

Spinal Anesthesia

Spinal anesthesia is a neuraxial technique which can provide the rapid onset of effective analgesia and anesthesia

ANESTHETIC CONSIDERATIONS:

- Consider spinal anesthesia as an option for abdominal and lower extremity surgery
- Rule out contraindications
- Monitor for complications

ANESTHETIC GOALS:

- Provide effective analgesia
- Employ optimal technique to minimize risk of complications

ANATOMY

- Vertebrae (33)
 - 7 cervical, 12 thoracic, 5 lumbar, 5 sacral (fused), 4 coccygeal (fused)
 - L4 (or L4-5 interspace) – Tuffier's line drawn between superior iliac crests
 - In pregnancy, Tuffier's line may instead cross L3-4 interspace due to pelvic rotation
- Ligaments (5)
 - Ligamentum nuchae (above T7)/supraspinous ligament (T7 to sacrum), interspinous ligament, R+L ligamentum flava (foramen magnum to sacral hiatus), anterior longitudinal ligament, posterior longitudinal ligament
- Epidural space
 - Boundaries: foramen magnum (sup), sacral hiatus/sacrococcygeal ligament (inf), posterior longitudinal ligament (ant), pedicles/intervertebral foramina (lat), ligamentum flavum/lamina (post)
 - Contains nerve roots, veins, arteries, lymphatics
- Meninges
 - Dura mater
 - Extends from foramen magnum to S2 and along spinal nerve roots
 - Mostly acellular; composed of collagen and elastin, inner edge highly vascular
 - Subdural space – potential space b/w dura and arachnoid; subdural injection occurs in 0.82% of intended epidural injections and up to 10% of intended subarachnoid injections; injection into this space can produce total spinal
 - Arachnoid mater
 - Avascular membrane composed of cells and connective tissue
 - Principal barrier to drugs crossing in and out of CSF
 - Arachnoid granulations penetrate through dura into epidural space
 - Subarachnoid space – lies b/w arachnoid and pia; contains CSF, spinal nerves, blood vessels, dentate ligaments; ends at S2 in adults vs S3-4 in neonates
 - Pia mater
 - Adherent to spinal cord
 - Highly vascular, composed of connective tissue and collagen
 - Filum terminale is an extension of pia mater beginning at conus medullaris
- CSF
 - Composed of electrolytes, protein, glucose, neurotransmitters and their metabolites, nucleotides, amino acids, etc; produced by ultrafiltration of plasma in choroid plexus and capillaries, and glucose oxidation which produces water as a byproduct
 - CSF produced at a rate of 20-25cc/hr and absorbed through arachnoid villi in superior sagittal sinus and spinal nerve roots; entire CSF volume replaced q6h, volume of 100-160cc present at any one time
 - Spinal CSF continuous w/ cranial CSF
- Spinal cord
 - Vertebral column lengthens more than spinal cord with growth → termination of spinal cord:
 - Fetus (first trimester) – spinal cord extends from foramen magnum to end of sacrum
 - Birth – spinal cord ends at L3
 - Adult – spinal cord ends at L1 in 60% (vs T12 in 30% and L3 in 10%)
 - Spinal cord gives rise to 31 pairs of spinal nerves, each composed of anterior motor root and posterior sensory root
 - Cervical – spinal nerves exit in foramen above their corresponding vertebra
 - Thoracic/lumbar – spinal nerves exit in foramen below their corresponding vertebra
 - Cauda equina – nerves that extend beyond end of spinal cord and end at S2
 - Preganglionic sympathetic neurons
 - Cell bodies located in intermediolateral gray matter of T1-L2 spinal cord segments
- Differential sensitivity of nerve fibers
 - Onset and recovery of sensory fibers occurs in the following order
 - First blocked, last to recover – C fibers
 - Second blocked, second to recover – A δ
 - Last blocked, first to recover – A β
 - Preganglionic sympathetic fibers (B fibers) are most sensitive to LA
 - Loss of cold-temperature discrimination (C-fiber and sympathetic fibers) occurs 2-4 spinal segments above level of pinprick (A δ) sensory blockade, which occurs 1-2 segments higher than level of anesthesia to light touch (A β)
 - Motor block (A α) occurs 2-4 segments lower than level of sensory anesthesia
- Level of spinal anesthesia required for common surgical procedures (Cousins Table 10-9)

Level	Surgical procedure
T4-5 (nipple)	Upper abdominal surgery, cesarean section
T6-8 (xiphoid)	Intestinal surgery (also appendectomy, gynecologic pelvic surgery, renal surgery)
T10 (umbilicus)	Transurethral resection, hip surgery, hernia surgery
T12	Thigh tourniquet
L1 (inguinal ligament)	Knee surgery, lower limb amputation
L2-L3 (below knee)	Foot surgery
S2-S5	Perineal surgery, hemorrhoidectomy

INDICATIONS

- Surgery in lower abdomen, perineum, lower extremities
- Use as an adjunct to allow a lighter GA

CONTRAINDICATIONS

- Absolute
 - Patient refusal despite adequate information
 - Inability for patient to remain still during procedure
 - Inadequate training or experience with spinal anesthesia
 - Dermatologic conditions that preclude aseptic skin preparation
 - Infection at puncture site
 - Frank coagulopathy (epidural hematoma)
 - Shock or severe hypovolemia (hypotension)
 - Raised ICP (risk of brain herniation when CSF lost through needle, or if further increase in ICP occurs with injection of large volume solution)
 - Allergy to local anesthetics
- Controversial (absolute vs relative)
 - Mild or isolated abnormality in blood coagulation (epidural hematoma)
 - Systemic infection – septicemia, bacteremia (meningitis)
- Relative (assess risk/benefit on individual basis)
 - Spinal column deformities
 - Preexisting disease of spinal cord
 - Chronic headache or backache
 - Certain cardiac diseases (eg: severe AS)
 - Tattoo on the back
 - Inability to achieve a spinal tap in 3 attempts

BENEFITS

- Consciousness maintained – pt preference or required by medical condition
- Avoidance of airway manipulation
- Less impact on respiratory function
- Diminished risk of N/V and aspiration
- Blunt stress response to surgery
- Decrease intraop blood loss
- Reduce incidence of postop thromboembolism
- Reduce morbidity and mortality in high risk surgical patients
- Provide analgesia
 - Postop (superior to parenteral opioids)
 - Outside of surgical setting

RISKS

- Complications (see below)
- Failure of technique

COMPARED TO EPIDURAL

- More rapid onset (disadvantage = more HD instability)
- Lower drug doses = less systemic absorption
- Lower risk of systemic toxicity (eg: in event of intravascular injx)
- Higher incidence and severity of pruritus with intrathecal opioid
- Single shot (unless use spinal catheter); unable to extend period of analgesia

PREPARATION

- **Drugs**
 - Standard emergency drugs, sedation, LA, opioid, adjuvants
- **Monitors**
 - Standard CAS monitors
- **Equipment**
 - Airway and resuscitation equipment immediately available
 - Skin prep solution
 - All antiseptic solutions are neurotoxic; avoid contaminating spinal needles or LA solutions
 - Chlorhexidine-alcohol prevents colonization better than povidone-iodine
 - Plastic drapes, syringes
 - Needles

- Cutting tip/aperture on end (Quincke) – more readily deflected, higher risk PDPH
- Pencil-point tip/aperture on side (Whitacre, Sprotte) – lower risk PDPH
- Smaller diameter (higher gauge) needles – lower risk PDPH
- Stylet prevents needle from being occluded by skin/fat, prevents dragging skin into epidural or intrathecal space where it may grow and form dermoid tumors
- Introducer
 - Inserted into interspinous ligament, prevents deflection of smaller needles w/in the ligament

TECHNIQUES

- **Positioning**
 - **Lateral decubitus**
 - Operative side down for hyperbaric LA; operative side up for hypobaric LA
 - Knee-chest position with neck flexed to spread spinous processes apart
 - Avoid interspaces above L2-3
 - **Sitting**
 - Helpful when low lumbar/sacral levels of sensory anesthesia adequate for surgery (perineal or urologic procedures); maintain sitting for 5min after LA injection
 - Midline more readily identified in setting of obesity or scoliosis; place supine immediately after LA injection, manipulate table to achieve desired block height
 - **Prone**
 - Selected when required for surgery (eg: rectal, perineal, lumbar)
 - Consider paramedian approach, may need to aspirate for CSF (against gravity), use hypobaric LA solution
- **Needle insertion**
 - **Midline**
 - Insert needle with 10-15° cephalad angulation
 - Path of needle: subcutaneous tissue → supraspinous ligament → interspinous ligament → ligamentum flavum → epidural space → dura mater → arachnoid mater
 - For needles smaller than 26g typically requires 5-10sec for CSF to appear at hub (may require >60sec in some pts)
 - If feel 'pop' but no CSF – turn needle 90° (obstructed nerve root), advance 1-2mm if using pencil-point (tip may be w/in intrathecal space while aperture remains outside intrathecal space)
 - If bone encountered – reposition/redirect needle (see Barash p. 933)
 - If paresthesia – determine if tip encountered nerve root in epidural vs subarachnoid space; stop advancing, remove stylet (? CSF), if not intrathecal redirect needle to side opposite paresthesia
 - Once in subarachnoid space, aspirate CSF and slowly inject LA (0.2-0.5mL/sec), aspirate/reinject CSF at end of injection then remove needle/introducer
 - Following block placement, reposition patient and monitor hemodynamic status closely, assess block height with pin prick and temperature sensation; if block not rising high enough or rising too high, tilt table as indicated
 - **Paramedian**
 - Useful when anatomy does not favor midline approach (inability to flex spine, heavily calcified interspinous ligaments)
 - Insert needle 1cm lateral and 1 cm caudad to superior spinous process of desired interspace, angle needle 45° cephalad with 10-15° medial angulation
 - Path of needle: subcutaneous tissue → ligamentum flavum → epidural space → dura mater → arachnoid mater
 - Bone encountered prior to ligamentum flavum is usually the vertebral lamina of cephalad vertebra (repeated contact with periosteum is painful)
 - Alternatively, insert needle with goal of identifying lamina and walk needle off superior edge of lamina into subarachnoid space
 - **Lumbosacral**
 - Same technique as paramedian although carried out at L5-S1 interspace
- **Catheter insertion**
 - For continuous spinal anesthesia; insert catheter 2-3 cm into subarachnoid space
 - Do not withdraw catheter back into needle; risk of shearing
 - Catheter size
 - Traditionally 20g catheter via 18g epidural needle; high rates of PDPH
 - 24-32g reduces risk of PDPH however area associated with neurologic injury including
 - FDA advises against using catheters smaller than 24g
 - Allows repeated drug administration to extend level or duration of spinal block
 - Top up – administer ½ of original dose of LA once block has reached 2/3 of its expected duration
- **Management**
 - First 5-10 min are most critical in adjusting level of anesthesia when hyper/hypobaric solutions used
 - Also, if no sensory or motor block after 10min, the injection was not intrathecal
 - First 10-20 min most critical in assessing CV responses
 - Consider anxiolytic/sedation, O2 by nasal prongs only necessary if sedation employed

PHARMACOLOGY

1. LOCAL ANESTHETICS

- Short-acting LA (duration < 90min) – procaine, lidocaine, mepivacaine
- Long-acting LA (duration > 90min) – tetracaine, bupivacaine, levobupivacaine (S), ropivacaine
- Chlorprocaine, plain bupivacaine, plain lidocaine, hydromorphone, fentanyl and sufentanil are not specifically approved for spinal anesthesia; their use off-label although routinely administered
- Pregnant pts require smaller doses of spinal LA than nonpregnant pts
- Side effects – hypotension, bradycardia, urinary retention

2. OPIOIDS

- Provide synergistic analgesia in combination with la
- Side effects – pruritus, nausea/vomiting, delayed gastric emptying, urinary retention, respiratory depression

BLOCK DETERMINANTS

- **Uptake**
 - Diffusion into nerve roots and spinal cord
- **Block height**
 - Baricity of LA relative to positioning most important determinant of block height
 - Direction of spinal needle opening affects block height
 - Drug dose – affects block height only at extreme low end of usual dose range for bupivacaine
 - Drug volume and concentration *have no effect on block height when dose is held constant*
 - Injection site – affects block height for isobaric solutions but not for hyperbaric solutions; less spread at lower injection sites
 - Speed of injection and barbotage *have no effect*
 - Patient characteristics
 - Age – increasing age results in higher block (also faster onset/longer duration)
 - Extremes of height – very tall = lower block height
 - BMI may have a minor effect – higher block height in obesity (abdominal mass compresses CSF)
 - Volume of CSF – greater spread with low CSF volume
- **Block onset**
 - BMI
 - Drug – lidocaine and mepivacaine produce faster peak block height (10-15min) compared to tetracaine and bupivacaine (>20min)
- **Block duration**
 - Block recedes gradually from most cephalad dermatome to most caudad
 - Elimination of drug from intrathecal space occurs by vascular absorption through vessels in pia and epidural space; no intrathecal metabolism
 - Drug – choice of LA is most important determinant of block duration; procaine shortest acting, lidocaine and mepivacaine intermediate acting, bupivacaine and tetracaine longest acting
 - Drug dose – higher dose increases duration of block
 - Baricity – plain solutions have a longer duration of action than hyperbaric solutions
 - Block height – higher blocks regress faster than lower blocks when dose held constant
 - Adrenergic agonists prolong duration and increase density of sensory and motor block
 - Effectiveness depends on LA with which they are combined and location of block
 - Epinephrine 0.2-0.5mg, phenylephrine 2-5mg, clonidine 75-150mg intrathecal
 - At max doses phenylephrine more effective than epinephrine
 - At lower doses, phenylephrine and epinephrine equally effective
 - Clonidine as effective as phenylephrine and epi although more hypotension (oral clonidine also prolongs spinal block)
 - Local anesthetic
 - Tetracaine – duration most dramatically prolonged by adrenergic agonists (phenylephrine > epi > clonidine)
 - Bupivacaine – clonidine ≥ epi has minor effect on duration, phenylephrine no effect
 - Lidocaine – adrenergic agonists may prolong lumbar/sacral block
 - Location of block
 - Adrenergic agonists more effective in prolonging lumbar/sacral block than thoracic
 - α₂-agonists
 - Clonidine intrathecal intensifies and prolongs sensory and motor block, also potentiates opioids, decreases shivering
 - Side effects – hypotension, bradycardia, sedation
 - Cholinergics
 - Neostigmine induces analgesia by inhibiting breakdown of ACh, and promoting NO release in spinal cord
 - Side effects – nausea, prolongation of motor block

PHYSIOLOGIC EFFECTS

1. CNS

- Sedation – block afferent input
- Hypothermia – vasodilation, impaired central thermoregulatory control

1. CV

- Sympathectomy
 - Venodilation effect predominates
 - Arterial dilation → ↓SVR 15%
 - Bradycardia – blockade of cardioaccelerator fibers (T1-T4)
- Myocardial O₂ supply-demand balance unchanged

2. RESP

- Small ↓ in vital capacity and expiratory capacity
- No change in tidal volume or inspiratory capacity
- Respiratory arrest from hypoperfusion of brainstem respiratory centers

3. GI

- Hyperperistalsis – unopposed parasympathetic/vagal activity
- ↓Hepatic blood flow 10% (minimal significance)

4. RENAL

- ↓RBF during neuraxial block of little physiologic importance
- Urinary retention

COMPLICATIONS

- **Failure of technique**
- **Backache**
 - Incidence 11% (vs 30% for epidural)
 - Note: 25% of all surgical patients undergoing anesthesia experience back pain regardless of technique (GA or neuraxial)
 - Mechanism – needle trauma, LA irritation, ligamentous strain from muscle relaxation
 - Presents w/ short term back pain; *no* relationship b/w neuraxial anesthesia and long-term back pain
- **Postdural puncture headache**
 - Definition (ICHD-II criteria)
 - Headache onset within 5 days of dural puncture, and occurring w/in 15 min of moving to upright position and resolving w/in 15 min of moving to supine position
 - One of the following symptoms must be present: nausea, neck stiffness, vomiting, ocular symptoms (photophobia, diplopia), auditory symptoms (tinnitus, hypacusis, hearing loss)
 - Incidence from 0.2-25% following dural puncture with spinal needle
 - Incidence ~52% following accidental dural puncture with large-diameter epidural needle
 - Mechanism
 - Loss of CSF through meningeal hole, ↑CBF as a compensatory mechanism for low CSF pressure or volume
 - Risk factors
 - Hx of PDPH
 - Age – most common age <40 y; uncommon age >60 y
 - Gender – 2F:1M
 - Body habitus – morbidly obese are *less* susceptible to PDPH
 - Vaginal delivery – expulsive forces, hormonal changes in cerebrovascular reactivity
 - Air travel
 - Neuraxial anesthetic technique
 - Multiple dural punctures
 - Needle design – ↑risk with cutting tip needles compared to pencil-point
 - Needle size – ↑risk with large diameter needles
 - Direction of bevel – ↑risk with bevel perpendicular to long axis of spine vs parallel
 - Hyperbaric LA
 - Controversial risk factors – midline vs paramedian approach, air vs saline for LOR
 - No impact on risk of PDPH – use of spinal catheter, CSE, lying supine following meningeal puncture/timing of ambulation
 - Prevention
 - Use noncutting small gauge spinal needles
 - Insert cutting needle w/ bevel parallel to long axis of meninges (parallel insertion spreads dural fibers, perpendicular insertion cuts the fibers resulting in larger meningeal hole; also, dura is under longitudinal tension so perpendicular hole pulled open whereas parallel hole pulled closed)
 - Following dural tap with epidural needle – risk of PDPH up to 90% in obstetric population
 - Beneficial – avoid dehydration, insertion of catheter into intrathecal space for 24h (↓risk to 6%), early ambulation,
 - Prophylactic blood patch ↓s duration of PDPH but not incidence; must delay until residual neuroblockade has resolved, avoid intrathecal injection of blood
 - May be beneficial, requires further study – abdominal binder, intrathecal opioid, intrathecal saline prior to needle withdrawal, prophylactic dextran patch
 - No impact on incidence of PDPH – greater hydration, bed rest, caffeine
 - Clinical presentation
 - Onset 3-72hrs after dural puncture
 - Rapid onset bifronto-occipital headache, mild to incapacitating
 - Posture-dependent – HA mild/absent when supine, aggravated when upright or coughing
 - Associated Sx
 - Common – N/V, neck stiffness, photophobia, diplopia, tinnitus, low freq hearing loss
 - Rare – seizures, abdominal pain, diarrhea
 - Duration – usually resolves spontaneously in a few days to a week (may persist months)
 - Differential diagnosis
 - Primary HA – tension headache, migraine, cluster headache, trigeminal autonomic cephalgia
 - Secondary HA – MSK, preeclampsia/eclampsia, PDPH, pneumocephalus, cortical vein thrombosis, SAH, SDH, CVA, brain tumor, pseudotumor cerebri, spontaneous intracranial hypotension, posterior reversible leukoencephalopathy, sinusitis, meningitis, caffeine withdrawal, fasting, lactation headache
 - Treatment
 - Conservative
 - Psychosocial support
 - Bed rest, prone position
 - Avoid dehydration – maintain fluid intake >3L/day
 - Pharmacologic
 - Analgesics
 - Cerebral vasoconstrictors – caffeine (transient benefit), theophylline
 - Sumatriptan – caution, may cause coronary vasospasm

- **Hemodynamic instability**
 - Physiologic consequence of sympathectomy – hypotension, bradycardia, cardiac arrest
- **High spinal anesthesia**
 - Spread of LA high enough to block entire spinal cord and occasionally brainstem
 - Profound hypotension and bradycardia (sympathetic blockade), respiratory arrest (respiratory muscle paralysis or dysfunction of brainstem respiratory control centers)
 - Management – supportive (vasopressors, atropine, fluids, O₂, mechanical ventilation)
- **Insufficient duration**
 - Need for iv supplementation vs rapid conversion to GA/airway management

CRITERIA FOR DISCHARGE FROM PARR

- Inpatients
 - Block receding appropriately (at least 4 dermatome regression) or spinal level < T10
 - Hemodynamically stable
 - Comfortable
- Outpatients
 - Ability to ambulate without orthostatic changes
 - Ability to void *if* in high-risk group for urinary retention

REFERENCES

- Barash Chapter 37
- Miller Chapter 51
- Cousins Chapter 10
- Chestnut Chapter 12, 23, 26, 31