
Spinal Anesthesia: Techniques And Complications

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Abstract

Spinal anesthesia is a neuraxial technique involving the injection of local anesthetic into the subarachnoid space to produce reversible sensory, motor, and sympathetic blockade. It is widely used for surgeries below the umbilicus, including lower abdominal, pelvic, perineal, lower extremity, and obstetric procedures. Despite its advantages, such as rapid onset and effective anesthesia, complications may include hypotension, bradycardia, high or total spinal, post-dural puncture headache (PDPH), neurological complications, hematoma, and infection. Therefore, appropriate patient selection, procedural technique, monitoring, and complication prevention are essential. This final assignment employed a literature review by examining relevant sources on spinal anesthesia, including anatomy and physiology, indications and contraindications, patient and equipment preparation, anesthetic agents and adjuvants, techniques, factors affecting block spread, monitoring, complications, prevention, and recent developments. The literature was descriptively analyzed to provide an overview of the clinical application and safety of spinal anesthesia. Spinal anesthesia is effective for various surgical procedures, with outcomes influenced by patient characteristics, drug selection, puncture technique, and anesthetic spread. Bupivacaine is commonly used, with anesthetic agents and adjuvants selected according to the desired block characteristics. Prevention of complications includes proper patient evaluation, atraumatic puncture, ultrasound guidance when appropriate, antithrombotic management, hemodynamic monitoring, and aseptic techniques. Recent developments include pencil-point needles, neuraxial ultrasound, intrathecal adjuvants, and unilateral spinal anesthesia. Safe spinal anesthesia requires appropriate preparation, technique, drug selection, monitoring, and early recognition and prevention of complications.

Keywords: Spinal Anesthesia, Neuraxial Anesthesia, Techniques, Complications.

INTRODUCTION

Stress and anxiety disorders represent continuously increasing global mental health issues, particularly among adolescents and young adults. Data from the Global Burden of Disease indicate that the prevalence of anxiety disorders has experienced a significant increase over the past few decades. Physiologically, chronic stress triggers dysregulation within the central nervous system, where an elevated activity of the Monoamine Oxidase-A (MAO-A) enzyme plays a detrimental role. MAO-A is an outer mitochondrial membrane-bound enzyme responsible for the oxidative deamination of monoamine neurotransmitters, including serotonin, dopamine, and norepinephrine. Excessive catabolism mediated by overactive MAO-A leads to a substantial depletion of these neurotransmitters within synaptic clefts, directly contributing to the onset of depression, anxiety disorders, and chronic psychological stress. Consequently, the selective and reversible inhibition of MAO-A activity serves as a primary pharmacological target and a strategic therapeutic avenue in the development of modern antistress and antidepressant therapies.

In recent years, the exploration of natural products for neuroprotective and psychotherapeutic agents has gained immense momentum. Indonesia possesses abundant tropical biodiversity and natural resources with immense potential to be developed as novel drug candidates, one of the most prominent being turmeric (*Curcuma longa*). Turmeric has long been utilized in traditional medicine systems and contains a vast array of secondary metabolites such as curcuminoids, monoterpenoids, and sesquiterpenoids which have been widely reported to possess broad biological activities, including antioxidant, anti-

inflammatory, and neuroprotective properties. Despite its traditional efficacy, evaluating the exact molecular mechanisms of dozens of individual constituents through conventional wet-lab experimentation remains exceptionally resource-intensive, time-consuming, and costly.

To overcome these limitations, Computer-Aided Drug Design (CADD) approaches specifically in silico molecular docking methodologies combined with robust pharmacokinetic (ADME) and toxicity predictions provide a highly efficient, rapid, and mechanistic strategy for evaluating the therapeutic potential of natural compounds at the molecular level. Molecular docking allows researchers to visualize and quantify the binding orientation, interaction energies, and affinity of phytochemical ligands within the active catalytic pocket of target macromolecules. Furthermore, computational ADME-Tox profiling ensures that prospective drug molecules possess acceptable drug-likeness, high oral bioavailability, favorable blood-brain barrier permeability, and minimal toxicity risks prior to synthesis. Building upon this technological framework, this study aims to comprehensively analyze the therapeutic potential of 70 secondary metabolites derived from *Curcuma longa* as target inhibitors against the MAO-A enzyme in silico, evaluate their comprehensive drug-likeness, ADME profiles, and toxicological safety parameters, and execute rational structural modifications on the selected lead candidate to obtain an optimized, safer, and highly efficacious antistress agent.

RESULTS AND DISCUSSION

Spinal Anesthesia

Definition

Spinal anesthesia is a neuraxial anesthesia technique in which local anesthetic is injected into the subarachnoid space containing cerebrospinal fluid (CSF). Intrathecal administration temporarily blocks nerve impulse transmission, producing reversible sensory, motor, and sympathetic blockade. Unlike epidural anesthesia, the needle penetrates the dura mater and arachnoid to reach the subarachnoid space (Olawin & Das, 2022).

Indications for Spinal Anesthesia

Spinal anesthesia is commonly used for surgery involving the lower abdomen, pelvis, perineum, and lower extremities, including cesarean section. It may also be used for ambulatory surgery, provided that the duration of the block is sufficient for surgery without unnecessarily delaying mobilization and discharge (Olawin & Das, 2022; Rattenberry et al., 2019).

Patient suitability should consider:

1. Surgical site and requirements: The block must adequately cover the operative area and tissue or organ manipulation (Olawin & Das, 2022).
2. Expected surgical duration: The duration of surgery should correspond to the duration of the local anesthetic, particularly with single-shot techniques (Rattenberry et al., 2019).
3. Clinical condition: Comorbidities, hemodynamic status, intravascular volume, and neurological status should be assessed (Olawin & Das, 2022).
4. Contraindications: Medication history, coagulation disorders, and infection should be evaluated before the procedure (Olawin & Das, 2022).
5. Consent and patient cooperation: Patients should understand the benefits, risks, and alternatives and be able to maintain the required position during the procedure (Olawin & Das, 2022).
6. Postoperative recovery plan: Drug selection and dosage should support appropriate sensory and motor recovery, particularly for ambulatory surgery (Rattenberry et al., 2019).

Contraindications

Contraindications may be classified as absolute or relative and should be assessed through history, physical examination, and appropriate investigations (Olawin & Das, 2022; NYSORA, n.d.).

Absolute contraindications

- a. Patient refusal: Spinal anesthesia should not be performed when a patient refuses the procedure after receiving appropriate information (NYSORA, n.d.).
- b. Infection at the puncture site: Needle insertion through infected tissue may introduce microorganisms into deeper structures, including the subarachnoid space (Olawin & Das, 2022).
- c. Uncorrected severe hypovolemia: Sympathetic blockade may worsen venous return and hypotension in patients with severe intravascular volume depletion (NYSORA, n.d.).
- d. Allergy to the intended medication: Confirmed allergy to local anesthetics or planned intrathecal drugs contraindicates their use (NYSORA, n.d.).
- e. Raised intracranial pressure due to a space-occupying lesion: Dural puncture may alter pressure gradients and increase the risk of cerebral herniation (Olawin & Das, 2022).

Relative contraindications

- a. Systemic infection or sepsis: Hemodynamic status, infection treatment, and response to therapy should be considered, particularly in hemodynamically unstable patients (NYSORA, n.d.).
- b. Cardiac disease limiting increases in cardiac output: Severe aortic stenosis or left ventricular outflow obstruction may be poorly tolerated because sympathetic blockade reduces vascular resistance and venous return (Olawin & Das, 2022).
- c. Pre-existing neurological disease: Progressive or unexplained neurological disorders require careful evaluation and documentation of baseline neurological status (Olawin & Das, 2022).

Coagulation disorders and antithrombotic therapy

Coagulopathy and the use of anticoagulants or antiplatelet drugs require careful assessment because of the risk of neuraxial hematoma. Eligibility should consider the specific medication, dose, timing of the last dose, renal function, and relevant laboratory results. Recommended intervals before neuraxial puncture vary according to the medication and should follow appropriate guidelines (NYSORA, n.d.; Pressler et al., 2025).

Patient and Equipment Preparation

Preparation includes pre-anesthetic evaluation, informed consent, fasting assessment, intravenous access, monitoring, and preparation of equipment and medications.

1. Pre-anesthetic evaluation: Assessment includes comorbidities, previous anesthesia, allergies, bleeding disorders, antithrombotic medication, cardiovascular and respiratory status, hydration, spinal anatomy, infection, and baseline neurological status. Laboratory tests such as complete blood count, renal function, and coagulation studies should be performed when clinically indicated rather than routinely in every patient (Olawin & Das, 2022; National Institute for Health and Care Excellence [NICE], 2016).
2. Information and consent: Patients should be informed about the procedure, benefits, risks, alternatives, possible awareness during surgery, and temporary numbness or weakness of the lower extremities (Olawin & Das, 2022).
3. Preoperative fasting: For healthy patients undergoing elective surgery, ASA guidelines recommend at least 2 hours for clear liquids and 6 hours for light meals, while fatty foods, fried foods, or meat generally require 8 hours or more. Requirements should be individualized in patients at increased aspiration risk or undergoing emergency surgery (American Society of Anesthesiologists [ASA], 2017).

4. Intravenous access and initial monitoring: Intravenous access should be established before the procedure. Baseline blood pressure, heart rate, and oxygen saturation should be recorded and monitored throughout anesthesia (Olawin & Das, 2022).
5. Equipment and medications: Required equipment includes spinal needles, introducers when needed, syringes, sterile gauze and drapes, sterile gloves, masks, skin antiseptics, local anesthetics, and appropriate intrathecal preparations. Medication identity, concentration, dose, and expiration date should be verified. Standard monitors, oxygen, ventilation and airway equipment, and drugs for treating hypotension and bradycardia should be immediately available. A time-out should verify patient identity, procedure, consent, and team readiness (NYSORA, n.d.; Olawin & Das, 2022).

Drugs Used

Local anesthetics are the primary drugs used in spinal anesthesia. They reversibly inhibit voltage-gated sodium channels, blocking nerve impulse transmission and producing sensory, motor, and sympathetic blockade (Hermanns et al., 2022).

Bupivacaine is a commonly used amide local anesthetic because of its relatively long duration. However, prolonged motor recovery may limit its use in ambulatory surgery. It is available in isobaric and hyperbaric formulations; the addition of glucose increases solution density and makes its distribution more dependent on gravity and patient position (Rattenberry et al., 2019).

Other local anesthetics include prilocaine, chlorprocaine, mepivacaine, levobupivacaine, and ropivacaine. Prilocaine and chlorprocaine may provide faster recovery, with chlorprocaine particularly suitable for short procedures. Lidocaine has a relatively short duration but is limited by the risk of transient neurological symptoms (TNS) (Rattenberry et al., 2019).

Local anesthetics may be combined with opioid adjuvants such as fentanyl and morphine. Fentanyl has rapid onset and shorter duration, whereas morphine provides longer analgesia but may cause pruritus, nausea, and delayed respiratory depression (Hermanns et al., 2022).

Non-opioid adjuvants, including clonidine and dexmedetomidine, may prolong blockade and analgesia but can increase the risk of hypotension, bradycardia, and sedation. Some intrathecal adjuvants remain off-label and therefore require consideration of safety evidence, formulation suitability, and patient condition (Hermanns et al., 2022).

Spinal Anesthesia Technique

Spinal anesthesia is generally performed at the lumbar intervertebral spaces, particularly L3–L4 or L4–L5, to reduce the risk of spinal cord injury. Patients may be positioned sitting or laterally with appropriate spinal flexion. The choice of position depends on patient condition, anatomical landmarks, and the intended spread of the block (Olawin & Das, 2022).

An aseptic technique is essential, including hand hygiene, sterile gloves and mask, sterile drapes, and appropriate skin antiseptics. The antiseptic solution should be allowed to dry completely and kept away from the needle and intrathecal drugs to prevent contamination and potential neurotoxic exposure (Azi et al., 2020).

The midline approach is commonly used. After local infiltration, the spinal needle passes through the skin, subcutaneous tissue, supraspinous and interspinous ligaments, ligamentum flavum, epidural space, dura, and arachnoid to reach the subarachnoid space. Correct placement is confirmed by free flow of CSF after removal of the stylet (Olawin & Das, 2022).

The paramedian approach may be useful when midline access is difficult, such as in degenerative spinal changes or limited flexion. Preprocedural ultrasound can assist in

identifying the intervertebral space, estimating depth, and planning needle direction in patients with difficult anatomical landmarks (Poots & Chin, 2024).

Once intrathecal placement is confirmed, the drug is injected slowly. Pain or paresthesia during injection requires cessation and reassessment of needle position. After injection, patient positioning is adjusted according to the procedure and characteristics of the solution. Sensory and motor blockade, hemodynamics, and respiration should be assessed before surgery (Olawin & Das, 2022).

Factors Affecting Block Spread

The spread of local anesthetic within CSF determines the extent of neural blockade. Block height is influenced by solution characteristics, patient position, injection technique, and patient anatomy and physiology (Hermanns et al., 2022).

Baricity and patient position are important interacting factors. Hyperbaric solutions tend to move toward dependent areas under gravity, whereas hypobaric solutions move toward nondependent areas. Isobaric solutions are less affected by gravity. Therefore, patient position and spinal curvature influence drug distribution (Hocking, 2006).

Dose, volume, and concentration also influence block characteristics. Increasing the dose may increase block duration and spread, although the relationship is not always linear. These variables should therefore be considered together (Hocking, 2006).

Lumbosacral CSF volume contributes to interindividual variation. A smaller CSF volume is associated with wider sensory spread because the drug is distributed within a smaller fluid volume. However, CSF volume cannot be accurately predicted solely from height or body weight (Imbelloni, 2014).

Age, pregnancy, spinal anatomical changes, puncture site, needle orientation, and injection speed may also affect block characteristics. Pregnancy may increase anesthetic effects because of neuraxial anatomical changes and increased neural sensitivity. Since these effects vary among patients, block height should be assessed directly after drug administration (Hocking, 2006; Hermanns et al., 2022).

Block Assessment and Monitoring

Block assessment should be performed before surgery to ensure adequate anesthesia. Sensory and motor blockade should be evaluated bilaterally, with the required sensory level determined by the surgical procedure. Cold, pinprick, and light-touch testing may produce different block levels and should therefore be clearly documented. For cesarean delivery, loss of light-touch sensation to approximately T5 or higher, together with motor assessment, is recommended (Plaat, 2022).

Motor blockade can be assessed using lower-limb movement, the Bromage scale, or straight-leg raising. Motor weakness alone does not confirm adequate sensory anesthesia. If the block is inadequate or the patient experiences pain during surgery, anesthesia should be reassessed and additional analgesia or conversion to general anesthesia considered according to clinical circumstances (Plaat, 2022).

Monitoring during spinal anesthesia includes oxygenation, ventilation, circulation, and temperature when indicated. Electrocardiography should be continuous, while blood pressure and heart rate should generally be assessed at least every five minutes. Pulse oximetry should be used to monitor oxygenation, and qualified anesthesia personnel should remain present throughout the procedure (American Society of Anesthesiologists [ASA], 2025).

In patients without sedation or with minimal sedation, ventilation can be assessed continuously through clinical observation of chest movement and breathing patterns. During moderate or deep sedation, exhaled carbon dioxide monitoring should be considered in addition to clinical observation. Temperature should be monitored when clinically indicated (ASA, 2025).

Postoperatively, recovery assessment should include regression of sensory and motor blockade, hemodynamic stability, pain, nausea, and urinary retention. Mobilization should occur after adequate recovery of motor function and balance. For ambulatory surgery, discharge should be based on functional recovery, clinical condition, and established discharge criteria rather than simply the completion of surgery (Rattenberry et al., 2019).

Complications of Spinal Anesthesia

Hemodynamic Complications

Hypotension is a common complication of spinal anesthesia. Sympathetic blockade causes arterial and venous dilation, reducing systemic vascular resistance and venous return, which may decrease stroke volume and cardiac output. The severity depends on the extent of sympathetic blockade and the patient's cardiovascular compensatory capacity, particularly in older adults (Ferré et al., 2020). Hypotension is often defined as a systolic blood pressure below 80% of baseline, although its clinical significance also depends on the magnitude and duration of the decrease and the patient's condition (Ferré et al., 2020).

Bradycardia results from reduced sympathetic activity and increased parasympathetic dominance. High thoracic blockade may inhibit cardiac accelerator fibers, while reduced venous return may trigger cardioinhibitory reflexes such as the Bezold–Jarisch reflex. Severe bradycardia may rapidly progress to asystole and therefore requires prompt attention (Lacey et al., 2022). Risk factors include low baseline heart rate, beta-blocker use, vagotonic symptoms, high thoracic blockade, and hypovolemia. It may also occur in young and apparently healthy patients (Lacey et al., 2022).

Management aims to restore venous return and maintain organ perfusion through appropriate fluid therapy and vasopressors. Phenylephrine may be used for hypotension, while ephedrine may be considered when hypotension is accompanied by bradycardia. Significant bradycardia may require atropine, and cardiac arrest requires immediate resuscitation according to established protocols (Ferré et al., 2020; Lacey et al., 2022).

High Spinal and Total Spinal

High spinal refers to excessive cephalad spread of neuraxial blockade beyond the level required for surgery, potentially impairing cardiovascular and respiratory function. Total spinal represents a more severe form characterized by apnea, loss of consciousness, and circulatory collapse (Sivanandan & Surendran, 2019).

Causes include excessive intrathecal dosing, unexpected drug spread, or inadvertent intrathecal administration of an epidural dose. Particular caution is required when spinal anesthesia follows inadequate epidural analgesia. A Dutch national surveillance study reported that three of five cases of high neuraxial block requiring intubation occurred after spinal anesthesia for cesarean delivery in patients who had previously received labor epidural analgesia (Beenackers et al., 2024).

Clinical manifestations may develop rapidly and include hypotension, bradycardia, hand tingling or weakness, difficulty breathing or speaking, diaphragmatic dysfunction, apnea, and loss of consciousness. Management requires immediate support of the airway, oxygenation, ventilation, and circulation, including oxygen, assisted ventilation or intubation, intravenous fluids, and treatment of hypotension and bradycardia. In pregnant patients, left uterine displacement should be performed to reduce aortocaval compression (Sivanandan & Surendran, 2019).

Post-Dural Puncture Headache (PDPH)

Post-dural puncture headache (PDPH) is a complication following dural puncture during spinal anesthesia. According to the *International Classification of Headache Disorders, 3rd edition* (ICHD-3), PDPH develops within five days of dural puncture and is associated with CSF leakage through a dural defect. It commonly worsens when sitting or standing and improves when lying down, although postural characteristics are not always

present (Headache Classification Committee of the International Headache Society [IHS], 2018; Alatni et al., 2024).

PDPH results primarily from CSF leakage, causing reduced CSF volume and pressure, intracranial traction, and compensatory cerebral vasodilation. Symptoms may develop within hours to several days and may resolve spontaneously within approximately two weeks (Headache Classification Committee of the IHS, 2018; Alatni et al., 2024).

Risk factors include female sex, younger age, pregnancy, previous PDPH, and needle characteristics. Larger-gauge and cutting needles such as Quincke needles are associated with higher risk than atraumatic pencil-point needles such as Whitacre or Sprotte. Studies have also reported higher PDPH rates with 25-gauge compared with 27-gauge needles and with Quincke needles (Alatni et al., 2024; Aniceto et al., 2023).

Diagnosis is primarily clinical. Additional investigations are generally unnecessary in typical cases but should be considered when symptoms are atypical, progressive, associated with neurological deficits, seizures, altered consciousness, or fail to improve as expected. Differential diagnoses include subdural hematoma and cerebral venous thrombosis (Headache Classification Committee of the IHS, 2018; Alatni et al., 2024).

Mild PDPH may be managed conservatively with analgesics and clinical observation. Severe or persistent symptoms may require an epidural blood patch (EBP), which remains the main interventional treatment. EBP involves injection of autologous blood into the epidural space to help seal the CSF leak. Other pharmacological treatments and nerve blocks have also been investigated, although evidence varies (Alatni et al., 2024).

Neurological Complications

Neurological complications after spinal anesthesia are relatively uncommon but may have significant consequences. They can range from transient sensory symptoms to permanent neurological deficits and may result from mechanical trauma, local anesthetic neurotoxicity, ischemia, or other neuraxial factors (Radkowski et al., 2023; Pozza et al., 2023).

Transient neurological symptoms (TNS) are characterized by pain or discomfort, particularly in the buttocks, thighs, or legs, after spinal anesthesia wears off. Symptoms usually develop within several hours to 24 hours and resolve spontaneously within several days. TNS is classically associated with intrathecal lidocaine. A meta-analysis of 24 clinical trials involving 2,226 patients found lower TNS risk with bupivacaine, levobupivacaine, prilocaine, procaine, and ropivacaine compared with lidocaine, although evidence quality varied (Forget et al., 2019).

Direct neurological injury may result from mechanical trauma to nerve roots or the spinal cord, particularly in patients with abnormal anatomy, incorrect puncture-level identification, multiple attempts, or needle contact with neural structures. Severe pain or electric-shock sensations during needle insertion may indicate neural contact. Manifestations range from paresthesia and sensory disturbances to motor weakness and, rarely, permanent deficits (Pozza et al., 2023).

Neurological injury may also result from ischemia. Severe and prolonged hypotension can reduce spinal cord perfusion and potentially cause lower-extremity weakness or paraplegia. Neurological changes that do not correspond to normal regression of the block require urgent evaluation (Radkowski et al., 2023; Pozza et al., 2023).

Adhesive arachnoiditis is a very rare neurological complication involving chronic inflammation and adhesion of the arachnoid and nerve roots. Causes include infection, bleeding, trauma, and exposure to irritating substances. Symptoms may include radicular pain, paresthesia, sensory disturbances, and motor deficits. MRI can support diagnosis, particularly in persistent or progressive cases (Shimizu, 2022; Al-Mutairi et al., 2024).

Persistent or progressive neurological deficits, sphincter dysfunction, significant motor weakness, or severe back pain require prompt evaluation to identify potentially serious complications (Radkowski et al., 2023).

Hematoma and Infection

Neuraxial hematoma is a rare but potentially serious complication that can compress neural structures and cause neurological deficits. Risk increases with impaired hemostasis, certain anticoagulant or antiplatelet therapies, and traumatic or repeated puncture. Clinical manifestations include back pain, sensory or motor deficits, and bladder or bowel dysfunction (Kietaihl et al., 2022; Radkowski et al., 2023).

New or progressive neurological deficits after neuraxial anesthesia should raise suspicion of hematoma. MRI is the primary diagnostic modality, and significant neurological compression may require urgent decompression (Radkowski et al., 2023; De Cassai et al., 2020).

Neuraxial infection is rare and may present as meningitis or epidural abscess. Risk factors include procedural contamination, hematogenous spread, systemic infection, and impaired immunity. Meningitis may cause fever, headache, neck stiffness, and altered neurological status, whereas epidural abscess may cause back pain and neurological deficits (Gimeno & Errando, 2018; Pozza et al., 2023).

Diagnosis requires clinical assessment and appropriate investigations. MRI is important when an epidural abscess is suspected, while CSF examination may be considered for suspected meningitis. Treatment depends on the infection and patient's condition and generally includes antibiotics, with drainage or decompression when indicated (Bond & Manian, 2016).

Prevention of hematoma focuses on assessment of coagulation status and antithrombotic medication before neuraxial procedures, while infection prevention requires strict aseptic technique (Kietaihl et al., 2022; Gimeno & Errando, 2018).

Prevention of Complications

Prevention begins with comprehensive preprocedural assessment, including hemodynamic and neurological status, puncture-site infection, spinal anatomy, and anticoagulant or antiplatelet use. In patients receiving antithrombotic therapy, neuraxial anesthesia should consider the drug type and dose, timing of the last dose, and renal function according to applicable guidelines (Kietaihl et al., 2022; Olawin & Das, 2022).

Appropriate and atraumatic puncture technique is important for reducing complications. Optimal positioning and accurate identification of the intervertebral space improve procedural success. Pencil-point or atraumatic needles reduce the risk of PDPH compared with cutting needles. Ultrasound can assist with identifying the neuraxial space and estimating its depth in patients with difficult anatomical landmarks (Alatni et al., 2024; Makino et al., 2025).

Hemodynamic complications can be reduced through regular monitoring of blood pressure and heart rate and readiness to provide appropriate treatment. Fluids and vasopressors may be used to maintain blood pressure and organ perfusion according to the patient's hemodynamic response (Ferré et al., 2020).

Consistent aseptic technique is essential to reduce neuraxial infection. Hand hygiene, skin antisepsis, sterile gloves, masks, and appropriate sterile equipment should be used. After administration, monitoring should continue for hemodynamic changes, regression of sensory and motor blockade, and neurological symptoms to facilitate early detection of complications (Olawin & Das, 2022; Radkowski et al., 2023). For single-shot spinal anesthesia, recent consensus recommendations also emphasize appropriate aseptic practices according to procedural risk (Phillips et al., 2026).

Developments in Spinal Anesthesia Techniques and Drugs

Recent developments in spinal anesthesia include improvements in puncture techniques, needle design, neuraxial ultrasound, and intrathecal drugs and adjuvants. These developments aim to provide adequate and appropriately timed blockade, reduce complications, and accelerate recovery. Pencil-point needles are an important development because they cause less dural trauma and reduce PDPH risk compared with cutting needles (Pierson et al., 2025; Alatni et al., 2024).

Neuraxial ultrasound is increasingly used, particularly in patients with difficult anatomical landmarks. It can help identify the midline, estimate vertebral levels and neuraxial depth, and determine the optimal needle trajectory. A 2025 Cochrane review found that ultrasound may reduce the number of puncture attempts and needle insertion time compared with anatomical landmarks alone and may improve first-attempt success (Makino et al., 2025).

Drug development includes local anesthetics with different durations of action and intrathecal adjuvants. Bupivacaine remains widely used for procedures requiring relatively prolonged blockade, whereas shorter-acting agents may be selected when faster recovery is desired. Opioids and $\alpha 2$ -adrenergic agonists may improve and prolong analgesia, although their use must consider adverse effects and patient characteristics (Pierson et al., 2025).

Unilateral spinal anesthesia aims to produce a more restricted block on the operative side and may reduce the hemodynamic effects associated with extensive sympathetic blockade. A 2025 systematic review and meta-analysis reported lower rates of hypotension and vasopressor requirements with unilateral compared with bilateral spinal anesthesia; however, the overall certainty of evidence was low, requiring consideration of patient characteristics and surgical type (Gong et al., 2025).

CONCLUSION

Spinal anesthesia is a neuraxial anesthesia technique involving the intrathecal administration of local anesthetic into the subarachnoid space to produce reversible sensory, motor, and sympathetic blockade. This technique is primarily used for various surgical procedures below the umbilicus, with its success influenced by an understanding of anatomy and physiology, patient condition, drug type and dosage, puncture technique, and intraoperative monitoring. Appropriate patient selection and adequate preparation are essential for achieving effective and safe spinal anesthesia.

Complications of spinal anesthesia may include hemodynamic disturbances such as hypotension and bradycardia, high or total spinal anesthesia, post-dural puncture headache (PDPH), neurological complications, as well as hematoma and infection. Most complications can be prevented or minimized through adequate patient evaluation, appropriate and atraumatic puncture techniques, proper selection of drugs and doses, appropriate management of antithrombotic therapy, strict aseptic techniques, and optimal monitoring. Early recognition of complications is also essential to ensure prompt management.

The development of spinal anesthesia continues to include the use of more atraumatic needles, ultrasound as a procedural aid, the development of local anesthetic and adjuvant options, and techniques designed to produce more limited block spread. These developments aim to improve procedural success, safety, and the quality of patient recovery. With adequate anatomical knowledge, appropriate patient selection, proper technique, and effective monitoring, spinal anesthesia can be used safely and effectively according to surgical requirements.

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