Updates in Continuous Spinal Anesthesia

Essay
Submitted for the partial fulfillment of Master degree in anesthesiology

By
Eslam Ayman Mohamed Shawki Kahla
(M.B.B.CH.)

Under the supervision of

Prof. Dr. Maher Fawzy Mahmoud
Professor of Anesthesiology
Faculty of Medicine
Cairo University

Ass. Prof. Dr. Ahmed Abd ElAziz Aref
Assistant Professor of Anesthesiology
Faculty of Medicine
Cairo University

Dr. Maha Mohamed Ismail
Lecturer of Anesthesiology
Faculty of Medicine
Cairo University

Faculty of Medicine
Cairo University
2010
Acknowledgement

I would like to express my sincere gratitude and profound thanks to Prof. Dr. Maher Fawzy Mahmoud, Professor of Anesthesiology, Faculty of Medicine, Cairo University, for his valuable remarks and advices, constant encouragement, and his meticulous supervision and outstanding support.

I'm also deeply indebted to Ass. Prof. Dr. Ahmed Abd ElAziz Aref, Assistant Professor of Anesthesiology, Faculty of Medicine, Cairo University for his sincere guidance and support to complete this work.

Also, I'm deeply grateful to Dr. Maha Mohamed Ismail, Lecturer of, Anesthesiology, Faculty of Medicine, Cairo University, for her generous help, valuable advices, great support and effort for this work.

I would like also to thank my parents, my wife and my brother for the continuous help and support they offered me during this work. Lastly I like to express my deepest gratitude to the oldest medical school in the Egypt, Kasr El Aini which offered me all the learning and training chances I needed to become a competent doctor who can give a hand of help to whoever needs it.
<table>
<thead>
<tr>
<th>Content</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index of Contents</td>
<td>I</td>
</tr>
<tr>
<td>Index of Figures</td>
<td>III</td>
</tr>
<tr>
<td>List of Abbreviations</td>
<td>V</td>
</tr>
<tr>
<td>Abstract</td>
<td>VI</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Chapter 1: Anatomy</td>
<td>4</td>
</tr>
<tr>
<td>Chapter 2: History</td>
<td>7</td>
</tr>
<tr>
<td>Chapter 3: CSA Kits, Drugs and Related Devices</td>
<td>12</td>
</tr>
<tr>
<td>- The Most Commonly Used CSA Kits</td>
<td>12</td>
</tr>
<tr>
<td>- Drug Agents That Can Be Used Intrathecally</td>
<td>16</td>
</tr>
<tr>
<td>- Implantable Intrathecal Drug Delivery Systems (Pumps)</td>
<td>22</td>
</tr>
<tr>
<td>Chapter 4: Indications &amp; Advantages of CSA</td>
<td>26</td>
</tr>
<tr>
<td>- Obstetric and Gynecological Procedures</td>
<td>28</td>
</tr>
<tr>
<td>- Surgeries in the Lower Part of the Body with or without Coexisting Disease</td>
<td>34</td>
</tr>
<tr>
<td>- Pediatric Open Heart Surgery</td>
<td>40</td>
</tr>
<tr>
<td>- General Advantages of Neuraxial Blocks</td>
<td>42</td>
</tr>
<tr>
<td>Chapter 5: Contraindications &amp; Complications</td>
<td>43</td>
</tr>
<tr>
<td>- Contraindications for Continuous Spinal Anesthesia</td>
<td>43</td>
</tr>
<tr>
<td>- Complications of Continuous Spinal Anesthesia</td>
<td>47</td>
</tr>
<tr>
<td>(A) General Complications</td>
<td>48</td>
</tr>
<tr>
<td>(B) Catheter-Related Complications</td>
<td>60</td>
</tr>
</tbody>
</table>
Conclusion ..................................................................................................................... 70
Summary ....................................................................................................................... 71
References ..................................................................................................................... 73
# Index of Figures

<table>
<thead>
<tr>
<th>Figure Number</th>
<th>Figure Description</th>
<th>Reference</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>A lumbar vertebra in lateral and antero-superior views.</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>02</td>
<td>The lumbar interlaminar gap.</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>03</td>
<td>The anatomy of lumbar puncture.</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>04</td>
<td>Midsagittal view of the meninges, ventricles, subarachnoid spaces, and cisternae.</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>05</td>
<td>Lemmon needle.</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>06</td>
<td>The Patient lying with the CSA needle protruding from his back</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>07</td>
<td>Hingson Ferguson needle.</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>08</td>
<td>Tuohy needle.</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>09</td>
<td>Tuohy Flowers needle.</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>Cappe and Deutsch needle.</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>11</td>
<td>CSA needle with Protective Shield over Lumbar spine.</td>
<td><a href="http://www.bbraun.com">www.bbraun.com</a></td>
<td>9</td>
</tr>
<tr>
<td>12</td>
<td>CSA needle metal protector.</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>13</td>
<td>SpinoCath® catheter over needle Kit.</td>
<td><a href="http://www.bbraun.com">www.bbraun.com</a></td>
<td>12</td>
</tr>
<tr>
<td>14</td>
<td>27G Quincke spinal needle with braided wire attached to it and catheter over both of them.</td>
<td><a href="http://www.bbraun.com">www.bbraun.com</a></td>
<td>12</td>
</tr>
<tr>
<td>15</td>
<td>Passing the spinal needle through the dura.</td>
<td><a href="http://www.bbraun.com">www.bbraun.com</a></td>
<td>13</td>
</tr>
<tr>
<td>16</td>
<td>Pulling on the wire to remove the needle from within the catheter.</td>
<td><a href="http://www.bbraun.com">www.bbraun.com</a></td>
<td>13</td>
</tr>
<tr>
<td>17</td>
<td>Conventional catheter through needle design with CSF leaking from around the catheter.</td>
<td><a href="http://www.bbraun.com">www.bbraun.com</a></td>
<td>14</td>
</tr>
<tr>
<td>18</td>
<td>SpinoCath® catheter over the needle design with the catheter sealing the dural puncture causing minimal CSF leak.</td>
<td><a href="http://www.bbraun.com">www.bbraun.com</a></td>
<td>14</td>
</tr>
<tr>
<td>19</td>
<td>Portex® Catheter through needle kit.</td>
<td><a href="http://www.smiths-medical.com">www.smiths-medical.com</a></td>
<td>15</td>
</tr>
<tr>
<td>20</td>
<td>Intrathecal drug delivery system: pump and catheter.</td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>21</td>
<td>Lateral view showing the advantage of using an oblique approach to the spinal canal. The catheter can easily be advanced if a shallow angle is used.</td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>22</td>
<td>Intrathecal pump and catheter assembly.</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>23</td>
<td>Scanning electron micrograph of a dural puncture hole made by a 25G Quincke (cutting) needle. View is from the inner (intrathecal) side of the Dura mater.</td>
<td>175</td>
<td>53</td>
</tr>
<tr>
<td>24</td>
<td>Scanning electron micrograph of a dural puncture hole made by a 25G Quincke (cutting) needle. View is from the outer (epidural) side of the Dura mater.</td>
<td>175</td>
<td>53</td>
</tr>
<tr>
<td>25</td>
<td>Scanning electron micrograph of a dural puncture hole made by a 25G Whitacre (non-cutting) needle. View is from the inner (intrathecal) side of the Dura mater.</td>
<td>175</td>
<td>54</td>
</tr>
<tr>
<td>26</td>
<td>Scanning electron micrographs of sterile catheters.</td>
<td></td>
<td>57</td>
</tr>
<tr>
<td>27</td>
<td>Scanning electron micrographs of sterile catheters.</td>
<td></td>
<td>58</td>
</tr>
<tr>
<td>28</td>
<td>Human lamina arachnoid. Scanning electron microscopy. Magnification 180X Bar: 100 µm.</td>
<td></td>
<td>61</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page 1</td>
<td>Page 2</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>29</td>
<td>Human spinal arachnoid trabecula. Trabecular arachnoid encircling motor and sensitive nerve roots at the entry site of nerve root cuffs. Scanning electron microscopy. Magnification 30X Bar: 1 µm.</td>
<td>198</td>
<td>61</td>
</tr>
<tr>
<td>30</td>
<td>Human spinal arachnoid trabecula encircling the spinal cord. Scanning electron microscopy. Magnification 40X Bar: 100 µm.</td>
<td>198</td>
<td>62</td>
</tr>
<tr>
<td>31</td>
<td>Diagram of a likely cause of temporary and permanent neurological complications following CSA.</td>
<td>198</td>
<td>62</td>
</tr>
<tr>
<td>32</td>
<td>The needle passing the nerve. The indwelling catheter touching the anterior Dura and is starting to bend.</td>
<td>198</td>
<td>65</td>
</tr>
<tr>
<td>33</td>
<td>Looping of the catheter. This is inevitable when the distance inserted exceed 30 mm.</td>
<td>198</td>
<td>65</td>
</tr>
</tbody>
</table>
List of Abbreviations

- aPTT: Activated Partial Thromboplastin Time
- ASA: American society of anesthesiologists
- CES: Cauda Equina syndrome
- CNS: Central nervous system
- COPD: Chronic obstructive lung disease
- CPB: Cardiopulmonary bypass
- CSA: Continuous Spinal anesthesia
- CSA/A: Continuous Spinal anesthesia/analgesia
- CSE: Combined Spinal-Epidural
- CSF: CerebroSpinal fluid
- DVT: Deep vein thrombosis
- FDA: Federal Drug Administration
- GABAB: Gamma Aminobutyric acid receptor type B
- GABA: Gamma Aminobutyric Acid
- G: Gauge
- IL: Interleukin
- IT: Intrathecal
- IONV: Intraoperative nausea and vomiting
- LMWHs: Low molecular weight heparins
- MLAD: Minimum effective local anesthetic dose
- NMDA: N-methyl-D-aspartate
- PCA: Patient controlled analgesia
- PDPH: Post Dural Puncture Headache
- SSSA: Single-shot Spinal anesthesia
- UFH: Un-Fractionated Heparin
Abstract

Continuous Spinal anesthesia (CSA) as a technique evolved since Augustus Bier described the first Spinal anesthetic with Cocaine in 1899, and in 1906 Henry Percy Dean invented the "exploring needle" which can be left in situ during the operation so that at any moment another dose can be injected. CSA has marked advantages in certain clinical circumstances, particularly patients undergoing lower body surgery who are old and/or have co-morbidities, they can benefit from avoiding the risks of endotracheal intubation and general anesthesia and in the same time avoiding rough hemodynamic changes associated with other types of neuraxial blocks without losing their advantages. Also the intrathecal catheter can be used for post-operative analgesia and for long term intrathecal drug administration to control chronic pain or spasticity. There are many types of intrathecal catheters that can be used with different techniques of insertion, advantages and disadvantages. Also there are possible complications to the technique which must be understood and managed, and contraindications with which the technique should be avoided or modified.

Keywords: Continuous Spinal anesthesia, neuraxial anesthesia, neuraxial blocks, high risk patients, intrathecal catheter, continuous analgesia, post-operative analgesia, chronic pain management, intrathecal pumps.
Introduction
Continuous Spinal anesthesia (CSA) is the technique of producing and maintaining Spinal anesthesia with small doses of local anesthetic which are injected repeatedly as required into the Subarachnoid space via an indwelling catheter.

Continuous Spinal anesthesia (CSA) as an alternative to general anesthesia for many surgical procedures is a method almost as old as the technique of Spinal anesthesia itself. Augustus Bier described the first Spinal anesthetic with Cocaine in 1899 and in 1906, Henry Percy Dean described a technique in which Spinal anesthesia could be extended. Dean was aware that Ester local anesthetic agents did not usually last long, that the dose requirement of local anesthetic agent varied in each patient and that the duration of surgery could be different. To overcome this, he considered giving another injection during the surgical procedure and he invented the "exploring needle" which can be left in situ during the operation so that at any moment another dose can be injected without moving the patient beyond a slight degree. However, the technique did not become accepted into practice and his efforts to promote it were probably limited due to his ill health and his retirement in 1933. [1]

CSA was rediscovered in 1940 and went through a "stuttering evolution" through the 20th century by Tobias et al. who gave a fascinating account of this technique. The CSA technique evolved further in the 1990s when Spinal micro-catheters were introduced, but the technique was surrounded by controversy due to assumed occurrence of Cauda-Equina syndrome leading to the banning of Spinal micro-catheters by the Federal Drug Administration (FDA) in the USA. But Denny questioned the etiology of Cauda-Equina syndrome and stated that "For a number of years and on several occasions CSA has prevented patients from needing postoperative ventilation and it would be unfortunate if this extremely useful
technique was abandoned due to its inappropriate application”. While in the same time, CSA continued to be used in clinical practice outside of the USA. [2]

CSA has been used in medically complicated patients (as in patients with respiratory failure) undergoing cardiac, vascular, orthopedic, and general surgeries. Many authors advocate general anesthesia with or without Epidural analgesia as first choice in fit patients undergoing abdominal procedures. While in selected patients undergoing surgeries on the lower extremities, perineum, groin and lower abdomen, who are living at the edge of their cardiovascular and respiratory physiological reserves and in whom general anesthesia is likely to increase morbidity and mortality, many authors advocate CSA as an alternative to general anesthesia. [2]

CSA allows conduction anesthesia to be tailored to individual patient needs and also for surgical operations of long durations. The Spinal anesthesia is not more dangerous than Epidural anesthesia, but when we combine the potential lack of knowledge with the unforgiving Subarachnoid space and with the narrow "therapeutic window" for Spinal local anesthetics, a background for significant iatrogenic injury is set. It is with this in mind, as well as from the historical perspective that the technique and its current applications are discussed. [3]

The best way to examine the clinical applications for CSA is by comparing it to other available major conduction anesthetics: single-shot Spinal anesthesia, continuous Epidural anesthesia and combined single-shot Spinal & continuous Epidural anesthesia and also to general anesthesia. Catheters used for performing CSA differ in sizes (gauge) and in technique of insertion:

1- Epidural catheter (macro-catheter):

A standard Epidural catheter can be used for continuous Spinal anesthesia (standard Epidural catheters range from 18 to 20G). The catheter is inserted into the subarachnoid space after a deliberate Dural puncture with an Epidural needle. These
sets are widely available and little additional training is required for those familiar with inserting a normal Epidural catheter. However, performing a deliberate Dural puncture with an Epidural needle may be psychologically difficult for some experienced clinicians, also Post Dural Puncture Headache (PDPH) is a risk as we will see later. It should be put in mind that if this catheter type is left in situ for post operative pain relief then there is potential for error, as an Epidural dose of drug could be administered intrathecally. [3]

2- Catheter over-needle type:

Represented by the B Braun SPINOCATH®. Perceived advantages of this kit is that CSF does not leak because the hole made in the Dura by the Spinal needle is sealed by the wider bore catheter resulting in less incidence of PDPH, also there is an unequivocal endpoint of catheter placement in the subarachnoid space because CSF can be aspirated through the catheter. [4]

3- Catheter through-needle type:

These catheters are available in varying sizes ranging from 25G (macro-catheter) to 32G (micro-catheter). Pajunk Intralong® manufactures 27G and 25G catheters which are introduced through 22 or 21G Sprotte needles. Smith Medical® produces the PORTEX® kit, a 28G micro-catheter with a 23G Crawford needle. Kendal® produces a 28G micro-catheter with a 22G Sprotte needle. [4]

In this study we will try to discuss the commercially available CSA kits and related devices, the advantages and indications of the CSA technique itself, its limitations and complications.
Chapter 1
Anatomy
1- The Lumbar Vertebrae:

The bodies of the Lumbar vertebrae are large and kidney-shaped (Fig.1), the vertebral foramen is roughly triangular, larger than in the thoracic but smaller than in the cervical region. The transverse processes are slender, they increase in length from L₁ to L₃, then become shorter again so that the third transverse process is longest. The Lumbar spines are horizontal and oblong. If the articulated vertebral column is inspected from behind, it will be noted that the laminae and spines so overlap and interdigitate with each other that the Spinal canal is completely hidden, except in the lower Lumbar region. This interlaminar gap (Fig.2) is increased by forward flexion of the spine: a combination of circumstances that makes Lumbar puncture possible. [5]

Fig.1 A Lumbar vertebra in (a) lateral and (b) antero-superior views. [5]

Fig.2 The Lumbar interlaminar gap, this anatomical fact makes lumbar puncture possible. [5]
2- **Anatomy of Lumbar Puncture:**

Lumbar puncture (or Spinal anesthesia) is usually performed with the patient in the lateral or sitting position. Whichever position is chosen, the patient should be asked to flex his/her spine as much as possible, there by widening the gaps between the Lumbar spinous processes (Fig.3). The line that joins the top of the iliac crests (the inter-cristal line) usually passes through the body of the 4th Lumbar vertebra, and is therefore a useful landmark. The space above this line is usually the L3/4 interspace, that below is usually the L4/5 interspace. The choice of interspace is important, as the Spinal needle should not be introduced at a level that may cause it to enter the Spinal cord. In the adult, the Spinal cord usually ends at the level of the 1st Lumbar vertebra. However, in children, it may end as far distally as the 2nd or even 3rd Lumbar vertebra. Spinal needles inserted for diagnostic or anesthetic reasons should not therefore be introduced above the L3/4 inter-space except in exceptional circumstances.\[5\]

![Fig.3 The anatomy of Lumbar puncture. \[5\]](image)

![Fig.4 Midsagittal view of the meninges, ventricles, subarachnoid spaces, and cisternae. \[5\]](image)
3- The Spinal Meninges:

The Spinal cord has three covering membranes or Meninges (Fig.4), the Dura mater, Arachnoid mater and Pia mater. The compartments related to the Spinal meninges are the Subarachnoid, Subdural and Epidural spaces. The Subarachnoid space contains the CSF. It is traversed by incomplete Trabeculæa, the Posterior Subarachnoid Septum and the Ligamentum Denticulatum. [5]

The Subdural space is a potential one only, the Arachnoid is in close contact with the Dural sheath and is separated from it only by a thin film of serous fluid. The Subdural space within the vertebral canal rarely enters the consciousness of the clinician, unless it is the accidental site of catheter placement during attempted Epidural analgesia or anesthesia. The Subdural injection of local anesthetic is thought to be associated with patchy anesthesia, often unilateral and often extensive. The Epidural (Extradural or Peridural) space in the Spinal canal is that part not occupied by the Dura and its contents. [5]
Chapter 2

History
History

1- CSA Needles:

While most were striving to improve the design of Spinal needles to decrease the incidence of complications, some workers were looking at ways of improving the technique of Spinal anesthesia to make it applicable to more surgical procedures.

Dean had described a technique of continuous Spinal anesthesia in 1907 in which he left the Spinal needle in situ during surgery and injected more local anesthetic solution as and when necessary "exploring needle", but his technique was not widely accepted. Lemmon published a paper in 1940 describing a 17G and 18G Nickel/Silver alloy malleable needle and introducer with a sharp, medium-length, cutting bevel and a small opening in the long side of the bevel to enable free flow of CSF (Fig.5). In 1943, Hingson presented his modification of the Lemmon needle. The distal and proximal portions of the needle were rigid, with an annealed middle.

The needle was placed in the subarachnoid space, was bent at the skin surface, and was attached to rubber tubing through which local anesthetic solution was injected when required. The patient lay on a mattress and table that had a hole placed so as to accommodate the protruding needle (Fig.6). On the introduction of Stainless Steel, the needle was manufactured from Stainless Steel annealed to render it malleable.

In 1943, Hingson presented his modification of the Lemmon needle. The distal and proximal portions of the needle were rigid, with an annealed middle.
portion that was malleable. The tip of the needle was a short-beveled point with a blunt cutting edge and an extra orifice near the tip. The hub had a reinforced steel collar to connect to small-bore tubing. There was a safety bead to prevent needle breakage (Fig.7).

The continuous Spinal needle had its problems and was technically difficult to use and keep in position. In 1944, Tuohy used a 15G directional Spinal needle through which he passed a Nylon Ureteric catheter into the subarachnoid space to allow continuous Spinal anesthesia. The needle had a fitted stylet with a matching bevel (Fig.8). The medium length bevel had cutting edges. A year later, he published an article describing an adaptation of his needle to incorporate a "Huber tip", which allowed directional control of the catheter to point cephalad or caudal as required, Tuohy needle had a sharp inner edge to the bevel that caused shearing of catheters, so it was modified.

Over the years, other modifications were made to the Tuohy needle. One modification was the Tuohy Flowers modification, with a shorter and blunter bevel and the stylet protruding beyond the bevel of the needle to ease insertion of the point through tough ligaments (Fig.9).
Following the introduction of the pencil-point needle for single-shot Spinal anesthesia, it was inevitable that a similar needle would be introduced for continuous Spinal anesthesia. Although Tuohy had already introduced the idea of continuous Spinal anesthesia using catheters rather than needles, the large Tuohy needles and catheters had a significant PDPH rate, so continuous Spinal needles were still in common use. Cappe and Deutsch described a malleable cone-tipped Spinal needle in 1953. It was 20G in diameter and had a Whitacre tip and an 18G introducer (Fig.10). The middle portion had been annealed to render it malleable so that the needle could be bent at the skin surface once the tip was in the subarachnoid space. There was an adjustable needle stop to stabilize the needle. They reported a PDPH rate of 6.6% in their needle group compared to 22% in the conventional cutting-tip needle group. [11]

Several devices have been invented to help protect the CSA needle while it is in the subarachnoid space like this shield (Fig.11) that is made of Plexiglass with a central channel that accommodate the needle protecting it from dislodgment. Also, there was another device which was called "Bishop's hat" (Fig.12) and was made of metal, it was used to protect the needle and the rubber tubing in case the special mattress for CSA wasn't available. [12]
2- Large-Bore Catheters (Marco-Catheters):

As we mentioned, CSA was first described by Edward Tuohy in 1944 using a Ureteric catheter via a 15G Huber point needle and initiating Spinal anesthesia with incremental doses of local anesthetic. He reported no increase in the incidence of PDPH compared with single injection techniques and no neurological complications. \cite{13,14}

In 1950, Dripps reviewed reports on single-shot Spinal anesthesia (SSSA) and CSA with a malleable needle and catheter techniques. He found an 8% (43 of 506) incidence of failed anesthesia with CSA compared with 1.9% (37 of 1921) with SSA. Also, he found more technical difficulties with the catheter technique and a significantly higher incidence of transient parasthesia (33%) than with single injection techniques (13%). Over the next 25 years, CSA was not used much, as reflected by the paucity of references in the literature, and it is hard not to conclude that this was a direct result of Dripps’ article. \cite{15}

Many studies were made later on CSA using large-bore catheters to detect the differences between it and the single-shot Spinal anesthesia in the technique and the complications. \cite{16-20} The PDPH incidence was found to be around 1% in the elderly population. \cite{21-24} Other studies were also made to compare it with the Epidural anesthesia reporting not only greater cardiovascular stability but a significantly lower failure rate than Epidural anesthesia. \cite{25-29}

3- Micro-Catheters:

The Spinal micro-catheter was described first by Hurley and Umbert. \cite{30} Their aim was to develop a sufficiently fine-bore catheter (32G) which could be threaded through an appropriately fine Spinal needle (26G) into the CSF. Theoretically, compared with large-bore catheters, this would enable CSA to be performed in younger patients with a reduced risk of PDPH. Their initial study with the 32G micro-catheter showed a 20% incidence of technical complications, similar
experiences were also reported by others.\textsuperscript{[31]} The 32G Spinal micro-catheter was difficult to handle, CSF could not be aspirated and it had a very high internal resistance, making injection of local anesthetic very slow.

A 28G catheter which could be passed through a 22G Spinal needle was then developed (Kendall\textsuperscript{®}). This catheter proved easier to use and did not have as many technical complications. Later studies with 28G catheters have shown a technical complication rate similar to that of large-bore catheters, including the incidence of PDPH.\textsuperscript{[32]} However, it was not long before cases of neurological complications, in the form of Cauda-Equina syndrome, were described after CSA with micro-catheters.\textsuperscript{[33]} Further reports of problems with the micro-catheter technique\textsuperscript{[34]} led the FDA in 1992 to ban the use of Spinal catheters smaller than 24G in the USA, while it was used in the rest of the world.\textsuperscript{[35]} In all, approximately 12 cases of Cauda-Equina syndrome after CSA with micro-catheters have been reported.\textsuperscript{[36]}
Chapter 3
CSA Kits, Drugs and Related Devices
The Most Commonly Used CSA Kits

1- Catheter-Over-The Needle Type:

**B Braun Spinocath®**

Spinocath® features a catheter-over-needle design where the catheter is positioned over the Spinal needle (Fig.13).

![Fig.13 Spinocath catheter over needle Kit.](www.bbraidun.com)

It consists of a standard 27 or 29G Quincke Spinal needle, a 22 or 24G tapered catheter tip that gently dilates the Dura and gives excellent tactile feedback and thus the first identification of successful Dural puncture with a side hole that assures aspiration through a second opening (Fig.14). The Perifix® catheter material is characterized by its superior handling characteristics, easy injection, aspiration and barbotage, good distribution of anesthetic and it is also suitable for syringe pumps.
The Quincke needle has a fluid exit side hole that lies within the catheter, and in addition the needle is connected to a smooth laser welded pull wire that allows it's safe and easy removal after correct positioning of the catheter. The kit also contains an 18G Epidural needle used to access the Epidural space.

The technique of insertion consists of identifying the Epidural space by the loss-of-resistance technique using the Epidural needle, then passing the Spinal needle (with the catheter mounted on it) through the Epidural needle in a manner that would be analogous to the needle through needle technique used for combined Spinal Epidural anesthesia (Fig.15). Once the Dura is punctured, the needle is advanced a little. CSF is detected within the catheter, as it emerges from the fluid exit side hole in the Quincke needle, and the braided wire is then withdrawn which also pulls back the Quincke needle, leaving the catheter within the intrathecal compartment which simultaneously seals the hole in the Dura (Fig.16). The Epidural needle is then withdrawn and the catheter is connected to a filter via a connector and is then ready for use.

Perceived advantages of this technique include an unequivocal endpoint of catheter placement in the Subarachnoid space because CSF can be aspirated through the catheter, with assumed less incidence of PDPH. It is believed that CSF does not leak because the hole made in the Dura by the Quincke needle is sealed by the wider
bore catheter (Fig.17, 18). It is reported that there is a definite learning curve as these catheters may be more difficult to insert than conventional catheters.\textsuperscript{37}

---

**2- Catheter-Through-The Needle Type:**

*(A) Standard Epidural catheter set*

It usually consists of a 20G macro-catheter inserted through an 18G Tuohy Epidural needle.

*(B) Smiths Portex®*

It consists of a 19G Tuohy needle with a 23G Crawford Spinal needle with optimized 30 degree angle of bevel, the needle bevel heel and sides blunted to minimize the risk of potential catheter shearing. Graduated markings permit accurate catheter positioning. It contains 28G micro-catheter with PTFE coated stylet that aids easy withdrawal from catheter (Fig.19).
It consists of a 28G micro-catheter and 22G Quincke needle.

Those last two sets are considered micro-catheters, they may be more difficult to insert and they kink easily if force is exerted during insertion. Once inserted, it is virtually impossible to aspirate CSF from them. However, it is observed that if sufficient time is allowed, one may occasionally see a drop of CSF emerge from the end of the catheter. Although CSF emergence is an unequivocal end point of a Spinal catheter placement, in routine clinical practice this would be an impractical method of confirming catheter location.\textsuperscript{38}

It is possible to overcome any resistance encountered during insertion of a 28G catheter by removing the catheter from the needle, withdrawing the needle slightly (ensuring CSF is still flowing from the needle) and then reinserting the catheter, an alternative method is to inject a small amount of local anesthetic via the Spinal needle and then insert the catheter. Although there are conflicting reports, no matter which catheter is inserted, it is better to insert the catheter in the sitting position. Insertion of a catheter more than 3 cm into the Subarachnoid space increases the chance of a caudally directed catheter end position.\textsuperscript{39}
In a study made to compare between the Portex® system (micro-catheter) and the Spinocath® system regarding PDPH in young adults no significant difference could be demonstrated between the two systems with different techniques of Dural perforation. However, analysis revealed a significantly shorter duration and reduced severity of headache in the over-needle group as assessed by the standardized headache assessment method. [40]

Whatever the chosen CSA kit is, it may be preferable to use a larger gauge catheter, accepting a higher incidence of headache, but a lower incidence of failure. [41]

**Drug Agents That Can Be Used Intrathecally (IT)**

Perhaps first among the important concepts that must be appreciated to conduct CSA safely is attention to the doses of medication used. CSA requires small doses of local anesthetics to achieve anesthesia and analgesia. Single-shot Spinal anesthesia doses are approximately 1/10th the amount of local anesthetic used in the Epidural space. CSA doses can be further reduced from doses needed with single-shot Spinal anesthesia by 25 to 33%. [42] This translates into small doses of Lidocaine (12.5–25 mg) or Bupivacaine (2.5–5.0 mg). In fact, when smaller amounts of local anesthetics do not produce anesthesia at expected levels, continuing to re-dose the same medication will often not produce more success but may result in complications. Switching to a different local anesthetic and/or baricity and/or re-positioning the patient may be the safer and a better plan.

Also important to remember is the relatively narrow "therapeutic to toxic window" for local anesthetics in the Subarachnoid space. Animal studies have shown that when CSA local anesthetic concentrations that do not cause Spinal cord injury are doubled, nerve damage is seen. [43]
1- **Lidocaine**

Lidocaine has been shown to be particularly problematic in animal studies at both high and low concentrations. Clinical evidence bears out that an excessive amount of 5% hyperbaric Lidocaine has been associated with Cauda-Equina syndrome in 1991. It is difficult to recommend Lidocaine of any concentration or baricity for initial use with CSA. More than a decade of laboratory studies and clinical results support the premise that intrathecal anesthesia can be performed without Lidocaine. \[44\]

First, both Cauda-Equina syndrome and transient neurological symptoms are more frequent events after intrathecal Lidocaine than after Bupivacaine. Decreasing both dose and concentration have not solved these problems. Considering Lidocaine to be a dangerous medication appears to be counter-intuitive to many anesthesiologists. \[45\] At least in the opinions of some authors, Lidocaine should be avoided for Spinal anesthesia. \[46\]

A possible role for Lidocaine may be with the rescue of (initially) failed CSA. Kung et al have shown that in 11 (out of 236) cases where CSA initially failed to produce T10 sensory anesthesia with 20 mg of (0.2%) Bupivacaine, surgical anesthesia was produced by switching to 1% Lidocaine solution. \[47\] It would be more prudent and safer to stop Bupivacaine at a lower dose (10 mg) when considering switching to Lidocaine. These observations are similar to those made by others who have shown a relative resistance to a local anesthetic that could be overcome with another local anesthetic. \[48\] However, continuing to dose with any one or a combination of local anesthetics is not advisable if no block or a block limited to sacral dermatomes develops despite aspiration of CSF.

2- **Bupivacaine**

All types of concentrations and baricity of Bupivacaine solutions have been used to conduct CSA safely. Bupivacaine in low concentrations (0.1–0.2%) can
also be used alone or in combination with Opioids to provide postoperative analgesia. For initial injection of CSA, 2.5-5.0 mg of either plain or hyperbaric Bupivacaine should produce a T10 sensory level of anesthesia. Additional incremental doses, using 2.5 mg, will expand and solidify the block. However, injection must stop at an absolute maximum of 12.5 mg of Bupivacaine even if this means that an alternative anesthetic technique is needed as there is no local anesthetic that is entirely non-toxic to nerves. While Bupivacaine is safer than Lidocaine, it can produce neurological injuries after intrathecal use. [49]

3- Ropivacaine

Intrathecal Ropivacaine has not been shown to be toxic in animal models. [50] Human data from single-shot Spinal anesthesia appear to support a clinical role for Ropivacaine. However, its major advantage of its use with Epidural anesthesia, brachial plexus anesthesia and other forms of regional anesthesia where large amounts of local anesthetic solutions are injected, is lost with intrathecal use. Also, Ropivacaine lacks the large body of clinical evidence to support its safe use that is available with Bupivacaine. The intrathecal potency ratio for Ropivacaine compared with Bupivacaine has been estimated as 2:1. [51]

4- Levobupivacaine

A Study was made to assess the minimum effective local anesthetic dose (MLAD) of Levobupivacaine and Ropivacaine in the context of continuous Spinal anesthesia with Spinal catheters that allows incremental dosing of local anesthetic. The results were that the MLAD of Levobupivacaine was 11.7 mg and that of Ropivacaine 12.8 mg. However, the small numerical difference (1.1 mg) in the MLADs does not allow us to make the interpretation that Levobupivacaine would be more potent than Ropivacaine, as the 95% confidence intervals overlap. [52]
5- **Procaine**

Procaine would appear to be a useful agent for CSA. Both its potency and baricity can be altered to fit the circumstances. Its short duration of action is also suited to a catheter technique. [53]

6- **Tetracaine**

Tetracaine can be used with CSA but, as a long-acting agent, it may reduce the flexibility of the technique. [53]

7- **Opioids**

   (A) **Fentanyl**: Intrathecal Fentanyl, alone or in combination with local anesthetics, can produce excellent postoperative analgesia. There is evidence that Fentanyl may also extend and solidify the anesthetic when used in single-shot Spinal anesthesia allowing using smaller doses of intrathecal Bupivacaine. It is likely that these smaller doses of Fentanyl (25 µg) can be used the same way with CSA. It is of interest that while intrathecal doses with local anesthetics is on the order of 1/10th the doses needed in the Epidural space, the requirements for intrathecal Fentanyl do not follow this pattern. The hourly Fentanyl dose should be limited to 25–50 µg given as a bolus or infusion, as larger amounts have been associated with increasing respiratory depression. [54]

   (B) **Sufentanil**: Given in 5-10mg boluses and limited to 40 mg, produced safe and effective post operative analgesia. [54]

   Used alone, these lipid-soluble Opioids may be sufficient for certain procedures such as lithotripsy.

   (C) **Morphine**: Can also produce safe and effective postoperative analgesia. Initially, higher doses (1–20 mg) were shown to produce profound analgesia. The trend over the past several years has been to employ much lower intrathecal
Morphine dosing (in the range of 0.1–0.4 mg/day) to avoid side effects. Avoiding side effects at the cost of less profound analgesia does not seem a good trade-off, however. We can produce low pain scores (0–4/10) while limiting complications in carefully monitored environments (intensive care environment) with Morphine infusions of 1-2 mg per day. In high-risk patients, or in less-well-monitored settings, lower-dose Morphine would be appropriate. However, in a study made by J. G. Forster et al on a total of 47 patients (range 51–95 years, ASA II–IV), they found that the combination of low-dose Ropivacaine and Morphine for continuous Spinal postoperative analgesia did not offer any benefit compared with the higher Ropivacaine dose alone. [55]

(D) Meperidine: (0.75–1.0 mg/kg) can be used as a sole Spinal agent because, in addition to being a mu Opioids agonist, it produces reversible motor and sensory anesthesia. [56]

Finally, whatever the Opioid used, careful patient monitoring is indicated.

8- Other Agents

(A) Magnesium Sulfate: A study was made by R. Arcioni et al to detect the effect of Magnesium sulfate (MgSO₄) on altering pain processing and reduction of the induction and maintenance of central sensitization by blocking the N-methyl-D-aspartate (NMDA) receptor in the Spinal cord. They investigated whether supplementation of Spinal anesthesia with combined intrathecally and Epidurally infused MgSO₄ reduced patients’ post-operative analgesia requirements or not. They found that direct intrathecal administration of MgSO₄ prolongs the action of Subarachnoid anesthesia in animal and human subjects. This administration route has been shown to be clinically safe in humans, [57] and its safety profile has been evaluated in several experimental settings, including histopathologic analysis. [58]
On the other hand, another trial made by R. Arcioni et al, they enrolled 120 consecutive patients undergoing orthopedic surgery under Spinal anesthesia concluded that for major orthopedic surgery, supplementation of Spinal anesthesia with combined intrathecally injected and Epidurally infused MgSO₄ considerably reduces patients’ post-operative PCA requirements, compared with Spinal anesthesia alone, simply, reliably and without inducing short term or long term adverse reactions. They stated that these encouraging findings in a small study sample suggest that, once MgSO₄ is approved for intrathecal and Epidural use, a low-cost, simple change in clinical anesthesiology practice will do much to decrease patients’ post-operative analgesic needs. [59]

While comparing the sensory, motor and analgesic block characteristics of Magnesium (50mg) with Fentanyl (25mg) and Saline when added to 0.5% Bupivacaine (10mg), it was found that the addition of Magnesium Sulfate (50mg) to 10 mg of Spinal Bupivacaine (0.5%) did not shorten the onset time of sensory and motor blockade or prolong the duration of Spinal anesthesia, as seen with Fentanyl. [60]

(B) Baclofen: It is a synthetic pre- and postsynaptic γ amino butyric acid receptor type B (GABAB) agonist. It decrease excitatory synaptic release of neurotransmitters such as Aspartate and Glutamate and also decrease Substance P in nociceptive afferent nerve endings thought to cause painful flexor spasms. Determining the etiology of the spasticity is critical for therapeutic benefit. [61] Generally speaking, patients with Spastic Diplegia secondary to Spinal cord injury, Familial Spastic Paraparesis, Multiple Sclerosis, spasticity following Ischemic Stroke and Spondylitic Myelopathy, also patients with spasticity of cerebral origin may benefit from intrathecal (IT) Baclofen. [62] Notably, IT Baclofen also may be beneficial in the treatment of patients with severe Spastic Hemiplegia. [63]
(C) Neostigmine, Diazepam, Aspirin (and other non-steroidal anti-inflammatory drugs), Alpha Agonists (Clonidine and Dexmedetomidine), Ketamine, etc. (medication to change the balance of Spinal Cytokines, Leukotrienes and Substance P) may have a role in producing intrathecal analgesia in both chronic and acute pain, but their usefulness for intrathecal use in the perioperative period remains to be defined. [63]

The continuing access provided by Spinal catheters will be important as the safety and efficacy of these (and other) agents are demonstrated.

**Implantable Intrathecal Drug Delivery Systems (Pumps)**

Intrathecal drug delivery systems are implanted for chronic pain when conservative therapies have failed, surgery is ruled out, no active or untreated addiction exists, psychological testing indicates appropriateness for implantable therapy, medical contraindications have been eliminated (coagulopathies, infections), and finally, a successful intrathecal drug trial has been completed. [64]

Patients needing intrathecal drug delivery can be divided into 2 broad categories:

1- **The 1st category:** Includes patients suffering from terminal illnesses such as cancer. These individuals generally respond well to intrathecal Opioids if they have been successfully managed on oral Opioids first. Invasive therapy should be considered if they have developed increasing pain and intractable side effects despite rotating oral Opioids. However, if patients are terminal and their life expectancy is less than six months, one has to weigh the benefits vs. the risks of such a venture. This type of therapy is generally recommended for individuals with a life expectancy of greater than six months. [65] It is important to rule out the presence of occult pathology in the Spinal canal and any obstructive metastasis in the Spinal column that could present a challenge during insertion of the catheter.
2- The 2nd category: Patients with chronic non-malignant pain, for example, failed low back surgery syndrome. The use of intrathecal drug delivery systems in chronic non-malignant pain is more controversial. Clearly, treatment for chronic pain should consider conservative approaches before more invasive treatments are considered.

Intrathecal pumps deliver small doses of medication directly to the Spinal fluid. It consists of a small battery-powered, programmable pump that is implanted under the subcutaneous tissue of the abdomen and connected to a small catheter tunneled to the site of Spinal entry (Fig.20). Sophisticated drug dose regimens can be instituted. Implanted pumps need to be refilled every 1 to 3 months. There is no evidence showing whether it is more clinically effective to use bolus or continuous dosing.
Pump insertion:

The placement of an implantable intrathecal pump consists of the catheter placement followed by implantation of the pump. A shallow angled paramedian approach with the Touhy needle allows easy rostral advancement of the catheter into the intrathecal space (Fig. 21). Positioning of catheter is checked with Fluoroscopy. After removing the needle, the catheter is anchored to the Supraspinous Fascia using a silastic anchor provided by the manufacturer. [68]

After the pump is prepared, an incision for the pump pocket is made in the right or left lower quadrant of the abdomen at or about the Umbilical level. The pump should be placed below the belt line, but not too close to the anterior rib or Iliac Crest as it may lead to prolonged discomfort. Because of refilling requirements, it is important not to place the pump too deep. In an obese patient the pump should be placed at the mid-fat plane of the lower quadrant of the abdomen. If the patient is thin, then the pump may be placed at the Rectus Fascia. The incision for the pump pocket should be made just large enough to accommodate the pump. After creating the pump pocket, tunneling from the pump pocket to the back wound should be done with the tunneling device. [69] It is vital that the tip of the tunneling device remains subcutaneous to prevent entering the peritoneal cavity or pleural cavity. The pump should be secured to the pocket by suturing to the abdominal fascia under the pump pocket (Fig. 22).
Medications used in implantable intrathecal drug delivery systems:

1-First line agents: Includes Morphine and Hydromorphone, and has clear support from data and extensive clinical experience.

2-Second line agents: May actually be chosen as first line in cases where an individual has prominently neuropathic symptoms. This consists of either Hydromorphone or Morphine with the addition of Bupivacaine or Clonidine. There is little data to confirm the safety of these mixed agents. [70]

3-Third line agents: Show clinical promise but both evidence and clinical experience is extremely limited. They are chosen only after failure of first and second line drug combination treatments, either due to intolerable side effects or inadequate analgesia. These drug combinations include adding both Bupivacaine and Clonidine to either Morphine or Hydromorphone. [71]

4-Fourth line agents: They are not supported by much clinical research evidence and experience. They include lipophilic Opioid agents such as Fentanyl and Gamma Aminobutyric Acid (GABA) agonists such as Baclofen and Midolazam. The reasoning behind using lipophilic Opioids is that there would be less drug diffusion to the rostral brain centers. [72]

Finally, which equipment to use is largely determined by personal experience, as few people will have extensive experience of more than one manufacturer’s design. Also the technique of insertion will depend on the type of CSA set used. Our advice would be to only use CSA where the staff has been given both verbal and written instructions. In addition, equipment should be clearly marked as an intrathecal infusion. Where infusions are used, we would recommend that closed systems are used with all the connections taped, to reduce the risk of both the wrong drug being injected and infection being introduced. We would also recommend that at present, CSA should be performed by experienced anesthetists.
Chapter 4
Indications & Advantages
Indications & Advantages of CSA

Conventional Spinal anesthesia is simple, safe and well established. Why then should anyone choose to complicate the issue with a catheter? This is currently the view of most anesthetists and it is a view with much to comment it. However, single-shot Spinal anesthesia (SSSA) does have limitations as the block may wear off before surgery is complete. Although there is little published work on the safety of administering sedation or general anesthesia immediately after Spinal anesthesia, anecdotal evidence points to significant problems, especially with hypotension. Lastly, there is the problem that the Spinal anesthesia provides exceptional analgesia for the surgery and recovery period, but does not provide analgesia postoperatively. There are also many patients for whom the risk of complications of SSSA, such as muscle paralysis, hypotension and the risk of a high block may lead to general anesthesia being considered.

A major advantage of CSA over continuous Epidural anesthesia is the improved efficiency in operative situations. In a retrospective review, Sutter et al showed a significantly higher failure rate with continuous Epidural anesthesia (9%) compared with CSA (1.7%), with half of the Epidural failures recognized only after the start of surgery.

It has been thought that continuous Epidural anesthesia will provide greater intra and postoperative flexibility and controllability than CSA, as it can be placed in proximity to the Spinal cord segments involved with surgery. While CSA provides continuous access to the Subarachnoid space where factors such as baricity, concentration and volume of the injectate can be used to influence the spread, duration and extent of anesthesia/analgesia. Also, with the use of smaller volumes and injection into the CSF, the patient will have markedly decreased blood
levels of medication. But this is not to imply that CSA can or might replace continuous Epidural anesthesia in every situation.\textsuperscript{[74]} 

However, even in cases such as thoracic surgery, where segmental thoracic anesthesia/analgesia may be perceived as standard of care, CSA can offer an effective and safe alternative.\textsuperscript{[74]} Finally, due to these factors, and combined with the fact that correct catheter position is (almost) always verifiable with catheters of all sizes by the flow of CSF, CSA allows the use of regional anesthesia when Epidural anesthesia would not be recommended (as in Aortic Stenosis \& Hypertrophic Cardiomyopathy)\textsuperscript{[75]} or might be difficult (as in severe obesity \& extremity of age).\textsuperscript{[76]} 

Continuous Spinal anesthesia (CSA) may therefore have a role in many patients and in many situations. Evidence based data suggests that there are several groups of patients for whom CSA can be useful:

I- Obstetric and Gynecological Procedures: 
1- Routine normal labors. 
2- High risk normal labors. 
3- High risk Caesarian sections. 
4- CSA was found to be also specially beneficial in pregnancy with coexisting Aortic stenosis, Eisenmenger’s Syndrome, Cardiomyopathy and Scoliosis.

II- Surgeries in the Lower Part of the Body with or without Coexisting Disease: 
1- Ankylosing Spondilitis. 
2- Orthopedic elderly patients. 
3- Urological elderly patients undergoing endoscopic procedures. 
4- Patients undergoing vascular interventions in the lower half of the body. 
5- Patients undergoing interventions for repair of Aortic aneurysms. 
6- General surgical patients undergoing major abdominal surgeries.
7- Morbidly obese patients.

III- Pediatric Open Heart Surgery.

**1- Obstetric and Gynecological Procedures**

1- **Routine Normal Labors:**

It was first described by Carpenter et al.\[77\] in 1951 using an infusion of procaine via a reusable vinyl catheter inserted through an 18G Quincke Spinal needle. The resulting analgesia was satisfactory, but the technique was limited by the inevitable headache associated with the large gauge needle and catheter. During the late 1980s, the development of 28G or smaller catheters that could pass through a 22G needle stimulated a resurgence of interest in continuous intrathecal labor analgesia. In 1990, Benedetti and Tiengo described repeated intrathecal injections of 0.25% Bupivacaine via a 32G Spinal catheter producing satisfactory labor analgesia in 12 parturients.\[78\]

Other investigators described successful continuous intrathecal labor analgesia using combinations of both dilute local anesthetics and Opioids given via a small-gauge catheter, as Valerie A.Arkooch et al. who published a study discussing safety of continuous Intrathecal Labor analgesia using a 28G catheter versus continuous Epidural labor analgesia, they concluded that providing intrathecal labor analgesia with Sufentanil and Bupivacaine via a 28G catheter has an incidence of neurologic complication less than 1%, and when compared to Epidural analgesia it produces better initial pain relief and higher maternal satisfaction, but is associated with more technical difficulties and catheter failures, with no significant differences regarding post-dural puncture headache or hemodynamic stability.\[79\]

Cardiac disease in pregnancy is now the leading medical cause of maternal mortality in the UK. Whilst anesthesia has not been the precipitant of this morbidity, its safety cannot be taken for granted.\[80\]
2- High Risk Normal Labors:

Epidural analgesia usually produces reliable analgesia, however patchy or incomplete pain relief remains a distinct possibility, especially in the event of emergency Cesarean Section, a dysfunctional Epidural catheter can cause time loss and intraoperative pain and may necessitate unplanned conversion to general anesthesia. In addition, if urgent Cesarean Section is required, Epidural anesthesia for operative delivery has a slow onset. A Spinal catheter allows rapid extension of the block whilst at the same time anesthesia can be titrated, limiting the hemodynamic effects of Spinal anesthesia. [81]

So it has been found that continuous Spinal analgesia during normal labor can offer the advantage of greater cardiovascular and hemodynamic stability combined with analgesia, without the undesirable local anesthetic effects such as motor blockade for all the duration of labor, this is of special interest in parturients in whom hemodynamic stability is essential as with coexisting heart disease. [82]

The suggested regimen consists of an initial dose of Fentanyl 25 µg added to 1.5 ml of saline. If a parturient complained of pain 15 min after the initial dose of Fentanyl, or thereafter, an additional 10 µg dose of Fentanyl could be injected up to every 15 min throughout the first stage of labor. In the second stage, 0.5% heavy bupivacaine 2.5 mg with saline 0.5 ml can be used to provide analgesia. Spinal Fentanyl provides effective analgesia during the first stage of labor, but during the second stage it is necessary to supplement with low-dose local anesthetic. The dose of Bupivacaine used in conjunction with Fentanyl is minimal and significantly less than that required when local anesthetic is used alone. [83,84]

Also intrathecal Fentanyl can be given as a 25mg plus Epinephrine 50mg (diluted with 5% Dextrose, total 1.5 ml) bolus through the intrathecal catheter, followed by an hourly infusion of Fentanyl 25mg plus Epinephrine 50mg (diluted
with 5% Dextrose at the infusion rate of 5.0 ml/h). Epinephrine can be added to augment the analgesic effect of intrathecal Fentanyl, which is hypothesized to stimulate Alpha-2 receptors, this combination can provide adequate analgesia in early labor with rapid onset of analgesia and without evidence of sympathetic blockade, resulting in good hemodynamic stability. [85]

3- **High Risk Caesarian Sections:**

Beside the disadvantages mentioned before for Epidural analgesia in normal labor, other options exist in case of Caesarian Section:

- *General anesthesia:* It excludes women from the birth experience and cannot match regional anesthesia for the quality of immediate postoperative analgesia.

- *Single-Shot Spinal:* It may result in unpredictable hemodynamic changes.

- *Combined Spinal-Epidural (CSE):* It may be a suitable alternative, and was the most commonly used technique and its successful use has been described in numerous case reports. [86] However, as CSE anesthesia requires an initial intrathecal drug bolus followed by Epidural supplements, early hemodynamic instability and subsequent unreliability are theoretical concerns.

So CSA may offer the potential to avoid these problems and provide safe and adequate anesthesia in these High risk patients. CSA can be performed in these cases by injecting 0.5% hyperbaric Bupivacaine in 0.25 ml increments with 25µ Fentanyl. Some authors also recommend using the Spinocath® system to help decrease the incidence of PDPH. [87]

4- **CSA was found to be also specially beneficial in pregnancy with the following coexisting diseases:**

(1) *Aortic Stenosis:*

The pathophysiology of Aortic stenosis is affected by the normal cardiovascular changes of pregnancy, such as a decrease in systemic vascular
resistance and an increase in circulating volume, so the anesthetic management of these pregnant women focuses on hemodynamic stability including maintenance of adequate pre-load, preservation of sinus rhythm, protection against tachycardia and extreme bradycardia, also avoidance of systemic hypotension, myocardial ischemia and myocardial depression are critical for a successful outcome.\textsuperscript{[88]}

During anesthesia and surgery, patients with Aortic stenosis are at higher risk for morbidity and mortality. A high maternal mortality has been reported and the use of Neuraxial analgesia for labor pain in these patients is controversial because of the potential detrimental effects of reductions in venous return and systemic vascular resistance, in the time that strategies to prevent or treat hemodynamic changes, such as the administration of Ephedrine or IV fluids can cause serious problems.\textsuperscript{[89]} Some authors question the use of Epidural or Spinal analgesia and anesthesia in these patients,\textsuperscript{[90]} while several others support the use of low dose continuous Epidural analgesia or titrated Epidural anesthesia for Cesarean Section in this patient group.\textsuperscript{[91]}

There is evidence, however, that regional techniques can be used safely in these patients.\textsuperscript{[92]} Lao et al., for example, reported on 20 pregnancies in parturients with Aortic stenosis who either delivered vaginally or by Cesarean Section, in all women Epidural anesthesia was used successfully.\textsuperscript{[93]}

Successful use of CSA for labor analgesia in patients with moderate to severe Aortic stenosis was reported by many authors.\textsuperscript{[94-96]} Good planning, invasive monitoring, senior staff involvement and the availability of an experienced obstetric anesthetist routinely involved in the management of high-risk pregnancies are important components of a successful outcome.
(2) **Eisenmenger’s Syndrome:**

The goal of anesthetic management of a patient with Eisenmenger’s syndrome is the maintenance of SVR to prevent increases in right-to-left shunt, the maternal mortality of Eisenmenger’s patients in vaginal deliveries (34%) is much lower than that in Cesarean Sections (75%).

Both general and regional anesthetic techniques have been reported. In the respiratory management of general anesthesia, intermittent positive pressure ventilation causes decreases in venous return and cardiac output and increases in pulmonary arterial pressure, which together produce an increase in right-to-left shunt. While single-shot Spinal may induce excessive sympathetic block and decreased SVR and may be associated with the additional risk of Subdural hematoma, because heparin is frequently given to parturients with Eisenmenger’s syndrome.

The application of Epidural anesthesia has also been reported in parturients with Eisenmenger’s syndrome undergoing elective Cesarean Section. Cardiovascular changes are relatively gradual but the onset of effect is slower than that of single-shot Spinal anesthesia and also the large doses of local anesthetics used can cause myocardial depression and hypotension, and the risk of bleeding into the Epidural space is higher than in Spinal anesthesia. Also incomplete Epidural anesthesia may induce undesirable sympathetic stimulation or the need for intra-operative conversion to general anesthesia.

On the other hand CSA provides a titratable and reliable Neuraxial block using minimal doses of local anesthetics, and has been used successfully in the anesthesia of parturients with Eisenmenger’s syndrome undergoing Cesarean Section, but careful monitoring of vital signs and prompt treatment of hypotension by Phenylephrine or Ephedrine to maintain SVR are essential.
(3) **Cardiomyopathy:**

Anesthetic management of patients with severe Cardiomyopathies include avoidance of myocardial depressants and cautious fluid management with judicious use of diuretics and vasodilators. In addition, basics of anesthetic management appropriate for other patients with limited cardiac function also apply, in other words, sinus rhythm must be maintained and extremes of blood pressure and heart rate should be avoided. \[104\]

Severe myocardial depression and cardiac arrest have been reported as a result of administration of general anesthesia to these patients. Continuous Spinal anesthesia appears to offer more hemodynamic stability than single-shot Spinal for Cesarean Section, as has also been shown with knee and hip surgery. Hemodynamic stability has been found to be similar to that with Epidural anesthesia. Furthermore, CSA may be more rapidly and effectively titratable. \[105\] However, care should be taken as anticoagulant therapy is often indicated in these patients due to increased risk of thromboembolic events. \[104\] So CSA was found to be the most adequate method of anesthesia for these patients during Normal Labor or caesarian Section.\[85,106\]

(4) **Scoliosis:**

CSA may also be beneficial in Cesarean Section or normal labor analgesia for these parturients, as titration of the local anesthetic can help avoid unintentional widespread of anesthetic agents caused by distortion of the Spinal canal due to spine deformity or the operation for its correction or any implanted instrument. \[107\]
II- Surgeries in the Lower Part of the Body with or without Coexisting Disease

In general practice of CSA, Plain Bupivacaine 0.5% can be injected through the intrathecal catheter in a 0.5 ml bolus, with additional boluses of 0.5 ml at 5 min intervals until the required block is achieved or a maximal dose of 3 ml has been administered. Because plain Bupivacaine is isobaric, the solution initially remains at the point at which it was injected and then diffuses in both caudal and cephalad directions.

The clinical picture is of a block which starts in the lumbar area and then spreads toward mid-thoracic and sacral levels over a period of around 10 min. Fentanyl can also be added in a maximum dose of 25µ per hour as a bolus or as a continuous intrathecal infusion.

1- Ankylosing Spondilitis:

Lower body surgeries in such patients can be performed under regional or general anesthesia. Regional anesthesia techniques described for such patients include Epidural, Spinal, combined Spinal Epidural. These patients present with some unique problems for the anesthesiologist, like limited respiratory excursion corresponding to restrictive lung disease, difficult airway due to fused cervical spine, difficulty in performing regional block due to fused Spinal spaces, risk of subluxation of Atlanto-Axial joint and increased risk of Cervical Spine fracture, making both general and regional anesthesia problematic. [108]

The CSA is beneficial here because of well defined endpoint of procedure and option of reliable, predictable and fast prolongation of duration of block, but it must be performed with provision of difficult airway, so difficult intubation cart should
be prepared including Fibreoptic Bronchoscope and alternate airways like Laryngeal Mask and airway management devices in case of need of assisted ventilation. [109]

2-Orthopedic Elderly Patients:

Both general and regional anesthesia is associated with side effects in geriatric patients. [110] Although regional anesthesia might have benefits over general anesthesia, hemodynamic stability may be impaired and can lead to myocardial ischemia. [111] Hypotension is more common, and also more hazardous, in elderly patients, as they may have decreased physiological reserve and compromised blood supply to various vital organs. [112] Many different techniques, such as IV crystalloid and vasopressor administration, have been used to attenuate this complication. [113] However, rapid infusion of large amounts of IV fluids may be detrimental to patients with cardiac dysfunction. [114] Moreover, Ephedrine and vasopressor can lead to serious cardiac side effects (excessive hypertension or tachycardia). [115]

CSA here can accomplish the advantages of regional anesthesia and in the same time better hemodynamic stability, this was supported by a study made on 74 patients aged >75 years who underwent surgery for open surgical repair of hip fracture, where the hemodynamic effect of continuous Spinal anesthesia (CSA) and small dose single-shot Spinal anesthesia (SSA) were compared. They found that the incidences of hypotension were significantly lower in the CSA group, as in the SSA group, 51% of the patients experienced at least one episode of severe hypotension versus 8% of patients in the CSA group, also the amount of local anesthetic solution was smaller in the CSA group ([2.5–10] versus 7.5 mg) and resulted in the lower level of sensory block. [116]

Also another study including 68 patients aged between 50 & 85 years undergoing elective hip surgery showed that CSA provided better hemodynamic stability during induction of anesthesia compared with SSA in addition to better
postoperative analgesia with less nausea and vomiting than patient-controlled intravenous analgesia with Morphine while the influence of possible drawbacks of applying continuous Spinal analgesia, such as prolonged immobility and the need for close monitoring is limited since the majority of patients taking advantage of this technique are old and severely disabled, moreover, rehabilitation does not start within 24 h after surgery. [117]

3- **Urological Elderly Patients Undergoing Endoscopic Procedures:**

These surgeries usually require anesthesia in the sacral segments to cover the insertion of the Cystoscope, as well as the lower thoracic segments to prevent the discomfort caused by bladder distension. The catheter is inserted in the sitting position and its tip is directed caudal and 0.5 ml of 0.5% heavy Bupivacaine is administered and the patient is left sitting for 5 minutes. The patient is then asked to return to the supine position after which further boluses of 0.5 ml of 0.5% Plain Bupivacain is administered as mentioned before till the required level of sensory block is achieved. [82] Injecting hyperbaric Bupivacaine first in the sitting position is to achieve good anesthesia and motor block of the lower abdomen and lower limbs and then utilizing isobaric Bupivacaine to fine tune the spread of the sensory block without resorting to various manipulations of posture which may be required with hyperbaric Bupivacaine if used alone. Isobaric Bupivacaine used during continuous Spinal anesthesia in the supine position produces a suitable and a more controllable anesthesia. [125]

4- **Patients Undergoing Vascular Interventions in the Lower Half of the Body:**

These patients are often extremely unwell as the disease process that affects vessels in the lower half of the body that require surgical intervention (as Atherosclerosis or Vasculitis) commonly affects vessels in other parts of the body too (as Coronaries and/or Carotids), and also such patients require good post-
operative analgesia. CSA can be used in these patients in the manner described before with plain Bupivacaine to minimize cardiovascular instability. For the postoperative period, the catheter can be left connected to a PCA (patient controlled analgesia) device programmed to deliver a bolus of 0.5 ml of 0.25% plain Bupivacaine with a lockout of 5 min. [118]

In these patients CSA provides a significantly lesser incidence of decrease in blood pressure and lower incidence of vasopressor use when compared to controls receiving continuous Epidural anesthesia. [119] It also avoids many of the disadvantages of General Anesthesia as the hemodynamic responses of direct laryngoscopy and intubation, in addition, the use of volatile anesthetics may lead to myocardial depression and peripheral vasodilatation. Also in a patient with coexisting chronic obstructive lung disease (COPD), complications associated with positive pressure ventilation and possible infectious risks associated with intubation are avoided. [120]

5- Patients Undergoing Interventions for Repair of Aortic Aneurysms:

Endovascular Stent Graft Repair of Aortic Aneurysms is increasingly common in patients who are at high medical risk and have vascular anatomy that is amenable to this approach. [121] Regional anesthesia is frequently administered because of the need to perform open surgery on the Femoral artery or distal Aorta, combined with the desire to avoid general anesthesia and endotracheal intubation in patients with severe cardiac and pulmonary disease. Also during open thoracic aortic aneurysm repair, lumbar drainage has been advocated to prevent, or reduce, Spinal cord ischemia by reducing cerebrospinal fluid (CSF) pressure and improving Spinal cord perfusion. [122]

The first case of combined Lumbar CSF drainage and Spinal Anesthesia administration through the same catheter in the management of Endovascular Stent
Graft Repair of a Thoracic Aortic Aneurysm was presented by Shin Su Kim et al in their case report of a 78 year old man presenting with a Thoracic Aortic Aneurysm that originated immediately distal to the orifice of the left Subclavian artery, despite the drainage of CSF, the duration of anesthesia was approximately the same as would be expected from a single shot administration without CSF drainage. This finding might show that the local anesthetic remaining in the CSF after initial binding to the Spinal cord and nerve roots is not a significant contributor to the duration, or density, of the Spinal anesthesia. [123]

6- General Surgical Patients Undergoing Major Abdominal Surgery:

There are only few reports in the literature regarding the use of CSA in abdominal surgeries requiring higher level of sensorial block, but one of them described its successful use in 52 patients (ASA III-IV) undergoing major abdominal surgeries resulting in a 91% patient satisfaction without any significant complications. [124]

It should also be noted that patients with multiple co-morbidities are usually aware that they are at higher risk, and are usually prepared to endure a bit of discomfort if it means they are given a chance to overcome the potential life threatening medical problem that has brought them to the attention of the anesthetist. [125]

Another case series demonstrated the effective use of CSA using a micro-catheter as a primary method of anesthesia in high-risk patients undergoing colorectal cancer and other major abdominal surgery (A total of 89 patients, ASA IV) [126] without any serious hemodynamic derangements except occasional mild hypotension which responded well to I.V fluid load and with an incidence of PDPH similar [127] or lower [128] compared to other published studies.
Postoperative pulmonary complications have been reported to occur in 4-22% of patients undergoing abdominal surgery under general anesthesia.\textsuperscript{[129]} Patients with severe obstructive airway disease have a 37% incidence of postoperative chest complications and it is suggested that avoiding general anesthesia with endotracheal intubation may decrease the risk of postoperative bronchospasm and decrease the risk of stay in intensive care.\textsuperscript{[130]} CSA is also known to minimize the risk of cardiovascular and respiratory disturbances\textsuperscript{[131]} and since respiratory depression is a well-recognized side effect of Spinal Opioids, using relatively small doses of Fentanyl (25µ/hour max) and also avoiding the concomitant administration of sedatives will prevent this complication.\textsuperscript{[132]}

7- Morbidly Obese Patients:

Many benefits have can be identified for Epidural anesthesia and analgesia intraoperative and during the postoperative period in these patients, including reduced postoperative pulmonary and thromboembolic complications, better preservation of cardiac function, reduced total Opioid consumption, and early ambulation and discharge from hospital. All the above benefits attributed to Epidural anesthesia also apply to CSA. However, there are distinct advantages of the CSA/A over the continuous Epidural technique. These are: technically easier catheter insertion in obese patients, maximal anesthetic/analgesic effect with a minimum amount of drug, faster speed of onset, and predictable and controllable level of anesthesia and analgesia.\textsuperscript{[133]}
III- Pediatric Open Heart Surgery

Infants and children undergoing cardiac surgery mount a substantial stress response, and in neonates, this has been shown to be associated with adverse outcome. High-dose intravenous Opioid techniques can reduce or even eliminate these responses to non-bypass surgery, but they remain substantial during and after cardiopulmonary bypass (CPB), even when very large doses of Opioids are used. Nevertheless, partial suppression with Opioids can improve markers of myocardial damage in adults and reduce morbidity and mortality in neonates. CPB is also associated with a profound inflammatory response that is in part related to the stress response.

Both in vitro and in vivo studies have demonstrated that Catecholamines increase the expression of pro-inflammatory Cytokines such as Interleukin 6 (IL-6) and high serum concentrations of IL-6 have been correlated with increased morbidity after CPB in infants and children. Therefore, techniques that can improve the control of stress, and hence indirectly inflammation, have the potential to improve outcome in pediatric cardiac surgery with CPB.

There are strong indications from the adult literature that both Epidural and Spinal techniques may confer advantages in terms of hemodynamic response, stress response, myocardial damage, and markers of postoperative recovery. Two recent retrospective reports have described the use of regional techniques in pediatric cardiac surgery and have suggested an outcome benefit, but expert commentaries have indicated that these are not techniques that should be adopted without careful objective measurement of risk versus benefit.

A Spinal catheter can be inserted before surgery, which provides high Spinal anesthesia, the high-level blockade achieved intraoperatively can be confirmed by the observation of bilateral dilated pupil (This blockade regress rapidly in the
postoperative period) and can also provide continuous regional analgesia in the postoperative period.

CSA when evaluated against high-dose intravenous Opioid anesthesia in a randomized controlled trial in infants and children aged up to 2 years undergoing open heart surgery showed that overall plasma Norepinephrine concentrations were significantly lower in the Spinal group. Also overall plasma Epinephrine concentrations were significantly lower in the Spinal group. Plasma Cortisol returned to baseline in the Spinal group at 24 h after cross clamp removal but remained suppressed in the intravenous Opioid group. Furthermore, plasma Lactate, a factor previously linked to increased morbidity and mortality in pediatric cardiac surgery was lower in the Spinal group which could be due to either improved cardiac output or enhanced peripheral perfusion.\(^{[143]}\)

It is also noted that although Opioids can effectively eliminate stress responses to non-bypass surgery, even very large doses of Opioids do not suppress the increases in cortisol and catecholamines associated with pediatric CPB.\(^{[144]}\) High-dose Opioid techniques are often avoided in simple cardiac procedures to facilitate early extubation while Spinal anesthesia has a relatively short duration and can provide conditions for early extubation in suitable patients.\(^{[145]}\) And so, according to the previous factors, CSA is considered more effective than intravenous Opioid anesthesia at controlling the stress response to CPB in pediatric patients undergoing cardiac surgery as well as providing adequate postoperative analgesia.\(^{[146]}\)
General Advantages of Neuraxial Blocks

In addition to the advantages of CSA technique itself, it was found that Regional anesthesia, in general, provides many advantages over General anesthesia (which off course also applies to CSA), these include improved survival, reductions in risk of venous thrombo-embolism, myocardial infarction, bleeding complications, pneumonia, respiratory depression, and renal failure. This was demonstrated in a study that included 141 different trials with a total of 9559 patients which showed that overall mortality was about one third less in the Neuraxial blockade group with no clear difference between different surgical groups. The effect on total mortality was not clearly lower in trials in which Neuraxial blockade was combined with general anesthesia than in trials in which Neuraxial blockade was used alone. [147]

Neuraxial blockade result in reduction of the risk of deep vein thrombosis (DVT) by almost half, there is one third fewer myocardial infarctions, the requirement for a transfusion of two or more units of blood is reduced by about half, the risk of developing Pneumonia is reduced, also the odds of respiratory depression is reduced by 59%, while there was no clear difference in the proportional effects with the use of concomitant general anesthesia. [147]

The benefits seen for Neuraxial blockade may be the result of multi-factorial mechanisms, including altered coagulation, increased blood flow, improved ability to breathe free of pain, and reduction in surgical stress responses. In particular, major surgery induces a “stress response” that is substantially altered by Neuraxial blockade but not by general anesthesia, the results suggest that these benefits are principally due to the use of Neuraxial blockade rather than avoidance of general anesthesia. Thus the key issue seems to be whether Neuraxial blockade is used or not. [147]
Chapter 5
Contraindications & Complications
Contraindications for Continuous Spinal Anesthesia

The Contraindications for continuous Spinal anesthesia (CSA) are generally those of neuraxial anesthesia as whole with some differences:

1- **Absolute Contraindications:**

Patient refusal, bleeding diathesis, elevated intracranial pressure and infection at the site of injection. Although no preoperative screening tests are required for healthy patients undergoing neuraxial blockade, coagulation studies and platelet count should be checked when the clinical history suggests the possibility of a bleeding diathesis. \[148\] CSA differs in that unlike other types of neuraxial blocks, severe hypovolemia, severe stenotic valvular heart disease or ventricular outflow obstruction are not considered a contraindication for CSA, in fact, it may be very beneficial in these situations as mentioned in the previous chapter.

2- **Relative and Controversial Contraindications:**

(A) **Clinical findings in the back:** Which is detected by physical examination of the back that may reveal important information, such as the presence of surgical scars, scoliosis, skin lesions, and whether the spinous processes are palpable or not.

(B) **Dementia, Psychosis, or emotional instability:** As regional anesthesia requires at least some degree of patient cooperation, and this may be difficult or impossible with these patients so the decision needs to be individualized. Young children also may similarly not be suitable for pure regional techniques.

(C) **Pre-existing neurological deficits or Demyelinating diseases:** These patients may report that their symptoms are worse following a block and it may be impossible to discern effects or complications of the block from preexisting deficits.
or unrelated exacerbation of preexisting disease. For these reasons, many practitioners argue against neuraxial anesthesia in such patients.

(D) **Sepsis or Bacteremia:** Neuraxial anesthesia in their presence could theoretically predispose patients to hematogenous spread of the infectious agents into the Epidural or Subarachnoid space, more discussion of the infective complications of CSA will come later.

(E) **Anticoagulant and Antiplatelet Therapies:** Decision of whether a block should be performed or not in the setting of anticoagulants and antiplatelet agents can be problematic. *The general guidelines are as follow:*

1- **Long-Duration Anticoagulants (Vitamin K antagonists):**

Such as **Warfarin.** The effects of Warfarin are not apparent until a significant amount of biologically inactive factors are synthesized and is dependent on coagulation factor half-life. The plasma half-life of Warfarin is approximately 48 hours. The INR is most sensitive to the activities of factors VII and X and is relatively insensitive to factor II activity. After temporary interruption of Warfarin therapy, the initial decrease in the INR reflects the decrease in factor VII levels and at least 5 days is required for recovery of the other vitamin K-dependent clotting factors (II, IX, and X).

2- **Intermediate-Duration Anticoagulants:**

**Danaparoid** is a low-molecular-weight heparinoid which has a plasma half-life of **25 hours.** Treatment with Danaparoid does not affect the aPTT, and anticoagulant monitoring relies on anti-Xa measurements. **Fondaparinux** is a synthetic anti-Xa inhibitor with stable pharmacokinetics, and a plasma half-life of **15 to 18 hours.** Although anticoagulant monitoring of Fondaparinux can be
done with anti-Xa levels, there is no proposed therapeutic range as with LMWHs.\textsuperscript{[149]}

3- Short-Duration Anticoagulants:

*Intravenous Un-Fractionated Heparin* (UFH) results in an immediate anticoagulant effect, while *subcutaneous* UFH results in a 1 to 2 hour delay before the onset of anticoagulant activity. The anticoagulant effect of UFH is monitored with the Activated Partial Thromboplastin Time (aPTT), with a target therapeutic aPTT of 1.5 to 2.0 times the baseline aPTT. Low-dose UFH (5,000 IU twice-daily), typically used for prophylaxis against deep venous thrombosis, *does not prolong the aPTT*, and laboratory monitoring is not required.

LMWHs such as *Enoxaparin* are derived by chemical or enzymatic depolymerization of UFH. The antithrombotic activity of LMWHs is primarily through an anti-Xa effect and to a lesser extent an anti-IIa effect, whereas UFH has the same anti-Xa and anti-IIa effects.\textsuperscript{[150]} Many cases of Spinal hematoma associated with neuraxial anesthesia followed the introduction of Enoxaparin (Lovenox) in the United States in 1993. Many of these cases involved intraoperative or early postoperative LMWH use, and several patients were receiving concomitant antiplatelet medication. So if bloody needle or catheter placement occurs, LMWH should be delayed until 24 hours postoperatively, because this trauma may significantly increase the risk of Spinal hematoma. If postoperative LMWH thromboprophylaxis will be utilized, catheters should be removed 2 hours prior to the first LMWH dose. If already present, the catheter should be removed at least 10 hours after a dose of LMWH and subsequent dosing should not occur for another 2 hours.\textsuperscript{[151]}
4- **Oral Anti-Platelet Agents:**

Inhibition of platelet adhesion, activation, and aggregation is a key component of several major classes of available antiplatelet drugs. Ticlopidine was the first drug, also Clopidogrel, a drug with a better safety profile, is now common therapy in the management of coronary stent implantation. There is a third class of antiplatelet drugs such as Abciximab but little literature is available on these newer classes of antiplatelet drugs and their potential for increasing the risks of neuraxial complications, however, their powerful effects on platelet action must make their use a contraindication for neuraxial anesthesia.

Urmey and Rowlingson reviewed the literature and concluded that antiplatelet drugs by themselves appear *not to represent* an added significant risk for development of Spinal hematoma in patients having Epidural or Spinal anesthesia. \[^{152}\] *It is the combination of antiplatelet agents with other anticoagulation drugs* that may increase the risk of bleeding complications. Careful preoperative assessment of the patient to identify complications that might contribute to bleeding is important. In contrast, potent agents should be stopped and neuraxial blockade should generally be administered only after their effects have worn off. The waiting period depends on the specific agent: for Ticlopidine (Ticlid) it is **14 days**, Clopidogrel (Plavix) **7 days**, Abciximab (Rheopro) **48 hours**, and Eptifibatide (Integrilin) **8 hours**. \[^{152}\]

5- **Aspirin:**

At low daily doses (30–300 mg), Aspirin inhibits production of Thromboxane A2, a platelet aggregate stimulator and vasoconstrictor, while at higher daily doses (1.5–2.0 g), it inhibits Prostacyclin. Thus, Aspirin increases bleeding tendency and prolongs bleeding time for the entire lifetime of the
platelets (7–10 days), however it is no longer considered a contraindication for neuraxial anesthesia. Non-Steroidal analgesics also can influence aggregation of platelets, but this is limited in time to 1 to 3 days after stopping therapy. \[153\]

6- Direct Thrombin Inhibitors:

Lepirudin irreversibly binds to and inactivates circulating and clot-bound Thrombin. Lepirudin has a plasma half-life of approximately 80 minutes and is cleared mainly by renal mechanisms. Consequently, it should be avoided in patients with impaired renal function. Monitoring of the anticoagulant effect of Lepirudin is done with the aPTT, with a target aPTT of 1.5 to 2.0 times the control value. Argatroban is a direct thrombin inhibitor that, unlike Lepirudin, reversibly binds to and inactivates circulating and clot-bound thrombin. Argatroban also differs from Lepirudin with a shorter plasma half-life (40-50 minutes) and elimination by hepatic mechanisms. Consequently, Argatroban is the direct thrombin inhibitor of choice in patients with impaired renal function. Its monitoring is done with the aPTT, with a target aPTT of 1.5 to 2.0 times the control aPTT. \[154\]

**Complications of Continuous Spinal Anesthesia**

The complications of CSA include those generally associated with any neuraxial block and complications related to the intrathecal catheter itself.

(A) **General Complications:** Coughing, discomfort, itching, nausea and vomiting (IONV), hypotension, Post-Dural Puncture Headache (PDPH), infective complications, aseptic meningitis, Spinal hematoma, Spinal cord or nerve root injury.
(B) Catheter-Related Complications: Cauda Equina syndrome, intrathecal
Granuloma, catheter migration, CSF leak, Spinal Myoclonus, Traumatic Syrinx

(A) General Complications

1- Coughing: Many patients are considered for the CSA technique because they
have poor respiratory function usually due to long standing chronic obstructive
airway disease and underlying chest infection, these patients may cough
spontaneously. Also the patient with acute abdominal pain requiring emergency
laparotomy and who has a concomitant active chest infection will be able to cough
on the operating table because their abdominal pain is relieved by Spinal anesthesia.
Patients who cough during surgery require the skills of a surgeon who is prepared to
tolerate a moving target.

2- Discomfort: There may be some discomfort during surgery under neuraxial
anesthesia, surgeons may occasionally touch the diaphragm during cholecystectomy
and other upper gastro-intestinal and colonic surgery. The diaphragm receives its
innervation from C3–5 and clearly these dermatomes are not blocked by Spinal
anesthesia resulting in a discomfort sensation for the patient, this may also be
caused by traction on the peritoneum.\[155\]

3- Itching: Some patients complain of minor itching of the nose and over the trunk
but they seldom require treatment.

4- Nausea and Vomiting: The incidence of IONV (Intraoperative nausea and
vomiting) during Spinal anesthesia for non-obstetric surgery ranges from 7% to
42%.\[155\] While the overall incidence of IONV during neuraxial anesthesia for
cesarean section is extremely variable (up to 80%) depending on the anesthetic
technique used and on the preventive and therapeutic measures taken.\[156\]
One of the causes of IONV is insertion of a nasogastric tube that is probably better being avoided unless needed badly. Other causes include Hypotension as it may lead to cerebral hypoperfusion and brainstem ischemia that may activate the circulatory, respiratory and vomiting centers in the medulla.\[157]\) It is also speculated that hypotension leads to gut ischemia and release of emetogenic substances such as serotonin from the intestine. Strategies to prevent rather than treat hypotension appear to be more likely to decrease the incidence of nausea and vomiting, this is where CSA is superior to single-shot Spinal anesthesia.\[158]\) Also excessive bowel handling by the surgeon and administration of intrathecal Opioids can cause IONV. Gentle handling of the bowel and administration of anti-emetics may reduce or prevent IONV.\[159]\)

5- **Hypotension:** It is the one of the commonest serious adverse reactions to neuraxial anesthesia especially during caesarean section (due to maternal physiological changes which makes this group more susceptible to hypotension). Hypotension of sufficient severity and duration has the potential to induce loss of consciousness, with the consequent risks of hypoxia through airway obstruction or aspiration of stomach contents. Such severe and problematic hypotension is rare in the normal population. But even a brief, mild hypotensive episode might be enough to precipitate irretrievable hemodynamic collapse in the presence of certain medical or obstetric conditions. Many would regard neuraxial anesthesia as contraindicated in these circumstances, but modern anesthetic techniques such as CSA in our case and anti-hypotensive regimens are forcing these views to be challenged.\[160]\)

The mechanism for this hypotension is the blockade of sympathetic vasoconstrictor fibers that emerge from Spinal segments T₁-L₂. Most if not all of these should be blocked at least partially, because a block to light touch to T4 is required to ensure comfort during anesthesia for abdominal surgeries if local
anesthetics alone are used. Blockade to T₆ seems adequate if a lipid soluble intrathecal Opioid is included, but the upper end of such a block is still likely to affect all sympathetic roots. The resultant loss of peripheral resistance and venous pooling causes the cardiac output to fall.

The main risk factors that predispose to hemodynamic instability during anesthesia in general and neuraxial anesthesia specifically are mentioned in Table (02). First of all, whenever possible, any treatable risk factor should be corrected before embarking on any form of anesthesia. For example, hypovolemia can be anticipated and can be corrected with appropriate intravenous fluid therapy and for patients with a reduced cardiac output due to cardiac disease they should have their condition as much as possible medically optimized with regular cardiological review. Then for most of the untreatable or unpreventable factors, the benefits of CSA come into action.

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Etiology of Risk Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preexisting Hypovolemia</td>
<td>- Hemorrhage, Vomiting or Diarrhea.</td>
</tr>
<tr>
<td>Risk of Hemorrhage</td>
<td>- Obstetric conditions such as Placenta previa.</td>
</tr>
<tr>
<td></td>
<td>- Bloody operations as Orthopedic procedures or Vascular surgeries.</td>
</tr>
<tr>
<td>Reduced Cardiac Output States</td>
<td>- Cardiomyopathy</td>
</tr>
<tr>
<td></td>
<td>- Valvular heart diseases such as tight aortic stenosis.</td>
</tr>
<tr>
<td></td>
<td>- Antihypertensive drugs as β Blockers.</td>
</tr>
<tr>
<td>Increased Aorto-Caval Compression</td>
<td>- Multiple pregnancy or Polyhydramnios.</td>
</tr>
<tr>
<td></td>
<td>- Obesity.</td>
</tr>
<tr>
<td></td>
<td>- Intra-abdominal masses.</td>
</tr>
</tbody>
</table>

Table 01. The main risk factors for hemodynamic instability during neuraxial anesthesia. [161]
Epidural anesthesia is a well-established technique that pretty much enforces a slow incremental induction, and thereby is associated with less frequent sudden and severe hypotension than Spinal anesthesia. Techniques to prevent and treat hypotension therefore usually work well. There is, however, a disadvantage and that is it's relatively poor performance in preventing intra-operative visceral discomfort when compared to Spinal anesthesia. Poor patient satisfaction scores, requirements for intravenous analgesic supplementation, conversion to General anesthesia, and complaints about intra-operative pain, are all more likely with Epidural than with Spinal anesthesia. Another disadvantage is the highly unpredictable block level and high incidence of patchy blocks.¹⁶²

Single-shot Spinal anesthesia is obviously not an appropriate choice when hemodynamic stability is vital. An audit was made in St. James’s University Hospital in 2004 revealed an incidence of symptomatic hypotension of 35% amongst healthy women having Spinal anesthesia for elective section, despite prophylactic Ephedrine infusions.¹⁶² However, for women where even a brief episode of severe hypotension might, by significantly reducing coronary blood flow, trigger hemodynamic collapse or dysrrhythmia, a gradual onset neuraxial block is the sensible choice.¹⁶³

Having earlier rejected Epidural anesthesia, continuous Spinal anesthesia (CSA) may be the best choice in this situation.¹⁶⁴ There is a surprising variation in total dose requirements with 0.5% hyperbaric Bupivacaine, ranging from 1.5 to 3.0 ml in patients of normal stature. Catheter and filter dead space is therefore significant. Case reports have testified to the success of this technique in high risk cardiac patients.¹⁶⁵ Introducing a T8 block over 30 min has in all cases preserved a very stable blood pressure with minimal need for fluid boluses or vasoconstrictors.
Thus this regimen can be considered a very successful way to deliver high quality, stable neuraxial anesthesia for operations in the lower half of the body. [166]

6- **Post-Dural Puncture Headache (PDPH):** It is another major complication of neuraxial anesthesia and after diagnostic lumbar puncture which has been a vexing problem for many patients. Clinical and laboratory research over the last 30 years has shown that use of small-gauge needles, particularly of the pencil-point design, is associated with a lower risk of PDPH than traditional cutting point needle tips (Quincke-point needles).

The incidence of PDPH following Spinal anesthesia has been reported to vary from 0.2 to 24% with a generally quoted incidence around 0.3%. [167] PDPH is more frequently noted in pregnant women receiving Spinal anesthesia and in patients less than 50 years of age. [168] There are certain demographic factors that seem to be associated with risk of PDPH for reasons that are not well understood. Patient age is a risk factor, with ages between 18 and 40 years showing the highest risk range. The risk of PDPH at age 25 years is 3–4 times that at age 65 years while children younger than 13 years rarely get PDPH. This is thought to be due to lower CSF pressure in children. [169]

PDPHs do occur with increasing frequency in adolescents and are similar to the risk seen in adults. [170] There is also significantly decreased frequency after age 60 years, which also may be related to lower CSF pressure. Female sex, regardless of age, is also at higher risk for PDPH for unknown reasons. Women have approximately twice the likelihood compared to men. [171] Race does not seem to be a factor in development of PDPH. A history of chronic or recurrent headache has been found in nearly 60% of those with PDPH. Previous history of PDPH is also a risk factor for development of future headaches. [172]
In addition to patient-related factors, there are several technical factors which can affect the incidence of PDPH. The most important technical factor in determining the incidence of PDPH is undoubtedly the size of the Dural hole produced during puncture. There are two major relevant sub-topics to this issue: needle size, and design of the needle point. There is a direct relationship of PDPH to Spinal needle tip diameter. The larger the diameter of the needle, the more frequent and more severe the headache.

There is an incidence of 80% with 16G needles versus 5% with 26G needles, the overall incidence was 11% of 10,098 spinals in one large study. Use of small gauge pencil-point Spinal needles has reduced the incidence to about 0.02–1.5%. This later factor is thought to be due to the smaller Dural hole produced by a pencil-point needle compared with that produced by a cutting (Quincke) point needle, resulting in less leakage of CSF.

Any theory explaining PDPH must account for the relationship of the headache to the loss of CSF. One theory states that the loss of CSF through a Dural hole results in intracranial tension or traction on nerves and meningeal vessels. While the bimodal theory suggests that there is a combination of both low CSF pressure and...
resultant cerebral vasodilatation in reaction to the stretching of vessels. The amount of CSF loss depends upon the size and shape of the Dural hole and the pressure difference between the Subarachnoid and Epidural spaces.\textsuperscript{[176]} The design of the Spinal needle tip and orientation of a cutting needle bevel are both factors in determining the rate of CSF loss. In one in-vitro study performed using human postmortem thoracolumbar Dura Mater, the median loss of CSF volume in 5 min was significantly less with a 22G Whitacre needle than with a 22G Quincke.\textsuperscript{[177]}

There was a 21% reduction in leakage of CSF if the Quincke needle bevel was parallel to the large axis of the vertebral column to bevel configuration. Cutting fewer fibers of the Dura reduces the size of the Dural hole. Needle tips that stretch Dural fibers should reduce the size of a resulting hole, in comparison to tips that cut fibers, hence the rationale for using pencil-point needles rather than cutting needles (Fig.23, 24, 25).\textsuperscript{[177]}

In 1988, Dittmann and colleagues reported that Dural fibers are not uniformly parallel, and that the thickness of the Dural sac is variable. They also described the so-called "Tin Can Lid" phenomenon.\textsuperscript{[178]}

\textbf{Fig 25. Scanning electron micrograph of a dural puncture hole made by a 25G Whitacre (non-cutting) needle. View is from the inner (intrathecal) side of the dura mater. Note that the fibers are 'torn' rather than 'cut', resulting in an ellipsoidal configuration.}[175]

\textit{Decreasing incidence of PDPH:} This include using an angled approach to the Subarachnoid space, such as a paramedian approach which is associated with a lower incidence of PDPH.\textsuperscript{[179]} Also avoiding multiple puncture holes in the Dura
Mater is also recommended to avoid PDPH. There is little advantage in using small (25–29G) Quincke point needles compared with 24G pencil-point needles, so most authorities suggest using smaller gauge, non-cutting needles.

In CSA, the risk of PDPH remains controversial, ranging from very low to over 30%. \[181\] And to reduce the risk of PDPH in CSA, small-gauge Spinal catheter systems with different techniques of Dural perforation have been developed. \[180\] Such as the over-needle group which showed a significantly shorter duration of PDPH and lower maximum pain intensity than the through-needle group concluding the potential benefit of the catheter over-needle technique for the reduction of the duration and intensity of PDPH. \[182\]

7- Infective Complications: Although individual cases have been reported in the literature, serious infections of the central nervous system (CNS) such as arachnoiditis, meningitis, and abscess following Spinal or Epidural anesthesia are rare. However, recent epidemiologic series from Europe suggest that the frequency of infectious complications associated with neuraxial techniques may be increasing.\[183\] Staphylococcus is the organism most commonly associated Epidural abscess, often these infections occur in patients with impaired immunity. Conversely, meningitis follows Dural puncture, and is typically caused by alpha-hemolytic Streptococci, with the source of the organism the nasopharynx of the performer. In order to reduce the risk of serious infection following neuraxial blockade, the clinician must be familiar with the pathogenesis of CNS infections, patient selection, and use of meticulous aseptic technique. \[184,185\]

Infectious complications may occur after any regional anesthetic techniques, but are of greatest concern if the infection occurs around the Spinal cord or within the Spinal canal. Possible risk factors include underlying sepsis, diabetes, depressed immune status, steroid therapy, localized bacterial colonization or infection, and
Chronic catheter maintenance. Bacterial infection of the central neural axis may present as meningitis or cord compression secondary to abscess formation.\textsuperscript{[186]} An indwelling neuraxial catheter, though aseptically sited, may be colonized with skin flora and consequently serve as a source for ascending infection to the Epidural or intrathecal space.\textsuperscript{[187,188]}

8- Aseptic Meningitis: Aseptic meningitis following Spinal anesthesia can be the consequence of a number of factors: trauma from the procedure itself, aggravation of an underlying disease of the central nervous system (CNS), inflammatory response to medication, or a foreign irritant (chemical) that had contaminated the equipment used. Diagnosis is by exclusion, and clinical signs and CSF findings vary greatly.\textsuperscript{[189]} The onset of meningitis usually occurs 24-48h later, but may be delayed by approximately 10 days.\textsuperscript{[190,191]}

Since aseptic contamination of catheters can occur due to involuntary or faulty maneuvers during their insertion, a study was made aiming to simulate such faulty maneuvers and to study, by electron microscopy, the results of the contamination to evaluate the potential danger. Also the tips of catheters used clinically were studied to check for the presence of traces of possible involuntary contamination (Fig.26).\textsuperscript{[192]}

The distal segments of the catheters are easily contaminated with powder from gloves (calcium carbonate) and disinfectant (Povidone-Iodine solution) when the tip is held between the thumb and index finger. This is true for both catheters made of pressed nylon resin and those made of polyamide, although the surface of the later is smoother and seem to retain a smaller quantity of powder. Passage through the lumen of the Spinal needle partially cleans the external surface of the catheter, but not the tip, so that any impurities present can enter into the Subarachnoid space.
Chapter 5
Contraindications & Complications

(Fig.27). Calcium Carbonate is an inert salt, only slightly hydro-soluble, and is considered incapable of inducing aseptic inflammatory reactions. [192]

On the contrary, talcum, still used as powder for gloves, can induce an aseptic inflammatory reaction (meningismus) in the Subarachnoid space. [193] However, most packets of gloves bear the instruction "After donning, remove powder by standard aseptic method". Also, very rarely the surface of a catheter can be contaminated by starch grains, which can induce an aseptic inflammatory reaction in the Epidural space and, probably, in the Subarachnoid space. [192]

Catheters also can easily be contaminated with Povidone-Iodine solution when touched with gloves stained with this solution, but it does not seem that Povidone-Iodine solution can induce meningeal reactions if the patient is not allergic to
Iodine. The adhesion of these particles is facilitated by the irregularity of the surfaces of Nylon catheters.\textsuperscript{[192]}

Bacterial contamination of catheters may also occur even when the anesthesiologist believes that he or she has operated under sterile conditions. Fortunately, in most cases, septic contamination is without consequences. It is, however, recommended that anesthetists, besides following the standard precautions, should wash their hands and forearms before donning sterile gloves and that they do not touch the tips of catheters.\textsuperscript{[192]}

---

Fig. 27 Scanning electron micrographs of sterile catheters.

(A) Tip of a Co-Span catheter touched with a powdered glove and passed through a 22-gauge spinal needle (300X).

(B) The presence of numerous granules of calcium carbonate adhering to the edge of the tip (1500X).

(C) and (D) A Micro-Spinal catheter tip appears to be very irregular, this might cause a narrowing of the lumen of the tip (350X).

(E) A Co-Span catheter tip at 45° (190X).

(F) A Co-Span catheter tip with manufacturing residue causing a partial obstruction of the lumen (190X).

\textsuperscript{[192]}
9- **Spinal Hematoma:** Its occurrence as a complication of neuraxial procedures is extremely rare. Guidelines such as those discussed previously have been helpful in providing guidance to practitioners who perform Spinal injections. A recent meta-analysis of 613 cases of Spinal hematomas occurring during the period from 1826 to 1996 identified no clear etiology in nearly half the cases (43.6%). Only in 10.3% of the cases was there a preceding Spinal injection or lumbar puncture. A total of 37 cases of hematoma were in patients who were either receiving anticoagulants or had coagulation disorders. In the final analysis, only 4.2% (26 cases) of the patients developed hematoma in proximal relationship to Spinal anesthesia or lumbar puncture.\[^{194}\] In another large review of Spinal hematomas, a total of over 1 million cases of Epidural anesthetics and Subarachnoid blocks yielded only 20 cases of hematoma.\[^{195}\]

The location of neuraxial hematomas is almost universally in the Epidural space, presumably because of the presence of significant Epidural venous plexuses. Subarachnoid hematoma is exceedingly uncommon, as the cerebrospinal fluid dilutes bleeding and vessels in the Subarachnoid space are not generally present. A careful medication history should reveal anticoagulants taken before the procedure, in addition, any patients experiencing weakness, back pain, sensory deficit, or urinary retention after a Spinal injection should be carefully evaluated for a Spinal hematoma or other neurologic injury.\[^{195}\]

10- **Spinal Cord or Nerve Root Injury:** It is a documented complication for neuraxial anesthesia as the needle can accidentally puncture the Spinal cord or nerves, leading to injury. The risk for Spinal cord injury is highest during high Epidural injections where there is a possibility that the needle cross the Epidural space and enter intrathecally causing traumatic injury of the Spinal cord. In CSA and Spinal injections, the needle intentionally enter the Subarachnoid space, so the
Contraindications & Complications

general guidelines indicate that the puncture is always made at L₃₋₄ or below (in adults) so as it's always below the level of termination of the Spinal cord. [196]

In addition, any pain experienced by the patient during insertion of the needle or advancement of the catheter, specially burning pain in the lower limbs should raise suspicion of an irritation of one or more of the Spinal nerve roots by the tip of the needle or the catheter requiring withdrawal of the needle or catheter and repositioning in the same level or in a whole different level. Also heavy sedation of patients during the procedure should be avoided as it may lead to their being unresponsive to pain that would otherwise warn the anesthetist that a nerve root is being compromised, The Cauda Equina syndrome that has been said to be associated with CSA will be discussed later with the Catheter-Related complications. [196]

(B) Catheter-Related Complications

1- Cauda Equina Syndrome (CES): The CSA technique gained a big momentum in the 1990s when micro-spinal catheters were introduced, but the technique was surrounded by controversy when with the beginning of 1991, a few cases of sudden onset of Cauda Equina syndrome (CES) following continuous Spinal anesthesia with 5% Hyperbaric Lidocaine through micro-catheters have been reported [196] leading to the banning of using Spinal micro-catheters (not the CSA technique itself) by the Federal Drug Administration (FDA) in the USA. Denny questioned the etiology of Cauda Equina syndrome and stated that "For a number of years and on several occasions CSA has prevented patients from needing postoperative ventilation and it would be unfortunate if this extremely useful technique was abandoned due to its inappropriate application". In Denny’s opinion, the most likely cause of Cauda Equina syndrome was maldistribution of hyperbaric Lidocaine when injected slowly through a small end-hole catheter. In the absence of convincing
evidence that the Spinal micro-catheter itself was the cause of the Cauda Equina syndrome, and as the availability of small bore micro-catheters increased, CSA continued to be used in clinical practice outside of the USA. [197]

The ultrastructure of the Spinal Arachnoid and its relationship with the Spinal nerve roots and Dural sac was studied to help explain the different patterns of local anesthetic distribution in the Subarachnoid space after Spinal anesthesia, as well as some neurological conditions associated with it. In scanning electron microscopy, the Arachnoid appears composed of two different layers: a compact layer in direct contact with the deep surface of the Dura Mater (Fig.28) and a trabecular layer that

![Fig.28 Human lamina arachnoid. Scanning electron microscopy. Magnification 180X Bar: 100 µm. [198]](image1)

![Fig.29 Human spinal arachnoid trabecula. Trabecular arachnoid encircling motor and sensitive nerve roots at the entry site of nerve root cuffs. Scanning electron microscopy. Magnification 30X Bar: 1 µm. [198]](image2)

lines the Dural sac internally. The later forms indentations or "Trabeculae" that surround every Spinal nerve root (Fig.29) as well as the Spinal cord itself (Fig.30), with most trabeculae reaching the pia mater. The Trabecular Arachnoid also encloses the blood vessels that cross the Subarachnoid space. This layer has a variable thickness of 10 to 60 nm offering little mechanical resistance. Trabecular Arachnoid limits nerve root movement to a certain extent, holding each root in its position within the Dural sac and in relation to other nerve roots. [198]
This distribution renders the Subarachnoid sac a compartmentalized space with micro-compartments that may promote uneven distribution of local anesthetics within the Dural sac. In those areas where the local anesthetic solution would not mix (dilute) adequately with CSF, neurotoxic concentrations could be reached, leading to nerve root damage. Anatomical factors may, in this way, help explain the pathogenesis of neurological syndromes like CES. [198]

Lidocaine in Spinal anesthesia has been used since 1948, with a favorable safety record. However, during the last two decades, an increasing number of reports have identified Lidocaine as a possible cause of temporary and even permanent neurological sequelae following Spinal anesthesia. [199]

In 1993, a new term, "Transient Neurological Toxicity" was introduced to describe the development of pain in the buttocks and legs without motor symptoms, following Spinal anesthesia with Lidocaine. Later, the terms "Transient Radicular Irritation" [200] and "Transient Neurological Symptoms" [201] were also introduced. In 1937, Ferguson and Watkins described this complication. [202] But it was not until the 1990s when CES was recognized in the context of continuous Spinal anesthesia. In patients suffering from CES, the Cauda Equine (that bundle of long lumbar and
sacral nerves roots) is affected and produces pain, leg weakness, perineal sensory loss, and urinary and fecal incontinence.

Possible mechanisms of injury include direct spine injury, intra-neural injection, catheter-induced trauma, and Epidural hematoma. Another postulated mechanism, as mentioned before, is poor mixing of hyperbaric local anesthetic with cerebrospinal fluid (CSF) especially when large volumes of anesthetics are used (eg: continuous techniques as CSA).\textsuperscript{[205]}

The use of Spinal micro-catheters (28-32G) has also been blamed as a contributor to the development of this syndrome.\textsuperscript{[203]} Flow through these small gauge catheters requires high perfusion pressure, which may promote the accumulation of local anesthetic in the dependent parts of the Subarachnoid space. This poor mixing of local anesthetic with CSF and the resulting higher concentrations of anesthetics around sacral roots may contribute to nerve injury. As a result, in 1992, the Food and Drug Administration (FDA) ordered the withdrawal of small-bore Spinal catheters (less than 24G) from the US market.\textsuperscript{[204]} Also it seems clear at this time that the risk of developing TNS after Spinal anesthesia after Lidocaine is significantly higher than after Bupivacaine, Prilocaine, or Procaine.\textsuperscript{[205]}

Compartmentalized areas around nerve roots could lead to accumulation of higher concentrations of local anesthetic in some parts of the Dural sac in detriment of others, resulting in inadequate or asymmetric Spinal blocks (Fig.31). Moreover, if a local anesthetic solution is inadvertently injected between the nerve root and its own Trabecular Arachnoid layer, as the electron microscopic studies deem possible, it could result in undiluted amounts of local anesthetics being in contact with such Spinal nerve root. So it is theorized that CES may be the result of inadvertent injection of local anesthetics into the perineural area enclosed by Trabecular Arachnoid.\textsuperscript{[198]}
Another factor which may contribute to nerve injury is the presence of 7.5% glucose (used to produce hyperbaric solutions of local anesthetics) which affects neuronal permeability and leads to edema and neuronal damage. However, its impact on nerve damage has not been demonstrated in more recent studies despite the fact that deleterious effects of hyperglycemia on neural function are well documented. It has been suggested that the lack of a nerve sheath could make the Cauda Equine particularly vulnerable to osmotic alterations and damage. [206]

In vitro experiments using cat rootlets demonstrated persistent block of some C fibers after a brief exposure of rootlets to sucrose solutions with osmolalities as low as 500 mOsm while the tonicity of 5% lidocaine in 7.5% glucose is 837 mOsm. Considering the differences in volumes of CSF between the Subarachnoid space and the compartment limited by the nerve root and its own Trabecular Arachnoid, it is possible that relatively high concentrations of glucose after hyperbaric Spinal blockade could reach certain nerve roots, with potential deleterious effects on neuronal function. [207]

There are other factors not related to concentration of local anesthetics, such as neuronal ischemia due to nerve fiber stretching that should also be considered. This can occur, for example, during surgeries performed in lithotomy position that stretch the nerve fibers of the Cauda Equine that may lead to ischemia and subsequent nerve damage. In fact, a prospective study by Pollock and coworkers showed that there was a significant difference in the incidence of TNS between patients having surgery in the lithotomy position and those having surgery in the supine position. [208] It has also been postulated that stretching of the Cauda Equina in the lithotomy position could increase the vulnerability of the nerve roots to the effects of local anesthetics.
On the basis of research in cadaver preparations, a glass "spine" model and clinical experience in over 200 cases, it was suggested how these problems might be avoided. Since none of the patients reported in the literature to have suffered neurological sequelae had experienced paraesthesia at the time of placement of the catheter, mechanical damage to the nerves had been discounted. The endoscopic views shown did, however, demonstrate that all catheters inserted more than 30mm developed loops (Fig.32, 33). It is readily envisaged therefore that such a loop could accidentally surround a nerve root. When the looped catheter is removed the loop could be tightened and cause direct nerve damage or nerve strangulation.

Although nerve trauma is normally accompanied by severe pain and paraesthesia, in this situation none of the patients who subsequently developed Cauda Equina Syndrome had full sensory and motor recovery of function prior to catheter removal. There would therefore remain the possibility that some degree of local analgesia was still present when the catheter was removed and that damage could have occurred without the usual warning of pain or paraesthesia. Although it has been said that direct nerve damage should result in unilateral lesions it would be
possible for a catheter loop to entrap more than one nerve root of the Cauda Equine there by producing more complex symptoms. [198]

Also piercing and transneural placement of the micro-catheter can occur. Under clinical circumstances this should be accompanied by pain and paraesthesia. However, there are reports in the literature of accidental injections into nerves which are not immediately accompanied by pain and paraesthesia, and indeed if pain and paraesthesia were a constant finding there would be little likelihood of such injections occurring at all. So it is recommended that the catheter shouldn't be introduced for more than 20 mm. In addition, all patients should be instructed to report any abnormal sensations during needle or catheter placement. [198]

It should also be noted that where there is no structural damage to nerves, permanent sequelae are rare. Indeed after therapeutic chemoneurolysis with alcohol or phenol to treat intractable pain, nerve function commonly returns after a variable amount of time. [210] Although there are reports of permanent damage following regional nerve blocks such as ischial or brachial plexus block, it has been shown that the extent of the lesions created depends not only on the actual local anesthetic used but also on the manner in which the nerve damage is inflicted (by direct subendoneural injection of the drugs). Additional support for this concept is available from the retrospective analysis of a further 714 catheters used in Austria since 1990 with no serious complications. [211]

So if the lack of complications is due to very careful handling of the catheters, then it would be wise to limit the technique to only very experienced personnel. If it is due to the use of 0.5% Bupivacaine, then Hyperbaric 5% Lidocaine should not be used for the continuous micro-spinal route. Anyway, it would appear to make no clinical sense to withdraw equipment which offers new horizons in anesthesia and pain relief.
2- **Intrathecal Granuloma**: A documented complication for intrathecal catheters is development of an intrathecal granuloma. It is mainly associated with *prolonged intrathecal infusions* rather than limited duration intrathecal anesthesia. It is an inflammatory mass that forms at the tip of an intrathecal catheter in response to the administration of medications. \[212\] The first intrathecal granuloma was reported in 1991 in a patient who presented with paralysis. \[213\] The prevalence of intrathecal granulomas is unknown. Reports have been published stating the prevalence is 0.1% to 5% with others documenting that the rate is up to 50%. \[214\] Intrathecal granulomas develop as a result of an inflammatory process.

Many theories have been postulated including reactions to the catheter itself (Some investigators have suggested an allergy to silicone, but the absence of these lesions in patients receiving Baclofen for spasticity does not support this hypothesis) as well as impurities in the medications infused. The current thinking is that a mitogen-activated protein kinase cascade that increases lymphocyte activity is the underlying etiology for the formation of a Granuloma. \[215\] This cascade is believed to be initiated by the presence of an intrathecal medication such as Morphine. Granulomas are unrelated to infection and are sterile masses.

There have been no cases of granuloma reported with Sufentanil. However, case reports have been published recently demonstrating that other medications may be responsible for these lesions. Bupivacaine and Baclofen have been mentioned as additional etiologies for intrathecal granuloma formation, although in these cases it appears the patient had previously received high-concentration Opioids. \[216,217\] The most controversial aspect in the etiology of granulomas involves the issue of catheter placement.
Most granulomas have been reported in the area of the thoracic spine. This has led many to conclude that catheters should be placed in the lumbar or cervical region to avoid the site of most granulomas. This conclusion is based on cerebrospinal fluid (CSF) flow in the region of the thoracic cord, where the flow volume is reduced. The ventral thoracic Subarachnoid space has the longest region of low-flow CSF within the entire intrathecal compartment. This stagnation of flow has been postulated to cause build-up of the offending drug, causing a peak in both concentration and total dose.

Another theorized risk factor for intrathecal inflammatory mass is the use of a single orifice catheter. This is suspected because of increased concentration of the medication in the cerebrospinal fluid near the single orifice as opposed to a multi-orifice catheter in which the medication is spread throughout the locations of the orifices in the intrathecal space.

Reviewing the reported cases of granuloma, the length of infusion of medication until granuloma diagnosis ranges between 0.5 and 72 months with the median being 24 months. Therefore, the prevalence of intrathecal granulomas may increase over time with prolonged infusion. So awareness of the condition and clinical suspicion are the keys to successful management of this complication.

3- **Catheter Migration:** It is also another serious complication that can result in new onset of exacerbated axial or radicular irritation due to the migration of the tip of the catheter. This may also result in decreased efficacy depending on the location of the tip. Changes in symptoms can be sudden and abrupt or may slowly develop over a long period of time. Aside from a thorough history and physical examination, imaging is likely necessary to determine the cause of the change in symptoms. Modalities to be considered include Computed Tomography, Magnetic Resonance, or Side Port Myelography.
4- **Cerebrospinal Fluid Leak:** There is a risk of cerebrospinal fluid leak any time the intrathecal sac is accessed. Patients who have undergone lumbar puncture for a neurologic workup are at risk for a low pressure cerebrospinal fluid headache as are patients on the labor and delivery ward who have had accidental Dural punctures during the Epidural placement. These complications related to cerebrospinal fluid leak and low CSF pressure can also occur following placement of an intrathecal drug delivery device. The leak can occur during the trial phase as well as the permanent phase. Externalized and internalized pumps are at risk. In patients with percutaneous catheters, the cerebrospinal fluid can travel through the same tract as the catheter through the skin. In patients with implanted pumps, the CSF can collect in a variety of locations, including along the catheter and in the pump pocket.

5- **Spinal Myoclonus:** It is characterized by focal involuntary muscular contractions.\(^{[223]}\)

6- **Traumatic Syrinx:** It is a rare event related to the introduction of a catheter into the intrathecal space and the presence of its tip within the substance of the Spinal canal. \(^{[224]}\)

<table>
<thead>
<tr>
<th></th>
<th>CSA</th>
<th>Single spinal</th>
<th>Epidural</th>
<th>Combined spinal/ epidural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of space (end point)</td>
<td>Definite</td>
<td>Definite</td>
<td>Blind</td>
<td>Definite</td>
</tr>
<tr>
<td>Level of insertion</td>
<td>Lumber 2–4</td>
<td>Lumber L2-4</td>
<td>Thoracic 7–8</td>
<td>Thoracic 7–8</td>
</tr>
<tr>
<td>Onset of block</td>
<td>Rapid</td>
<td>Faster</td>
<td>Slow</td>
<td>Faster</td>
</tr>
<tr>
<td>Titration to desired level of anaesthesia</td>
<td>Possible with minimum manipulations</td>
<td>Not possible</td>
<td>Possible after manipulations</td>
<td>Possible after manipulations</td>
</tr>
<tr>
<td>Sensory blockade</td>
<td>Excellent</td>
<td>Excellent but limited</td>
<td>Inadequate block may occur</td>
<td>Better than epidural</td>
</tr>
<tr>
<td>Motor blockade</td>
<td>Dense</td>
<td>Dense</td>
<td>Partial</td>
<td>Dense/partial</td>
</tr>
<tr>
<td>Circulatory impairment</td>
<td>Minimum</td>
<td>Minimum</td>
<td>Significant</td>
<td>Significant</td>
</tr>
<tr>
<td>Respiratory impairment</td>
<td>Minimum</td>
<td>Minimum</td>
<td>Significant</td>
<td>Significant</td>
</tr>
<tr>
<td>Duration of anaesthesia</td>
<td>Possible to extend</td>
<td>Limited</td>
<td>Possible to extend</td>
<td>Possible to extend</td>
</tr>
<tr>
<td>Recovery from residual anaesthesia</td>
<td>Short</td>
<td>Short</td>
<td>Longer</td>
<td>Longer</td>
</tr>
<tr>
<td>Postoperative pain relief</td>
<td>Possible</td>
<td>Limited</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Systemic toxicity due to volume of local anaesthetic agent</td>
<td>No</td>
<td>No</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Neurological damage if any</td>
<td>Minor</td>
<td>Minor</td>
<td>Significant</td>
<td>Significant</td>
</tr>
</tbody>
</table>

Table 02. General comparison between the four types of Neuraxial blocks. \(^{[147]}\)
In conclusion to the discussion before, CSA was found to be a technique which has marked advantages in many clinical circumstances, such as the patient with multiple co-morbidities who needs lower body surgery in which general anesthesia and other types of neuraxial blocks may have marked side effects on his condition. CSA combine the benefits of both GA and other neuraxial blocks in the term of better hemodynamic stability, minimal drug load, extension of anesthesia for long operations, accurate control over the level of the block, decreasing incidence of most intra and post-operative anesthesia related complications (pulmonary, cardiac, CNS, embolic and hepatic complications) In addition, it can also be used for post-operative analgesia.

But as any other interventional technique, there are complications for CSA which must be understood regarding their incidence, etiology and management, in order to be able to minimize them and manage them efficiently if they occur. Those include complications of neuraxial blocks in general and other complications related to insertion of intrathecal catheter during CSA. An important part of avoiding complications is avoiding using CSA in the presence of a contraindication for it such as a patient on active anticoagulation, as mentioned before there are guidelines for using CSA with different types of anticoagulation which must be followed. And also, it is recommended that this technique is performed by a senior anesthetist who is experienced in neuraxial blocks.
Summary

CSA is a technique which has marked advantages in certain clinical circumstances, particularly patients undergoing lower body surgery who are old in age and/or have co-morbidities such as in the lungs (as COPD) and/or in the cardiovascular system (as severe valvular heart lesions) who can benefit from avoiding the risks of endotracheal intubation and general anesthesia and in the same time avoiding rough hemodynamic changes associated with other types of neuraxial blocks. CSA is effective for intra-operative anesthesia as well as for post-operative analgesia, and also the intrathecal catheter can be used for long term intrathecal drug administration to control chronic pain or spasticity.

Catheters used can be a micro-catheter (<24G) or a macro-catheter (>24G), the micro-catheter allow using smaller spinal needles thus decreasing the incidence of PDPH, but it present more technical difficulties. It can be inserted in a catheter-over-the needle or a needle-over-the catheter fashion according to the CSA set used, catheter-over-the needle type (Spinocath®) can decrease duration and severity of PDPH by decreasing CSF leak from around the catheter.

A few guidelines for safe performance of CSA can be summarized as: review its indication for every individual patient and assess the presence of any contraindication, discuss it thoroughly with the patient explaining its advantages and complications. Use strict aseptic measures, also the tip of the catheter shouldn't be touched by the gloves or by the disinfecting material (as Betadine). Catheters should be inserted in one of L3-4 or L4-5 spaces. Paramedian approach is preferred especially in elderly patients. The catheter should only be inserted 2-3 cm maximum in the subarachnoid space.
Any pain or parasthesia experienced by the patient during insertion of the needle or threading of the catheter necessitates withdrawal of the catheter and the needle as one unit and reintroduction in the same or another interspace. The catheter injection port should be marked clearly "INTRATHECAL". Avoid using Lidocaine or Hyperbaric Lidocaine intrathecally, Bupivacaine has the best established safety profile in this setting. Finally, till now it is recommended that it is performed by a senior anesthetist who is experienced in performing neuraxial anesthesia techniques.
References
(9) Tuohy EB. Continuous spinal anesthesia, its usefulness and technic involved. Anesthesiology 1944; 5: 142-148.
(14) Tuohy EB. Continuous Spinal anesthesia, its usefulness and technique. Anesthesiology 1944; 5: 142-148.


(25) Hampl KF, Schneider MC, Pargger H. A similar incidence of transient neurological symptoms after spinal anesthesia with 2% and 5% lidocaine. Anesthesia and Analgesia 1996; 83: 1051-1054.


(38) Forster JG, Rosenberg PH, Niemi TT. Continuous spinal microcatheter (28 gauge) technique for arterial bypass surgery of the lower extremities and comparison of ropivacaine with or without morphine for postoperative analgesia. British Journal of Anaesthesia 2006; 97: 393-400.


(42) Tuohy EB. Continuous spinal anesthesia, its usefulness and technique involved. Anesthesiology 1942; 3: 522-529.


(45) Thompson GE. This fight isn’t fair. Anesthesia and Analgesia 1994; 79: 608-609.


References


References


(162) Bamber JH, Dresner M. Aort-ocaval compression in pregnancy, the effect of changing the degree and direction of lateral tilt on maternal cardiac output. Anesthesia Analgesia 2003; 97(1): 256-258.


Salmela L, Aromma U. Transient radicular irritation after spinal anaesthesia induced with hyperbaric solutions of cerebrospinal fluid diluted lidocaine 50 mg/ml or mepivacaine 40 mg/ml or bupivacaine 5 mg/ml. Acta Anaesthesiologica Scandinavica 1998; 42: 765-769.


(221) Pasquier Y, Cahana A, Schnider A. Subdural catheter migration may lead to baclofen pump dysfunction. Spinal Cord 2003; 41: 700-702.


التخليص

التخدير النصفي المستمر هو تكنولوجيا معينة تستخدم في مواقع إكلينيكية كثيرة للمرضى الذين يستخدمونها في عمليات الفم و الكبد و الأطراف الأخرى مثل أمراض الرئة (الكأسادات الشعب المزمن) أو أمراض القلب (كسائتربات أمراض القلب الشديدة).

تختلف أنواع التخدير النصفي بناءً على الظروف المحيطة و مستوى التدخل. يمكن استخدام هذا التكنولوجيا بنجاح للتخدير النصفي لإجراء العملية. التكنولوجيا المستخدمة تشمل القسطرة المستخدمة (24G < micro-catheter) أو ذات قطر كبير (24G> macro-catheter).

تحتاج القسطرة المستخدمة يتم استخدام إبرة شوكة ذات قطر صغير في مكان الاستخدام (24G). تفيد القسطرة ذات القطر الصغير أيضاً بالتالي تخفيف نسبة حدوث الصداع الذي يتبوع استخدام الإبرة الشوكة، ولكن مع مشاكل تكنولوجيا أكبر.

يمكن استخدام إبرة شوكة لتدفق الدم من داخل القسطرة، من خلال إبرة على حسب نوع القسطرة المستخدمة. يساعد تصميم الإبرة من داخل القسطرة (Spinocath®) في تقليل شدة و حدة الصداع الذي يتسبب في النزف الشوكي عن طريق تقليل تسرب السائل الشوكي من حول القسطرة.

لتحقيق الإستعمال الأمان للتخدير النصفي المستمر يوصى بالآتي: مراجعة الحاجة لهذا التكنولوجيا مع كل مريض مسبق، و التحقق من عدم وجود أي من التعرفات لاستخدامه. يجب مناقشة المريض بإستفادة حول مميزات هذا التكنولوجيا و أعراض الجانبية و نسب حدوثها. تكبير القسطرة في ظروف كاملة التحقيم، و أيضاً يجب تجنب لمس طرف القسطرة للقذف المعقم أو مادة التعقيم.

القشرة القطنية الثالثة و الرابعة أو الباببق و الخالسة. يفضل تركيب القسطرة بجانب خط الوسط الظهري خصوصاً في المريض كبار السن، و يجب أن لا تتشكل طول جزء القسطرة الذي داخل الفراغ تحت العنكبوتية 2-3 سم.

عند وصف المريض حدوث أي ألم غير طبيعي أو تتبس بالاجزاء أثناء إدخال الإبرة الشوكة أو تمرير القسطرة من خلالها يجب سحب الإبرة و القسطرة كوحدة واحدة وإعادة إدخالهما في نفس المستوى أو في مستوى آخر. يجب تقديم فتحة الحقن بالقسطرة بعلامة "INTRATHECAL" بطريقة واضحة، كما
يجب تفادى حقن الليدوكين أو الليدوكتين الثقيل بالقسطرة حيث أن البوبيفاكين يتمتع بفضل قاعدة استخدامهما وامانًا في هذا الخصوص. حتى الآن يوصي أن يقوم بتنفيذ هذا التكنيك طبيب تخدير متقدم وله خبرة في استخدام تقنيات التخدير النصفي المختلفة.
الجديد في التخدير النصفي تحت العنكبوتية المستمر

بحث مقدم ليل درجة الماجستير في التخدير

مقدمه

اسلام ايمن محمد شوقي كحة

تحت اشراف

أ.د/ ماهر فوزي محمود

أستاذ التخدير

كلية الطب البشري

جامعة القاهرة

د/ أحمد عبد العزيز عارف

أستاذ مساعد التخدير

كلية الطب البشري

جامعة القاهرة

د/ مها محمد اسماعيل

مسر التخدير

كلية الطب البشري

جامعة القاهرة

كلية الطب البشري

جامعة القاهرة

2010