close his eyes upon verbal command. With time, however, consciousness can diminish rapidly, and the anesthesia renders the patient unconscious. When consciousness is lost, the pupils are usually fixed, but occasionally anisocoria and pupillary constriction can be observed.

8. Level of consciousness

Awareness is integrally related to the reticular formation, and consciousness is lost when its function is suppressed. As the level of spinal anesthesia rises, the patient's consciousness varies according to the brain levels under anesthesia. Even before total spinal anesthesia, one can observe a gradual decrease in consciousness, as the level of spinal anesthesia rises. When total spinal anesthesia is achieved, consciousness is completely lost. On rare occasion when consciousness is not completely lost in total spinal anesthesia, this can be accomplished by a small dose of hypnotics, so that there is no memory of discomfort as the patient recovers from anesthesia and surgery. Based on my temporal observations on the loss of consciousness, this action cannot be explained by target organs involved through the pia mater after administration of lidocaine into the subarachnoid space. Rather, this action seems to differ from that of hypnotics or induction of general anesthesia.

The brain thinks only by receiving the

sensory information from 32 pairs of spinal nerves and 12 pairs of cranial nerves. Even if the neural network of the brain is fully functional, however, if the sensory input is impaired, consciousness would be impaired as well. Unconsciousness can thus be thought to comprise central unconsciousness and peripheral unconsciousness, and the unconsciousness resulting from total body conduction block might be peripheral unconsciousness.

I have carefully observed the effects of total spinal anesthesia beginning from its induction to recovery, after patients undergoing various surgeries were placed under total spinal anesthesia, and described in detail the effect of spinal anesthesia according to each organ.

Regional versus general anesthesia

Woodbridge defined anesthesia as having four components: 1) mental block (unconsciousness), 2) sensory blockade of afferent nerve impulses (analgesia), 3) reflex blockade of efferent impulses (muscles relaxation), and 4) reflex blockade of the respiratory, cardiovascular, or gastrointestinal tract. However, Woodbridge made no effort to define methods of assessing each of these components.

Anesthesia as a category can be classified into two main groups: general and regional anesthesia. General anesthesia will be defined as the use of inhaled or intravenous agents in any combination or dose range sufficient to cause loss of consciousness and some

attenuation of response to surgical stimulation but conduction activity still remains. Regional anesthesia may include all the regional block such as spinal block, epidural block, plexus block, nerve block, and local infiltration which block the conduction of nerve impulses by local anesthetics.

General anesthesia induce unconsciousness, but does not block the other three components. It only suppresses the conduction of nerve impulses. On the contrary, regional anesthesia does not induce unconsciousness, but block the other three components completely or partially.

Criles concept of anociassociation may give us lessons for different responses between regional and general anesthesia.

- 1) Conscious patients in whom auditory, visual, olfactory, and traumatic nociceptive impulses reach the brain.
- 2) Patients in whom only traumatic nociceptive impulses reach the brain during general anesthesia.
- 3) Patients in whom traumatic nociceptive impulses from the seat of injury are blocked during regional anesthesia, but auditory, visual, and olfactory impulses reach the brain.
- 4) Patients in whom all the auditory, visual, olfactory and traumatic nociceptive impulses are blocked during combined general and regional anesthesia.

The choice of anesthetic technique for surgical patients has implications which

are compatible with the choice of surgical techniques in different regions.

- 1) The safest technique for pain control in a large segment of the surgical procedures. The incidence of cardiac arrest is 1:2,500 cases of regional anesthesia
- 2) Regional anesthesia provides an alternative technique which can be combined with general anesthesia.
- 3) Currently developed local anesthetics (amide type) have practically no allergic responses.
- 4) The amide type of local anesthetics do not potentiate digitalis and have no undesirable effects on the neuromuscular junction.
- 5) Skillful use of local anesthetics provide both short and very long lasting blockade.

The advantages of regional anesthesia over general anesthesia

1. Suppression of stress response : Regional anesthesia produces only minor changes in metabolism and acid-base balance. The blood concentration of glucose in the upper abdominal surgery under general anesthesia is increased by 65%, as compared with 10% increase under epidural anesthesia which blocks the adrenal glands.

General anesthesia renders a patient unconscious, but transmission of stress impulses from the surgical site to the brain is not inhibited. The stress response causes the secretion of several hormones such as cortisol and

- catecholamines. By contrast, regional anesthesia blocks the transmission of afferent stress impulses and no changes in endocrine functions are seen. A study showed that the plasma cortisol response to the surgical incision was depressed by epidural anesthesia, but not by general anesthesia. The plasma concentration of epinephrine was also measured in the same patient category. In the patient receiving epidural anesthesia, the initial epinephrine level decreased, but the level returned to normal in two hours postoperatively. There are a number of studies suggesting that regional anesthesia may be the safer technique, reflected by lower incidence of morbidity and mortality of the patients.
2. Postoperative ileus can be avoided by continuous epidural analgesia. Peristalsis resets in sooner, as demonstrated by radiography and auscultation.
 3. Conduction anesthesia allows sufficient perfusion to the kidneys and preservation of renal function. In contrast, general anesthesia always reduces renal blood flow and glomerular filtration rate.
 4. In patients with eclampsia, lowering the blood pressure by epidural or spinal anesthesia removes them from the convulsive range and reestablishes diuresis.
 5. Conduction anesthesia makes it possible for the patient to cooperate during the surgical procedure.
 6. Perioperative pain relief by regional anesthesia avoids the use of a large dose of opiates and improves the pulmonary ventilation. The use of centrally acting analgesics will cause only a slight improvement in vital capacity without any changes of the other defects.
 7. Patients with coronary insufficiency and hypertension are ideal candidates for regional anesthesia.
 8. Regional anesthesia, especially continuous epidural anesthesia, has made a great contribution to obstetric anesthesia in recent years. An epidural block of the T11-L2 segments eliminates the uterine pain during dilatation. During the expulsive stage, the pelvic floor can be anesthetized through a second larger dose of the anesthetic agent administered in the sitting position. Regional anesthesia has particular advantages over general anesthesia in relaxing the pelvic floor in breech deliveries, premature deliveries, and multiple births. For mothers with cardiac problems, it is very important to decrease the effort they have to in order to overcome the resistance of the pelvic floor to the advancing head of the fetus.
 9. Aspiration of gastric content is practically eliminated in the mother who is awake.
 10. Intraoperative and postoperative blood loss is distinctly less in patients under conduction anesthesia.
 11. The rate of the thromboembolic phenomena is markedly reduced after

- epidural anesthesia, compared to straight general anesthesia.
12. Anesthesia and therapy can be combined in epidural anesthesia for vascular occlusion in the lower extremities.
 13. Airways are not compromised by prone position.
 14. Epidural anesthesia can be used in patients with a low serum potassium or in patients with myasthenia gravis.
 15. The danger of cardiac arrest due to hyperkalemia after succinylcholine can be entirely avoided by regional anesthesia.
 16. Patients with airway diseases are ideal candidates for regional anesthesia.
 17. When previous anesthesia with halothane and other halogenated hydrocarbons are contraindications for the use of the same agents, regional anesthesia offers an alternative.
 18. There is no danger of trace gas exposure to operating room personnel.
 19. Malignant hyperthermia can be avoided by regional anesthesia, using procaine or tetracaine in patients with family history.

Contraindication for conduction anesthesia

Hysteria, patients with a tendency for exaggerated complaints, neurologic complications, skin infections near the site of the injection, septicemia, bleeding tendencies, and hypovolemia *etc.*

Table 1. Advantages and disadvantages in general anesthesia

Advantages*	Disadvantages
Ease of administration	Applies primarily to cardiovascular and respiratory stability
Continuous depth control	Usually responding to unfavorable events(reactive control)
Amnesia for OR	Postoperative CNS depression
Stress response (neuroendocrine/metabolic)	Frequent breakthrough requires high dose of drug
Suppression	
Postop. pain control	Sedation/systemic effects
High arterial (perfusion) pressure	Increased myocardial oxygen consumption
Choice of agents for precise effects	Drug interactions Interpatient variability

*The advantages of general anesthesia over regional anesthesia. OR= operation room;
CNS = central nervous system; Postop. = postoperative.

Table 2. Advantages and disadvantages in regional anesthesia

Advantages*	Disadvantages
Decreased myocardial afterload	Decreased arterial pressure
Decreased myocardial preload	Volume loading frequently necessary
Stress response suppression	Neuraxial complication of catheter
Improved postop. pulmonary function with continuous catheter techniques	Neuraxial complication of catheter Continuous infusion needed
Less postop. sedation with spinal narcotics, local anesthetics	Delayed respiratory depression, continued sympathectomy
Decreased operative blood loss	Decreased arterial pressure and flow redistribution
Improved lower extremities blood flow	Sympathectomy Peripheral pooling
Decreased thromboembolic events postop.	Sympathectomy volume loading

* The advantages of regional anesthesia over general anesthesia; Postop. = postoperative.

Regional balanced anesthesia (combined epidural and general anesthesia)

It has been standard practice in many institutions to use a combination of light general anesthesia and epidural anesthesia for the abdominal and pelvic surgeries.

Development of pain clinic

In recent decades, pain clinic in many anesthesia departments has been developed and becomes a subspecial field of anesthesia. Major works in pain clinic are nerve blocks by conduction anesthesia. Therefore, all anesthesiologists should put more effort into training residents in this field of regional anesthesia.