# INTRODUCTION

An advantage of local anaesthesia is that it can be used for anaesthesia or analgesia in a selective part of the body (regional anaesthesia or analgesia), with minimal interference with the patient's vital systems.

Around 1980, several clinical reports of fatal outcome after accidental intravenous (i.v.) injection or overdose of bupivacaine, indicated that bupivacaine possessed a relatively high cardiotoxic potency. It was also found that patients with severe cardiac reactions, such as ventricular fibrillation or arrest due to bupivacaine toxicity, were unexpectedly difficult to resuscitate, especially female patients in late pregnancy ***(Reiz and Nath, 1986)***.

A clinical consequence of bupivacaine's high cardiotoxic potency was that anaesthetists sometimes hesitated to use adequate doses, which could result in insufficient anaesthesia and use of general anaesthesia instead ***(Reiz et al., 1989)***.

As a result of these negative experiences with bupivacaine, several efforts were done to develop a less cardiotoxic alternative. The result of these efforts was the long acting local anaesthetic ropivacaine ***(McClure, 1996).***

Ropivacaine has a lower systemic toxicity than bupivacaine and levobupivacaine. The wider safety margin of ropivacaine allows the use of higher concentrations and

doses (up to 300 mg) compared with bupivacaine (where the maximum dose recommended is up to 200 mg) with less risk of systemic toxicity, ensuring better surgical anaesthesia ***(Knudsen et al., 1997)***.

The profile of anaesthesia with ropivacaine includes rapid onset, profound sensory and motor block and motor/sensory separation upon cessation of effect, which allows patients to benefit from early mobilization. It is less potent than bupivacaine and has a slightly shorter duration of action ***(Stienstra, 2003).***

Ropivacaine has been administered either alone or in combination with opioids and effective pain relief has been demonstrated when used alone thus avoiding the side effects associated with opioid use ***(Stienstra, 2003)***.

# AIM OF THE WORK

To compare hyperbaric ropivacaine 0.5% (in glucose 5%) with isobaric ropivacaine 0.5% (in normal saline 0.9%) for spinal anaesthesia in elective lower abdominal and lower limb surgery as regard clinical efficacy, extent of sensory block, limb motor bock, arterial blood pressure and heart rate.

# ANATOMICAL CONSIDERATIONS

## Subarachnoid Space:

The subarachnoid space is the compartment within the spinal column which contains the cerebrospinal fluid (CSF). CSF is produced in the ventricular system of the brain. It communicates freely with the subarachnoid space via the foramina of Luschka and magendi near the brainstem. CSF entering the subarachnoid space circulates caudad toward the lumbar cistern. Most of this is returned to the venous system via arachnoid villi which are present on the dural sleeves of spinal nerves although a small amount returns to the brain ***(Tortora and Grabowski, 1993).***

The subarachnoid space is bounded by the spinal meninges. These form a fluid filled dural sac which surrounds the spinal cord. The pia mater is a delicate, vascular membrane which closely invests the surface of the spinal cord. The subarachnoid space lies between the pia mater and, the arachnoid mater. The latter is a thin, avascular membrane which adheres closely to the fibrous dura mater, creating between them a potential space of small capacity, called the subdural space (fig.1). Inadvertent administration of local anaesthetic solution into this space can result in a subdural block. This is one of the mechanisms postulated for the complication of epidural blockade referred to as a total spinal block ***(Tortora and Grabowski, 1993).***

The subarachnoid space extends from the basal cisterns surrounding the brain stem superiorly, to its termination opposite the level of the second sacral vertebra. The meninges continue caudad from this point fused as the filum terminale which anchors the spinal cord to its attachment on the coccyx ***(Tortora and Grabowski, 1993).***

The dimensions of the subarachnoid space are determined by the cross sectional shape of the spinal cord at each segmental level. The sac widens in the cervical and lumbar regions which correspond to the enlargement of the spinal cord by nerves subserving the limbs. Above the level of the first lumbar vertebra it exists as a ring shaped recess. Here, the distance between the arachnoid mater and undivided spinal cord is 2-3 mm. The caudal end of the spinal cord, the conus medullaris, usually lies opposite the disc between the first and second lumbar vertebrae. Below this point, the subarachnoid space expands as a large lumbar cistern which contains the mobile cauda equina. The diameter at this point approaches 9 mm ***(Shapiro, 1975).***

## The Epidural Space:

The epidural space contains the dural sac, the spinal nerve roots, the extradural venous plexus, spinal arteries, lymphatics and fat. The veins are valveless and distend when the patient strains or coughs. They drain via the azygos vein to the inferior vena cava and may distend when there is obstruction to the vena cava (e.g., in advanced pregnancy or with a large abdominal tumour). They are

continous below with the pelvic veins and above with the intracranial veins. A misplaced epidural injection that inadvertently enters the extradural veins can cause local anaesthetic agent or air to track intracranially. The extradural space is widest posteriorly and at this point is occasionally divided by a fold of dura mater into two or three compartments that do not always communicate with each other. The consequence of this infrequent abnormality may be patchy analgesia after an epidural anaesthetic. Prolongations of the dura surround the nerve roots (dural cuffs) and fuse with them as they traverse the intervertebral foraminae. The anterior and posterior nerve roots cross the epidural space before they join in the intervertebral foramina and thus can be anaesthetized by the epidural route ***(Tortora and Grabowski, 1993).***

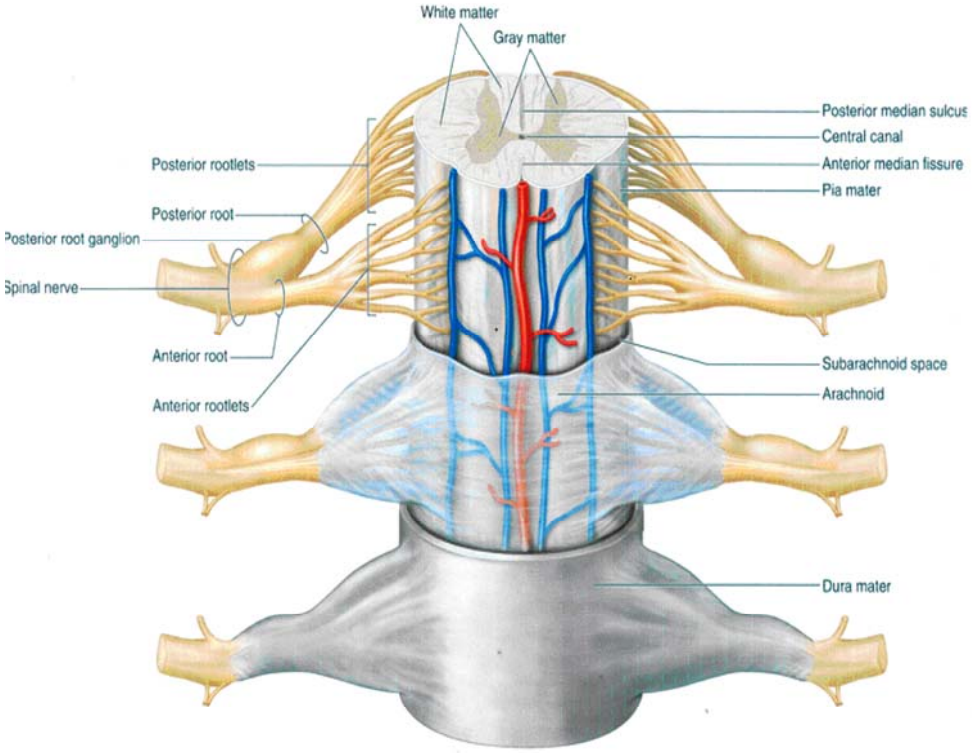


**Fig. (1):** Diagram showing anatomy of spinal cord and meninges ***(Bellenir, 1997).***

# SPINAL ANAESTHESIA

Professor Bier performed the first surgical operation using spinal anaethesia at the Royal Surgical Hospital of the University of Kiel, Germany on August 16, 1898, heralding the advent of major regional anaesthesia using neuraxial blockade ***(Bier, 1899)***. In 1927, spinal anaesthesia was performed by Labat at the Mount Sinai Hospital ***(Labat, 1927)***. Since then, of course, it has been well incorporated into the practice of anaesthesiology ***(Bacon, 1996)***.

Spinal anaesthesia has had fervent advocates since the first description of "anoci association" by Crile in 1911, with his claims that the brain could be protected from stress by blocking the input noxious stimuli from the periphery ***(Crile, 1911)***.

## Intrathecal drug spread:

Spinal anaesthesia has the definitive advantage that profound nerve block can be produced in a large part of the body by the relatively simple injection of a small amount of local anaesthetic. However, the greatest challenge of the technique is to control the spread of that local anaesthetic through the cerebrospinal fluid (CSF), to provide block that is adequate (in both extent and degree) for the proposed surgery but without producing unnecessarily extensive spread and so increasing the risk of complications. The

great interpatient variability in spread was observed and described by Bier ***(Bier, 1899),*** the first person to use the technique clinically, and has challenged many subsequent workers. In fact, the definitive studies were performed nearly 100 years ago by Arthur Barker, a London surgeon who was the first to use solutions made hyperbaric by the addition of glucose, but his principles have had to be re-learned virtually each time a new drug has been introduced for the technique ***(Barker, 1907)***.

### *Mechanisms of intrathecal drug spread*:

The CSF of the vertebral canal occupies the narrow (2-3 mm deep) space surrounding the spinal cord and cauda equina, and enclosed by the arachnoid mater. As the local anaesthetic solution is injected, it will spread initially by displacement of CSF and as a result of any currents created within the CSF. The next stage, which may be the most crucial, is spread due to the interplay between the densities of both CSF and local anaesthetic solution under the influence of gravity. Gravity will be 'applied' through patient position (supine, sitting, etc.) and, in any horizontal position, by the influence of the curves of the vertebral canal. Many factors are said to affect these mechanisms with some having greater impact than others. The key ones are the physical characteristics of CSF and the solution injected, the clinical technique used and the patient's general features ***(Greene, 1985)***.

Once bulk spread of the injectate under the influence of the physical forces outlined above is complete, the final stage is diffusion of the drug through the CSF and into the nervous tissue ***(Hocking and Wildsmith, 2004)***.

**CSF characteristics:**

CSF is an isotonic, aqueous medium with a constitution similar to interstitial fluid. The terms density, specific gravity and baricity define its physical characteristics, but are often used loosely and interchangeably, causing confusion.

Baricity is analogous to specific gravity and accordingly, a hypobaric local anaesthetic is defined as a solution with a density more than 3 standard deviations (SD) below mean human CSF density ***(Connolly and Wildsmith, 1998).***

The units of density are weight per unit volume. The mean density of CSF at 37°C is 1.0003 g litre$^{-1}$, with a range of 1.0000-1.0006 (± 2SD) g litre$^{-1}$. Most glucose-free solutions used intrathecally are just hypobaric ***(Parlow et al., 1999)*** but behave in a hyperbaric manner if cooled to 5°C before injection ***(Mignonism et al., 1992).***

CSF density is lower in women than in men ***(Schiffer et al., 1999),*** in pregnant than in non-pregnant women ***(Richardson and Wissler, 1996)***, and in premenopausal women compared with postmenopausal women and men ***(Lui et al., 1998)***. Theoretically, these differences could lead to differences in the movement of a particular solution in the various patient groups (e.g. a solution that is isobaric in men may be hyperbaric in pregnant women), but the differences between groups are small and probably unimportant clinically ***(Hocking and Wildsmith, 2004)***.

**Factors affecting intrathecal spread**:

***I. Characteristics of the injected solution*:**

***** Baricity:

Almost 100 years ago. Barker was the first to study systematically the factors affecting intrathecal spread. Using glass models of the spinal canal and coloured solutions, he deduced that gravity and the curves of the vertebral column could be used to influence the spread of solutions made hyperbaric by the addition of glucose ***(Barker, 1907)***. Babcock employed the opposite approach, using solutions made hypobaric by the addition of alcohol ***(Babcock, 1912)***, while Pitkin used alcohol and strychnine in 'Spinocain' ***(Pitkin, 1929)***. Given the neurotoxic effects of such substances, it is not surprising that the addition of glucose is the only method of altering baricity to remain in routine use. The usual choice for the clinician is between a

hyperbaric solution and one with a baricity at, or just below, that of the CSF. Hyperbaric solutions are more predictable, with greater spread in the direction of gravity ***(Tetzlaff et al., 1995)*** and less interpatient variability ***(Brown et al., 1980)***. In contrast, most plain solutions exhibit greater variability in effect and are less predictable ***(Vercauteren et al., 1998)*** so that the block may either be too low, and therefore inadequate for surgery, or excessively high, causing side effects ***(Taivainen et al., 1990)***. The greater mean spread of hyperbaric solutions may be associated with an increased incidence of cardiorespiratory side effects ***(Moller et al., 1992)***, although this is not always the case ***(Critchley et al., 1999)*** and may depend on the concentration of the glucose. Commercially available solutions contain up to glucose 8%, but most of the evidence shows that any concentration in excess of 0.8% will produce a solution that behaves in a hyperbaric manner (fig. 2), but with somewhat less extensive spread if the glucose concentration is at the lower end of the range ***(Connolly et al., 2001)***.

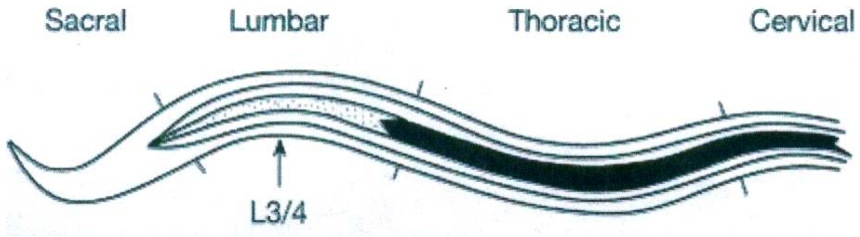


**Fig. (2):** Curves of the vertebral canal influencing movement of drugs according to gravity. Spread is influenced initially by bulk displacement, injection currents and gravity/baricity, then by diffusion through the cerebrospinal fluid and into the central nervous system ***(Hocking and Wildsmith, 2004)***.

*****Volume/dose/concentration injected:

Clearly, it is impossible to change one of these factors without changing another, but this is not always appreciated. For example, many studies purporting to show an effect of volume fail to change the concentration of local anaesthetic, with a consequent increase in the dose administered. When the effect of volume (up to 14 ml) is isolated from other factors, most studies suggest there is no significant influence on mean spread ***(Van Zundert et al., 1996; Ben David et al., 1996)***. However, one study has reported that volume is an important determinant of the spread of a truly isobaric solution ***(King and Wooten, 1995).*** Low volume injections (1.5-2 ml) may reduce mean spread ***(Schmidt et al., 1990).***

Similar basic concerns apply to studies of the effects of different doses: a change in dose will be accompanied by a change in either volume or concentration. Some studies designed to control for changes in the other factors have shown that increased dose is associated with increased spread ***(Khaw et al., 2001)*** and others there is no difference ***(Runza et al., 1998).*** What really needs to be appreciated is the scale of the effect. If no drug is injected there will be no effect, and a massive overdose (e.g. accidental intrathecal injection during epidural block) will produce a total spinal, but there is not a straight line relationship inbetween. Within the range of doses normally used, a 50% increase in the dose injected will result in an increase of mean spread of only a dermatome or so ***(Brown***

***et al., 1980).*** Such differences may, on occasion, be statistically significant, but are rarely clinically so, although the increase in duration is associated with a larger dose ***(Hocking and Wildsmith, 2004)***.

***** Temperature of the solution:

Both CSF and local anaesthetics exhibit a curvilinear decrease in density with increasing temperature. CSF is at core body temperature whereas local anaesthetic solutions are administered at room temperature. There will be some local decrease in CSF temperature (2-3°C with a 2.7 ml bolus; 6-8°C with a 12 ml bolus) immediately after injection ***(Ernst, 1968)*** but the core temperature is restored within 2 min, so solution density should be reported at body temperature. The consequences of temperature effects are most relevant with plain solutions, bupivacaine 0.5%, for example, being slightly hyperbaric at 24°C (density 1.0032 kg $m^{-3}$), but slightly hypobaric at 37°C (density 0.9984 kg $m^{-3}$) ***(Nicol and Holdcroft, 1992).*** Even such minor differences in baricity can cause completely opposite distribution patterns ***(Callesen et al., 1991)***, and may also account for the large variability in the spread of plain bupivacaine when injected at 'room' (which may vary considerably) temperature ***(Stienstra and van Poorten, 1988).***

*****Viscosity:

This factor has received little attention, but addition of glucose to an aqueous solution changes viscosity as well as

density. Using tetracaine, Okutomi and colleagues in 1998 compared solutions with a similar specific gravity but different viscosities (containing glucose 10% or NaCl 5%), and others also with a similar specific gravity but only slightly different viscosities (containing glucose 5% or NaCl 2.5%). The most viscous solution (glucose 10%) produced significantly greater mean spread than the others, suggesting that this factor is relevant to spread. Plain solutions are considerably less viscous than those containing glucose, which may be less miscible with CSF ***(Okutomi et al., 1998)***. The injected bolus of drug may thus spread further before mixing fully with CSF, but producing a more 'even' distribution as it does so. Pitkin in 1929 also considered viscosity important and included starch paste in his 'Spinocain' solution ***(Pitkin, 1929)***.

***II. Local anaesthetic drugs and additives*:**

Studies of a wide range of local anaesthetic drugs indicate that intrathecal spread is the same, no matter which one is used, as long as the other factors are controlled ***(Glaser et al., 2002).*** Solutions containing vasoconstrictors spread in exactly the same way as those without, although block duration may be prolonged ***(Kito et al., 1998)***. The addition of other drugs, such as opioids or clonidine, has a dual effect. First, such additions are achieved by mixing the adjuvant and local anaesthetic solutions, usually reducing the density of the latter. In theory this might make the mixture behave in a more hypobaric manner ***(Parlow et al., 1999)***, but no effect has been shown in