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Review Article

Segmental Spinal Anesthesia: Systematic Review of Techniques and Outcomes

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ABSTRACT

The anatomical characteristics between the thoracic and lumbar spine are significantly different. Several MRI studies have demonstrated that there is a greater depth of the posterior subarachnoid space. Despite anatomical data, anesthesiologists are reluctant to consider higher levels for spinal anesthesia largely due to direct threats to spinal cord. Several articles published in the literature have demonstrated the safety of performing thoracic puncture for anesthesia. The puncture can be performed with a single puncture with a cut tip or pencil tip, or with the aid of the combined epidural-spinal block. In thoracic puncture, isobaric or hyperbaric anesthetics can be used, with or without opioids. The use of hyperbaric solutions provides a sensitive block of longer duration than the motor block. Thus, it is an excellent indication for outpatient surgery with low doses of local anesthetic and early discharge. Most of these articles report only were transient paresthesia, with no occurrence of definitive neurologic complications. Low doses of local anesthetics for segmental spinal anesthesia have already been performed in different types of surgery and certainly in the future more studies related to this technique will allow greater safety for its performance.

Keywords: Spinal anesthesia; Segmental; Thoracic puncture; Needles; Local anesthetic

INTRODUCTION

Segmental epidural anesthesia using low anesthetic volumes are often used for cervical-brachial surgical procedures, thoraco-abdominal plastic surgery, thoracic surgery and orthopedic surgery of the upper limbs. However, segmental spinal anesthesia is rarely used.

In 1909 it was proposed to perform General Spinal Anesthesia, which would be to perform segmental spinal anesthesia by using subarachnoid puncture as close as possible to the innervation of the operative field [1]. He performed high thoracic puncture in T2 for surgeries on the head, neck, upper limbs, and thorax and puncture between the T12 and L1 vertebrae for lower abdomen and lower limb surgeries. The mid-dorsal puncture between the T7 and T8 vertebrae is very often difficult to perform, and is not necessary, for perfect analgesia of the lower segment of the thorax can be obtained by puncture made between the last dorsal and first lumbar vertebrae, which is easier to perform and produces also anesthesia of the whole lower part of the body.

In 1932, a technique was described to produce segmental spinal anesthesia [2]. With the patient in a lateral position with the Trendelenburg position, a lumbar spinal puncture was performed and the cerebrospinal fluid (CSF) was removed and replaced by air injection. Immediately afterwards, a hypobaric solution of nupercaine was introduced into the subarachnoid space below the air. Subsequent injections of air would move the local anesthetic to the head region. In 1937, this technique was modified by removing the air injection and obtaining segmental spinal anesthesia [3]. In 1934, segmental anesthesia was obtained using two needles, one by subarachnoid puncture lumbar and one by puncture in the cisterna magna [4]. In a book "Spinal Anesthesia, Technic and Clinical Application" released in 1934, segmental anesthesia was obtained by high subarachnoid puncture [5]. He seeks to convince us that, by the adoption of his technique, the anesthesia is absolutely controllable He showed that novocaine in the subarachnoid space diffused under the influence of gravity, keeping the patient in the supine position for a few minutes, before adopting the Trendelenburg position to cause cephalic dispersion. In this way, he is able to extend the sensory block with virtually no motor block.

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Segmental spinal anesthesia can be produced by diluting local anesthetics with low doses [6]. The technique performed was through lumbar puncture between L2-L3 with 16G Huber-point needle and introduction of 25-35 cm catheter cephalic head and injection of 1-2 mg of pontocaine hydrochloride (Figure 1).

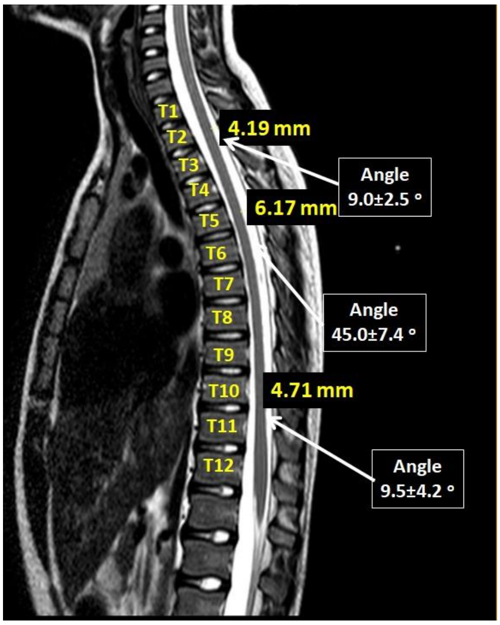

Figure 1: Magnetic resonance imaging of the spinal column, Distance of the Dura Mater to the Spinal Cord, Angle Relative to the Tangent at the Insertion Point on the Skin.

Anatomy for Thoracic Puncture

The anatomy of the thoracic spinal canal was investigated with magnetic resonance imaging (MRI) in 50 patients [7]. The space between the dura mater and spinal cord in the thoracic region measured with MRI was 5.19 mm at T2, 7.75 mm at T5, and 5.88 mm at T10 [7]. Calculating on the MRI the angle of entry between the intersection of T5 and T6, an angle of 45° was found, thus increasing the distance from the tip of the needle to the posterior surface of the cord. MRI confirms that the spinal cord and the cauda equina are touching the dura mater posteriorly in the lumbar region and anteriorly in the thoracic region [7]. This position increases the distance to a point that allows needle advancement without touching the cord, such as in the case of accidental perforation of the dura mater during the administration of spinal anesthesia. These results confirm those of a previous study that found a greater depth of the posterior subarachnoid space at midthoracic levels than at lumbar and upper thoracic levels [8]. This can be an anatomical explanation [9] of the low incidence of neurologic complication during accidental perforation of the dura mater in an attempt to give thoracic epidural block [10,11] and the safety of the segmental spinal anesthesia when performing a thoracic approach [12,13] and during the lateral cervical puncture for myelography or cerebrospinal fluid collection [14]. In a study with 636 patients [13] it was demonstrated that thoracic spinal puncture with cut point needle and pencil point needle presented an incidence (6.1%) less than the incidence of paresthesia (20%) as the lumbar approach [15].

REVIEW

Reasons for using spinal segmental anesthesia

Spinal anesthesia provides cardio-circulatory, respiratory and neurological changes depending on the dose and type of anesthetic used. Thus, techniques that enable limit anesthesia only in the field to be operated with more diluted and lower solutions doses, undesirable effects can certainly be avoided.While spinal anesthesia is the method of choice for lower extremity operations, it is within the abdominal cavity that it becomes the ideal procedure, because it provides unprecedented relaxation of the abdominal muscles, abdominal silence and an almost complete absence of postoperative complications. Unfortunately, this inherently splendid method has so far been regarded as a procedure of poorer quality and not suitable for segmental use.

Intrathecal block can be performed in three distinct zones: 1st) a low zone, limited above by the 1st nerve segments of the lumbar region, for operations on the lower limbs and perineum; 2nd) a middle zone, limited above the 10th thoracic segment (belly button), for operations on the lower abdomen and pelvis and 3rd) a high zone, limited above by the 4th thoracic segment (nipple area), for operations on the abdomen upper and lower thoracic.

Segmental spinal anesthesia of the lower thoracic was used in 1954 [16]. The information that there is substantially more space in the dorsal subarachnoid space at thoracic level, might lead to potential application in regional anesthesia [7,9]. The thoracic spinal puncture at T10 showed a rapid onset of action, regardless of baricity, decrease in the incidence of hypotension with faster recovery of the blockade, with low incidence of paresthesia and no spinal cord injuries in 636 patients [13].

If it were possible to limit anesthesia to the operative field and to use anesthetic agents in more diluted solutions and in smaller doses, certain undesirable effects of spinal anesthesia could also be avoided. This is the fundamental reason for using hemi anesthesia (posterior or unilateral) or segmental spinal anesthesia.

Spinal cerebrospinal fluid

Cerebrospinal fluid (CSF) is a clear, colorless body fluid found in the brain and spinal cord. There is about 125-150 mL of CSF at any one time, and about 500 mL is generated every day [17]. Spinal CSF dynamics are highly sensitive to respiratory performance and instantaneously reflect intraabdominal and intrathoracic volume and associated pressure changes. Forced inspiration and expiration therefore lead to upward and downward CSF flow in the spinal canal, respectively [18]. In addition, the CSF volume influenced the duration of spinal sensory anesthesia when the injection was made with the patient in a seated position, but not in the lateral position [19]. CSF density and volume influence the spread of spinal anesthesia with plain bupivacaine and that CSF volume also influences the duration of spinal anesthesia [20]. The entire spinal CSF volume, the cervical, thoracic, and lumbosacral CSF volumes and the spinal cord volume were calculated using MRI in healthy elderly individuals [21]. The total spinal CSF volume was 81 ± 13 ml (range 52-103 ml). The amount of CSF in the cervical region was 19 ± 4 ml, in the thoracic region 38 ± 8 and in the lumbosacral region 25±7 ml. In the thoracic region, the latency of thoracic spinal anesthesia is practically immediate and does not differ between hyperbaric and isobaric solutions [13].

Baricity and segmental spinal anesthesia

In 1907, Baker, in England, and Chaput, in France, developed the principles of gravity control of the technique [22], principles that are accepted until today. Barker used 10% stovain, with 5% glucose (ρ =1.0300) and Chaput 10% stovain, plus 10% sodium chloride (ρ =1.0831), both heavier than the CSF. They placed pillows under the head and neck to exaggerate the lumbar and dorsal curvature, most of the injected solution was attracted to the middle of the dorsal curve (5th and 6th thoracic vertebrae), providing segmental anesthesia suitable for the abdomen. In 1808, Jonnesco [1] presented his method with high (T2) and low (T12-L1) thoracic puncture using stovain with strychnine. His method of varying the height of anesthesia by spinal puncture in different interspaces provided segmental spinal anesthesia.

Only in 1932 was there new work with the objective of obtaining segmental spinal anesthesia [2]. The technique consisted of removing CSF and replacing it with air, position of the head down and the buttocks elevated, and injection of hypobaric solution thus obtaining low segmental spinal anesthesia. In 1947, it was proposed to perform segmental spinal anesthesia through the use of a subarachnoid catheter by lumbar puncture and the introduction of 25-35 cm of the catheter, using hyperbaric pontocaine hydrochloride [6].

The solutions frequently used in segmental spinal anesthesia cover all known solutions. In the beginning, a hypobaric solution was used. Subsequently, isobaric solutions were used. Modernly, hyperbaric and isobaric solutions can be used, depending on what you want to achieve with segmental spinal anesthesia. Isobaric solutions injected at the level of the 5th thoracic space can simultaneously block sensitive and motor roots, providing safe anesthesia. Likewise, if the hyperbaric solution is used, it can diffuse more sensitive fibers by bathing, providing a longer-lasting sensory block than motor block.

Segmental spinal anesthesia with continuous lumbar puncture

In 1946, Saklad proposing in his intraspinal segmental anesthesia work wrote: “with the advent of the catheter technic for fractional administration of drugs for spinal anesthesia and with the knowledge of the efficacy of dilute solutions, a more satisfactory method of segmental spinal anesthesia has been evolved ” [6]. He proposed performing segmental spinal anesthesia by placing a catheter by puncture between the second and third lumbar interspace with a 16G Huber point needle. The patient was placed in a lateral decubitus position with the horizontal table. After proper placement of the needle in the subarachnoid space, a catheter is passed in a cephalic direction. The catheter was advanced slowly and paresthesia could occasionally occur, with a 25 to 35 cm catheter being introduced. After removing the needle, a 10 mL syringe containing coupled hyperbaric pontocaine hydrochloride and small volumes of 1 to 3 mL were administered until segmental spinal anesthesia was obtained. In 24 procedures performed, satisfactory anesthesia occurred in 20 patients. In four patients there was a failure to place the catheter. Hyperbaric solution was injected and showed that the primary effect occurred in the posterior roots, and the sensory block was greater than the motor block. When hypobaric solution was injected, a greater number of anterior roots are affected in this way; there was a greater incidence of motor block compared to sensory block.

With the use of continuous spinal anesthesia with a microcatheter or catheter outside the needle (Spinocath®), no scientific article was found proposing the performance of segmental spinal anesthesia.

In two recent retrospective analysis with 318 patients [23] and 455 patients [24] using a micro-catheter or catheter outside the needle, no attempt was made to perform segmental spinal anesthesia.

Segmental spinal anesthesia with thoracic puncture

If it were possible to limit spinal anesthesia to only the field to be operated on, some of the side effects of this technique could be avoided. One of these possibilities is the use of more diluted anesthetic solutions or in low doses, associated or not with opioids. The standard spinal anesthesia technique with a lumbar puncture requires that the solutions of the anesthetic agents differ significantly from the CSF baricity, so that local anesthetic dispersion occurs within the subarachnoid space. Thus, the injected solution must have a relatively high concentration in the lumbar region, so that it can spread to the most distant nerve roots and obtain complete surgical anesthesia.

For segmental spinal anesthesia to occur, it is necessary to deposit the anesthetic as close as possible to the innervation of the surgical site. This was proposed by high or low chest puncture [1], removal of CSF and air injection [2], through continuous spinal anesthesia with catheter introduced in the lumbar region [6], or through combined epidural-spinal block with chest puncture [25,26].

Studies of the thoracic spine with MRI showed that there is a space between the dura and the spinal cord [7-9]. Modernly, segmental spinal anesthesia can be performed by single thoracic puncture [12,13,27] or through combined epidural-spinal anesthesia [25,26].

Thoracic single puncture

Spinal anesthesia by lumbar puncture is used for several surgical procedures. However, anesthesiologists are reluctant to perform higher punctures, largely due to the presence of the spinal cord.

The low thoracic puncture between T10-T11 was performed in 300 elective surgery patients, using the cut point needle and pencil point needle, both in the sitting position and in the lateral decubitus position [12]. Paresthesia occurred in 20/300 of patients (6.6%), all transient and no neurological complications were observed, showing that a lower thoracic puncture is safe.

Studying 636 patients have undergone open herniorraphy, urologic, laparoscopic surgery, gynecologic and orthopedic surgeries under thoracic spinal puncture comparing hyperbaric and isobaric bupivacaine there was no significant difference between the onset block, the duration of sensory block and incidence of hypotension [13]. All patients developed spinal anesthesia without failure or need for supplementation with general anesthesia. The incidence of paresthesia was 6.1%, and none of these patients had neurological symptoms at follow-up. There were no serious complications such as epidural hematomas, infection, or permanent nerve injuries in all 636 patients.

In another study comparing thoracic puncture with 7.5 mg hyperbaric bupivacaine +20 μg fentanyl vs lumbar puncture using 15 mg hyperbaric bupivacaine +20 μg fentanyl for laparoscopic cholecystectomy showed that the lowest dose causes less hypotension and fewer requirements for vasopressor to support blood pressure [28]. The time to reach the T3 thoracic level was significantly shorter with thoracic puncture. There was no significant difference in the time of pneumoperitoneum use or in the duration of surgery. In both groups, the duration of sensory block was significantly longer than that of motor block. The low-dose strategy and thoracic puncture may have an advantage in ambulatory patients because of the earlier recovery of motor and sensory function and earlier discharge.

In a prospective study with 200 patients, the parameters of thoracic spinal anesthesia (latency, motor block and paresthesia) and the incidence of cardiovascular and complications with low doses of isobaric and hyperbaric bupivacaine were compared [29]. In all patients, thoracic spinal anesthesia with isobaric or hyperbaric bupivacaine was sufficient for the orthopedic procedure and there was no failure. There was no significant difference between the solutions in relation to the beginning of the blockade. The duration of motor block was greater than the sensitive with isobaric and the duration of sensory block was greater than the motor block with hyperbaric solution. The incidence of hypotension was 12.5% with no difference between the two local anesthetic solutions. The incidence of paresthesia was 4%. There was no neurological damage in all patients. For providing a sensory block of longer duration than the motor block hyperbaric bupivacaine is reflected in a better indication for orthopedic surgeries of lower limbs.

Used segmental spinal puncture anesthesia between T5-T6 and injection of 5 mg hyperbaric bupivacaine +20 µg fentanyl for in breast surgery compared to general anesthesia, it showed an adequate option for mastectomy [30]. Among its advantages are the quality of postoperative analgesia, lower incidence of nausea and vomiting, and shorter recovery time, with the consequent early hospital discharge.

Thoracic puncture with combined epidural-spinal block

A segmental spinal anesthesia was performed through combined epidural-spinal block by thoracic puncture, without neurological complications [25,26]. Combined epidural-spinal block offers advantages over epidural or spinal anesthesia with a single injection. This technique was first described in 1937 [31]. Careful use of intrathecal injections into thoracic segments can be both an option and an epidural one for the experienced anesthetist. Both a spinal needle with a pencil point or a cutting point can be used. The orifice of the pencil tip needle is 0.8 mm indented from the tip, making it necessary to introduce almost 2 mm into the subarachnoid space to make sure that the orifice is within the subarachnoid space and to obtain the CSF [32]. The atraumatic needle (pencil point) has at least 1 mm of blind point beyond the orifice and there is a tendency to move further into the subarachnoid space, much more than necessary than with the cut point needle, which after entering the dura immediately reflecting the CSF. In this way, it becomes safer to insert the cut point needle in the thoracic region. Likewise, the entry angle between T5-T6 (almost 45°) lengthens the distance from the tip of the needle to the posterior surface of the spinal cord, measured by MRI, making it safer [7,9].

In a recent review of the perioperative management of patients with chronic obstructive pulmonary disease, the authors conclude that: whenever possible, neuraxial block, peripheral nerve block or general anesthesia without intubation is an indicated technique [33]. Thus, considering that regional anesthesia is described as the preferred modality in patients with chronic obstructive pulmonary disease, segmental spinal anesthesia with the injection of low doses of anesthetic in the subarachnoid space and the passage of the catheter in the epidural space, for possible reinjection should be the technique of choice. The use of low doses and thoracic puncture allows the segmentation of spinal anesthesia.

Arterial hypotension during spinal anesthesia occurs due to the decrease in systemic vascular resistance and central venous pressure due to sympathetic block with vasodilatation and redistribution of central blood volume to the extremities and splanchnic vascular bed [34]. In the case of segmental spinal anesthesia, this sympathetic block is rarely complete and some preservation of the sympathetic reflex for challenging situations typically occurs [34]. Interesting in this type of anesthesia segmenting both blood pressure and heart rate are at normal levels. Likewise, both oxygen saturation and $EtCO_2$ are always within normal limits throughout the procedure. High segmental spinal anesthesia confirms that it can be safe, even without tracheal intubation.

Local anesthetic solution

The solutions frequently used in segmental spinal anesthesia cover all known solutions. In the beginning, a hypobaric solution was used. Subsequently, isobaric and hyperbaric solutions were used. Modernly, hyperbaric and isobaric solutions can be used, depending on what you want to achieve with segmental spinal anesthesia. Isobaric solutions injected at the level of the 5^{th} thoracic space can simultaneously block sensitive and motor roots, providing safe anesthesia. Likewise, if the hyperbaric solution is used, it can diffuse more sensitive fibers by bathing, providing a longer-lasting sensory block than motor block.

Likewise, the puncture can be performed in the sitting or lateral position and immediately the patient must be placed in a cephalaclive position with the isobaric solution and cephalodeclivity with the hyperbaric solution. Both solutions may migrate to the cervical regions, preventing diffusion to the lower regions and providing segmental spinal anesthesia (Table 1).

Table 1: Doses and solutions used in the various articles.

Author	Puncture	Needle	Position	Bupivacaine	Dose	Opioids
Imbelloni[12]	T10-T11	27 Q and 27 W	LD or SEA	Iso and Hyper	No	No
Imbelloni[13]	T9-T10	27 Q and 27 W	LD or SEA	Iso and Hyper	5 to 10 mg	Fenta=20 µg
vanZundert[25]	T10	CES Kit	LD	Iso	5 mg	Sufenta=2.5 µg
Imbelloni[26]	T5-T6	CES Kit	LD	Iso	8 mg	Mor=50 µg
Hobaika[27]	T9	27 Q	SEA	Iso	5 mg	No
Imbelloni[28]	T10-T11	27 W	LD	Hyper	7.5 mg	Fenta=20 µg
Imbelloni[29]	T9-T10	27 Q and 27 W	LD or SEA	Iso and Hyper	10 mg	No
Elakany[30]	T5-T6	27 Q	LD	Iso	5 mg	Fenta=20 µg

Q: Quincke; W: Whitacre; LD: Lateral Decubitus; SEA: Seated; Iso: Isobaric; Hyper: Hyperbaric; Fenta: Fentanyl; Mor: Morphine; Sufenta: Sufentanil; CES: Combined Epidural-Spinal Kit

CONCLUSION

Spinal anaesthesia is one of the most popular and widely used anesthetic procedures. It is a simple, cost effective and efficient technique that provides complete sensory and motor block, as well as postoperative analgesia with a high success rate. In segmental spinal anesthesia, a limited number of nerve roots are bathed by an anesthetic solution within the subarachnoid space, providing surgical anesthesia in the surgical field dermatomes.

The amount of CSF could be of importance for performing segmental spinal anesthesia. Segmental spinal anesthesia can be obtained with thoracic puncture and single injection of isobaric or hyperbaric local anesthetic. Likewise, it can be achieved through combined epidural-spinal block, with intrathecal injection and later passage of the epidural catheter.

The study of the thoracic spine with MRI showed that the thoracic puncture to perform segmental spinal anesthesia is safe and so far without neurological damage. Because hyperbaric bupivacaine solution provides a longer sensitive block as compared to the isobaric solution it is better suited segmental spinal anesthesia.

CONFLICTS OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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