Review Article

Current Concepts in Spinal Anesthesia

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Spinal anesthesia was introduced into clinical practice during the last decade of the nineteenth century. The technique owes its origins to the work of Bier in Germany and Tuffier in France. They worked independently, but Tuffier, although he did more to popularize the method, acknowledged Bier’s priority. Because of the problems associated with the use of cocaine, spinal anesthesia was not widely used until more suitable drugs, such as stovaine and procaine, became available.

It was with stovaine that Barker (in London) performed his classic experiments on the effects of the curves of the vertebral column and the baricity of the injected solution on the distribution of blockade. This work formed the basis for the techniques of spinal anesthesia developed by many subsequent workers. Solutions (of a wide range of drugs) were classified as hypobaric, isobaric, or hyperbaric relative to CSF and the effect of gravity, manipulated by the use of posture, was employed to direct these solutions along the curves of the vertebral column. It was recognized that other factors, such as speed, level of injection, and barbotage were relevant, but Barker’s findings became the cornerstone of clinical practice.

Until recent years few, if any, of these points had been tested in patients in properly designed and controlled trials, and workers in several centers began to realize that many of the “established” facts were contradicted by their own clinical experience. As a result, much has been published in the last few years on the clinical factors that influence spinal anesthesia. Some of this work has challenged some of the most firmly held views. For instance, dose has been considered to have a major effect on the extent of blockade, but little effect on duration, and many practitioners relate the amount of drug they administer to the size of the patient. Isobaric solutions have been considered to be unreliable and vasodilators have been thought to prolong duration of block. The aim of this paper is to review some of the newer work, emphasizing those aspects that appear to contradict some of the traditional views and to indicate how the newer work is relevant to everyday clinical practice. Where possible, open studies performed in a controlled, randomized, double-blind manner are referred to.

Baricity of Solution/Posture of Patient

Everything that has been published has confirmed Barker’s original finding that the most important factor in spinal anesthesia is the interrelationship between the baricity of the solution and the posture of the patient. What has been challenged in recent years is the belief that the combination of posture and baricity may be used to direct the solution through the CSF with some precision. Spinal solutions are classified according.
to their densities relative to that of CSF. Hyperbaric solutions will tend to move downward and hypobaric ones upward, whatever the posture of the patient. The spread of isobaric solutions will be unaffected by gravity. It is, therefore, important to relate the spread of these different solutions to the posture in which the patient is placed during and after injection.

The Supine Patient

Probably the most common posture sequence employed is for the lumbar puncture to be performed in the lateral position, with the patient turned supine with extended legs immediately after injection. In such patients, Brown and his colleagues (using 0.5% tetracaine injected at the third lumbar interspace—the space used in most papers reviewed here) found that the mean upper level of block was in the mid-thoracic dermatomes with hyperbaric solutions, but that blocks produced by isobaric and hypobaric solutions were restricted to the lower thoracic segments. It would seem that the hyperbaric solutions gravitate to the spinal hollows, but that the other two solutions remain close to the site of injection. In terms of distribution of block, there was little basis for choice between isobaric and hypobaric solutions in this situation, but they noted that the hypobaric solutions tended to produce “patchy” blocks. These authors also suggested that isobaric solutions might have advantages when a block restricted to the legs and perineum is required.

The Sitting Patient

In the sitting patient, hyperbaric solutions will tend to sink down into the sacrum and hypobaric solutions to rise up toward the thoracic segments. For instance, Tuominen and his colleagues found that 0.75% bupivacaine plain (which is hypobaric) spread to T-8 in supine patients, but to T-4 in those kept sitting for 5 minutes after injection.

The degree of effect will depend on the length of time the patient is maintained in the sitting position and the volume injected. Wildsmith and his colleagues were able to produce classic saddle blocks in patients who received 1 ml of hyperbaric tetracaine and then kept sitting for 5 minutes, but a group who received a larger volume and then kept sitting for only 2 minutes had blocks that spread almost as far as in patients who were placed supine immediately after injection. The same study confirmed that posture has no effect on the spread of isobaric solutions.

The Lateral Patient

In order to produce blocks that are restricted to one side, some anesthesiologists inject a hyperbaric solution and keep the patient lying on the operative side for awhile afterward. The aim is to limit the blockade of sympathetic nerves to the side of the operation and thus decrease the likelihood of hypotension. One study of this technique found that, at 5 minutes after injection, distinctly unilateral block had been produced, but that, over the next 15 minutes, the block on the other side developed to virtually the same level. The block on the “lower” side was more profound and lasted longer than that on the “upper” side, but there was virtually no difference in spread between these patients (who were kept on the side for 5 minutes) and a group turned supine straight after injection.

Dose, Volume, and Concentration of Solution

It has been a widely held belief that the larger the dose of local anesthetic injected, the greater the resultant spread of the solution. Recent studies, however, have begun to question if, within the range of volumes normally used for spinal anesthesia, this is true. Injection of isobaric 0.5% tetracaine in a dose of 5, 10 or 15 mg produces blocks that are indistinguishable in spread and are usually limited to the legs and perineum. This lack of influence of injected dose amount on the spread of isobaric solutions seems to apply whatever the posture. With hyperbaric solutions, the inter-relationship between dose and spread may depend on the patient’s posture, although the results of recent studies are somewhat contradictory.

In one study of patients placed supine straight after injection in the lateral position, the dose of hyperbaric tetracaine did not affect spread, a finding that was repeated with hyperbaric 0.5% bupivacaine in the same center. However, Sundnes and his colleagues found that the spread of hyperbaric bupivacaine in supine patients was linearly related to injected dose, although, in their study, doubling the injected dose only raised the mean level of block from T-10 to T-7. Axelson and his colleagues found a much greater effect of dose on the spread of hyperbaric bupivacaine in patients kept sitting for 2 minutes after injection. Spread
was directly related to the log of the volume of the local anesthetic solution. Their smallest volume (1 ml) produced typical saddle blocks, and the largest (4 ml) produced blocks to the mid-thoracic level.

Dose may also be a more important factor in determining spread of hyperbaric solutions in patients kept in the lateral position after injection. For instance Moore found that 12 mg of tetracaine produced blocks of good quality on both sides (as in the study referred to earlier), but that with 7.5 mg the block on the "lower" side was much more profound than on the "upper" side, which was inadequate for skin incision.

Obviously an important factor in consideration of the dose and volume of a solution is its concentration. The three factors are interdependent and a change in one will always affect another. As an example of the way this may affect results, Chambers and his colleagues found that spread of 0.5% hyperbaric bupivacaine was unrelated to dose, but that there was a linear relationship between the two when a 0.75% solution was employed. Very little work has been done that looks at the effects of changing the volume of solution without altering the dose. A study that did just that with isobaric tetracaine found that, as volume increased, there was a small increase in the mean level of block, but that the most important effect of increasing the volume injected was simply to increase the unpredictability of spread.

**Minor Factors Affecting Spread**

It has always been recognized that the level of injection into the spinal column will affect the upper level of block. Recent work has confirmed that this is so and that speed of injection and barbotage are also relevant, but it has also suggested that neither effect is very predictable. Needle size does not seem to have an effect on its own.

**Factors Affecting Duration**

As with all other local anesthetic techniques, the prime factor in deciding duration of blockade is the drug employed. The relative durations of blocks for the different agents is similar to those found in other situations, but the question of absolute values is complicated by several points that have to be considered. First, spinal anesthetics wear off, starting at the uppermost segment blocked and moving progressively downward. Second, the first point has resulted in the evolution of several quite different methods of assessment of duration, so that comparison of the results of different studies may not be easy. Finally, there are a number of other factors that may affect duration (see following section). It is a reasonable assumption, however, that lidocaine will produce a block lasting at least 1 hour and bupivacaine and tetracaine at least 2 hours.

As was indicated in the previous section, there is some controversy as to whether drug dose affects the spread of spinal anesthesia. What all the reports that are quoted previously have found is that, contrary to previous views, an increase in dose will prolong duration, often by quite significant amounts. Duration is also affected by the level of block that is produced. If a block is produced.

### Table 1. Effect of Vasoconstrictors on Duration of Spinal Anesthesia (Data Derived from Refs 13-15)

<table>
<thead>
<tr>
<th>Local Anesthetic Drug</th>
<th>Vasoconstrictor</th>
<th>Increase at T-12</th>
<th>Duration Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lidocaine 5%</td>
<td>Epinephrine 1:1000</td>
<td>0.1, 10</td>
<td>18*</td>
</tr>
<tr>
<td>with dextrose 7.5%</td>
<td></td>
<td>0.2, 12</td>
<td>19*</td>
</tr>
<tr>
<td>1.5 ml</td>
<td></td>
<td>0.3, 5</td>
<td>17*</td>
</tr>
<tr>
<td>Bupivacaine 0.5%</td>
<td>Epinephrine 1:1000</td>
<td>0.2, 33</td>
<td>17*</td>
</tr>
<tr>
<td>with dextrose 8%</td>
<td>Phenylephrine 1%</td>
<td>0.5, 14</td>
<td>12</td>
</tr>
<tr>
<td>3 ml</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetracaine 1%</td>
<td>Epinephrine 1:1000</td>
<td>0.2, 5</td>
<td>40*</td>
</tr>
<tr>
<td>without dextrose</td>
<td>Phenylephrine 1%</td>
<td>0.5, 30*</td>
<td>65*</td>
</tr>
<tr>
<td>1.5 ml</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant increase; N.B.: 15 mg plain tetracaine lasts 50% longer at T-12 than 10 mg.
duced to mid-thoracic level, it will be of shorter duration than if the same dose of the same drug spread only to the upper lumbar level. Presumably the greater spread of solution results in a lower concentration in each nerve blocked.

Vasoconstrictors

In many centers it is a matter of faith that the addition of vasoconstrictors to the anesthetic solution will prolong the duration of block. However, a series of studies by Chambers and his colleagues in Edinburgh has questioned the usefulness of this practice. Table 1 summarizes some of their results in terms of the increase in duration of blockade at T-12 and time to complete regression. It can be seen that the percentage increases, especially at T-12, are relatively small, particularly when it has been shown that increasing dose by 50% will increase duration by about the same amount. Only with tetracaine were there significant prolongations in duration, a finding that has been confirmed by others.

![Figure 1](https://example.com/fig1.png)

**Fig. 1.** Illustrates the poor relationship between patient height and level of sensory anesthesia with two local anesthetic solutions. Data derived from Reference 21.

Individual Patient Factors

In all the previous discussion there has been much reference to the mean level of block produced in the various studies. It is important to appreciate that, in all these studies, the blocks seen varied by at least two segments above and below that mean and in some cases by much more. What factors contribute to this variation?

It is said that taller patients require more solution to reach a desired level. This might be so, but recent work (Figure 1) has shown that the correlation between patient height and spread of block is very poor. What little evidence there is does not suggest that level of block is much related to body weight in the nonobese, although the morbidly obese patient seems to develop blocks to higher levels than others as the pregnant patient who is near term. The common factor in the latter two groups might be a low CSF volume around the cord. Distended epidural veins in pregnancy and epidural fat in the obese might displace fluid rostrally, allowing greater bulk spread of the injected solution. This is pure hypothesis, although there is no doubt that prior removal of CSF does produce higher blocks. A decrease in CSF volume with age might explain the slight tendency to greater spread in the elderly. This might also be related to abnormalities of the spinal curvature which are more common in the elderly.

Summary and Clinical Implications

What is the clinician to make of all this sometimes conflicting evidence, and how can it be related to everyday clinical practice? Figures 2 and 3 summarize the factors that affect the spread and duration of intrathecally injected local anesthetic solutions. Those that affect spread are cataloged.

<table>
<thead>
<tr>
<th>Major Factors</th>
<th>Baricity of solution</th>
<th>Posture of patient*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dose/volume injected*</td>
<td></td>
</tr>
<tr>
<td>Minor Factors</td>
<td>Level of injection</td>
<td>Barbotage</td>
</tr>
<tr>
<td></td>
<td>Speed of injection</td>
<td>Needle size</td>
</tr>
<tr>
<td></td>
<td>Physical status of patient</td>
<td></td>
</tr>
</tbody>
</table>

*Not relevant to isobaric solutions.

![Figure 2](https://example.com/fig2.png)

**Fig. 2.** Factors affecting the spread of intrathecal injections of local anesthetics.
as having a major or minor effect, and this also implies their importance in developing clinical techniques. What Figure 2 cannot show is that the main effect of many of the minor factors is really to increase the unpredictability of the block in a way similar to the effect of volume mentioned previously. All the studies reviewed showed some variation in blocks around the mean levels quoted. Of more clinical interest than the mean level are the lowest (for guaranteed efficacy) and highest (risk of hypotension) blocks produced. Figure 4 illustrates this by indicating the range of blocks likely to be produced by three different solutions. The techniques described in the following have been derived with this general point in mind.

The question of clinical techniques is simplified by considering just what we require from spinal anesthesia. In essence, three levels of block are needed:

1. A "saddle" block for procedures on the perineum. This may be reliably produced by injecting a small volume of a hyperbaric solution in a patient kept sitting for at least 5 minutes afterward. There is some inherent delay but minimal risk of hypotension.

2. A block to the level of the inguinal ligament for procedures on the lower limb. This may be produced by injecting an isobaric solution. Such a block may also be used instead of a saddle block, since the risk of hypotension is also very low, the patient does not have to be kept sitting, and the hip joint is anesthetized. Since most patients for saddle block will be placed in the lithotomy position, this may avoid discomfort due to acute hip flexion.

3. A block to mid-thoracic segments for abdominal surgery. This may be produced by injecting a hyperbaric solution into the patient turned supine immediately afterward. For many patients (especially those having operations such as herniorrhaphy) this will produce a block that is somewhat higher than necessary. This would not matter too much except that the risk of hypotension is greater. To avoid and keep the block a few segments lower, the patient may be kept sitting for a short time lying with hips and knees flexed to flatten the lumbar curve. However, it should be remembered that the effect of the latter two maneuvers is not predictable.

In each of these suggested techniques it is assumed that lumbar puncture is performed at the lumbar interspace and that small volumes are injected slowly. Similar results are possible using different approaches, but we would suggest that these methods have the benefits of simplicity and reliability. Duration will depend on the particular drug and dose employed.

**Drug Variations**

The previous discussion has at least implied that different drugs behave in much the same way when injected intrathecally. In general this is probably the case, although it has been suggested that tetracaine is more predictable in its spread than either dibucaine or bupivacaine. In addition, tourniquet pain has been found to be more common with tetracaine than with bupivacaine, and tetracaine to cause more hypotension than dibucaine. However, it is important to ensure that the solutions are otherwise equal when two drugs are compared. A most obvious example of this relates to the recent popularity of plain bupivacaine as a spinal anesthetic agent. It is often considered to be isobaric, although it does not produce results comparable to isobaric tetracaine.
(Figure 4). The reason is simple—it is slightly hypobaric and it behaves in just the way a hypobaric solution would be expected to. Any differences between drugs in their behavior after intrathecal injection must be considered to be "not proven" until studies are performed with the agents dissolved in solutions that are identical in terms of baricity, tonicity, etc.

References

5. Tuominen M, Kalso E, Rosenberg PH. Effects of posture on the spread of spinal anaesthesia with isobaric 0.75% or 0.5% bupivacaine. Br J Anaesth 1982;54:313-318.