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A Comprehensive, Review of Complications Associated with Spinal Anesthesia

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ABSTRACT

Spinal anesthesia (SA) is generally regarded as a safe technique, but it can cause side effects such as hypotension and bradycardia. Hypotension mainly results from sympathetic nerve blockade and vasodilation. Although elderly patients face a higher risk of hypotension and its complications, spinal anesthesia is more commonly used in this population. The incidence of hypotension in elderly patients is estimated to exceed 70%. Preventing hypotension in these patients poses a challenge, as the measures taken may increase the risk of hypervolemia or myocardial ischemia. Both hypotension and bradycardia can be triggered by the Bezold-Jarisch reflex (BJR); spinal anesthesia reduces preload, which activates the BJR, potentially via peripheral serotonin (5HT-3) receptors. These receptors are found on cardiac vagal afferents peripherally and in the central chemoreceptor trigger zone. Shivering frequently occurs during and after spinal anesthesia. Its exact cause is not well defined but likely involves several factors, such as altered thermoregulatory thresholds, decreased core body temperature, redistribution of body heat, and the cooling effect of fluids injected into the neuraxis. Although shivering causes significant discomfort, it also produces interference with monitoring equipment and elevates postoperative pain, heart rate, oxygen consumption, and metabolic rate. These effects can contribute to myocardial ischemia, hypoxemia, hypercarbia, and lactic acidosis.

KEYWORDS: *Spinal anesthesia, Hypotension, Bradycardia, Bezold-Jarisch reflex (BJR), Shivering.*

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1. General Introduction

Spinal anesthesia marked its first centennial in 1998 and continues to serve as a cornerstone of contemporary regional anesthesia. German physician August Bier pioneered the technique in 1898 by successfully administering cocaine for spinal anesthesia to his assistant Hildebrandt, whose case was the first published report; both experienced postdural puncture headaches (PDPH) afterward, possibly exacerbated by celebratory wine and cigars. Despite early claims of its safety for even head, neck, and thoracic surgeries with low mortality, tragic incidents like the 1950s Woolley and Roe cases where two patients developed paraplegia likely due to contaminated needles or syringes tarnished its reputation in places like the UK, nearly rendering it obsolete amid advances in inhalation anesthesia.

Large-scale studies in the 1950s, involving over 10,000 patients, reaffirmed spinal anesthesia's safety profile, demonstrating rare serious morbidity or mortality. Today, refined equipment, aseptic techniques, and pharmacological advancements have solidified its role as a cost-effective, versatile option in modern anesthesiology.

In the past decade, ambulatory and "fast-track" spinal anesthesia has surged for short-stay procedures, emphasizing minimal side effects and high patient satisfaction amid rising outpatient surgeries. Recent innovations include low-dose bupivacaine with opioids for tailored blocks, ultrasound-guided techniques to reduce PDPH (now <5% incidence with pencil-point needles), and prophylactic measures like intrathecal fentanyl to mitigate hypotension in elderly comorbid patients. These adaptations ensure safe use for both minor ambulatory cases and major surgeries in high-risk populations.

2. Failure of Spinal Anesthesia

Failure of spinal anesthesia remains a significant and often distressing complication for both patients and anesthesiologists. Unlike many regional anesthesia techniques, spinal anesthesia typically has a clear indicator of correct needle placement free flow of cerebrospinal fluid (CSF) from the needle. Despite this, failure can still occur, similar to general anesthesia where patients may remain aware during surgery. Proper patient selection, timing, and the anesthesiologist's skill can reduce failure rates, which range from 3% to 17% in most studies, with some reports as high as 30%. Failure is usually due to technical issues rather than the anesthetic agent itself.

Spinal anesthesia failure is defined by the inability to complete surgery without adding general anesthesia or other regional blocks. Issues such as difficulty locating the subarachnoid space, needle movement during injection, abnormal anatomy, obesity, or patient discomfort can complicate the procedure. If repeated attempts or numerous paresthesias occur, it is advisable to change the anesthesia plan to avoid further complications. High-risk patients for spinal anesthesia failure often coincide with those at high risk for general anesthesia, posing a challenge for anesthesiologists.

To minimize failures, meticulous technique ensuring free CSF flow before anesthetic injection and steady needle fixation are essential. Sometimes, failure happens despite free-flowing CSF, possibly due to the needle entering an arachnoid cyst disconnected from the main subarachnoid space. Needle design, like the Sprotte needle's large, distal side hole, has been suggested to influence failure rates, though comparative studies with Quincke needles show no significant difference.

Low-dose spinal anesthesia (bupivacaine under 10 mg) has gained popularity for ambulatory surgeries without increasing failure risk when performed correctly. This technique is typically used for lower extremity surgeries or bilateral procedures like tubal ligation. Patient positioning during and after injection affects the anesthesia spread, especially with baricity variations of the anesthetic used. Hyperbaric bupivacaine and ropivacaine allow modulation of the sensory block level with patient repositioning, whereas isobaric bupivacaine's effect is less predictable and harder to adjust, with a tendency for higher block levels when administered at higher lumbar interspaces.

This understanding underscores the importance of patient cooperation, anesthesiologist expertise, and individualized approaches in spinal anesthesia to minimize failure rates and ensure patient safety and comfort.

3. Epidemiology and overall incidence

Complication rates after spinal anesthesia vary greatly by the nature of the complication, patient population (e.g., obstetric vs. elderly orthopedic), and the techniques/needles used:

- **Hemodynamic instability** (hypotension/bradycardia) is common, especially during cesarean delivery, with clinically significant hypotension reported in a large proportion of parturients unless prophylactic measures are taken. Recent meta-analyses support prophylactic vasopressor use (phenylephrine or norepinephrine) to reduce maternal hypotension.
- **Post-dural puncture headache (PDPH)** incidence has decreased with the widespread adoption of atraumatic pencil-point needles but remains an important cause of morbidity for younger and obstetric patients; epidural blood patch remains the most effective treatment for moderate severe PDPH.
- **Serious neurologic events** (permanent paralysis, cauda equina) are exceedingly rare. Spinal/epidural hematoma is a catastrophic but low-frequency event whose risk is strongly associated with anticoagulation and coagulopathy; when suspected, urgent MRI and neurosurgical decompression are crucial. Contemporary consensus documents and society guidelines (ASRA/ESAIC) give explicit timing recommendations for neuraxial procedures in patients on antithrombotic agents.
- **Transient neurologic symptoms (TNS)** historically linked to intrathecal lidocaine have been better characterized; many centers now avoid spinal lidocaine for ambulatory cases to reduce TNS risk.

4. Mechanisms and pathophysiology

4.1. Hemodynamic effects: hypotension and bradycardia

Sympathetic blockade from SAB causes arterial and venous vasodilation, venous pooling, reduced preload, and decreased cardiac output. Higher block levels greater sympathetic blockade. Pregnancy (aortocaval compression, increased sensitivity to sympathectomy) magnifies the effect. Prevention strategies informed by trials include coloading rather than preloading, and routine prophylactic vasopressor infusion (commonly phenylephrine in obstetrics; norepinephrine is an emerging alternative with a favorable heart-rate profile).

4.2. Post-dural puncture headache (PDPH)

PDPH is attributed to persistent CSF leakage causing intracranial hypotension and traction on pain-sensitive structures. Risk factors: younger age, female sex/pregnancy, variant connective tissue, larger or cutting needles, multiple punctures. Pencil-point (atraumatic) needles significantly reduce PDPH incidence; when conservative measures fail, epidural blood patch (EBP) is the most effective therapy and is supported by practice guidelines.

4.3. Neurologic injury, TNS, and cauda equina

- **TNS**: Characteristically transient buttock/thigh pain after recovery; strongly associated with intrathecal lidocaine, lithotomy positioning, and outpatient procedures in older series. Many institutions have switched to alternative agents for short procedures to lower TNS risk.
- **Cauda equina / permanent injury**: Rare, with potential causes including direct needle/needle-trauma, high-concentration local anesthetic pooled in the cauda equina (maldistribution), or compressive lesions (hematoma/abscess). Early MRI and neurosurgical referral improve outcomes.

4.4. Infectious complications

Infectious complications (bacterial meningitis, epidural/spinal abscess) are uncommon but severe. Several reports have linked provider oropharyngeal flora to meningitis after neuraxial procedures; strict asepsis, including face masks and chlorhexidine-alcohol skin prep, reduces risk.

4.5. Spinal/epidural hematoma

Hematoma arises from bleeding into the neuraxial space, producing compression of neural structures. Antithrombotic use and coagulopathy are the principal modifiable risk factors. Contemporary society guidance details acceptable intervals for holding DOACs, low-molecular-weight heparin (LMWH), unfractionated heparin, and antiplatelets before neuraxial procedures. If hematoma is suspected (new motor deficit, severe back pain, bladder/bowel dysfunction), urgent MRI and decompression (ideally within hours) are associated with better neurologic recovery.

4.6. Local anesthetic systemic toxicity (LAST) & neurotoxicity

Although systemic toxicity is rare with spinal doses, inadvertent intravascular injection or extremely high doses can precipitate CNS/CV toxicity. Historical concerns about lidocaine neurotoxicity and TNS have prompted shifts toward alternative intrathecal agents for short procedures.

5. Risk factors-patient, technique, and provider

- **Patient:** pregnancy, extremes of age (young → PDPH risk; elderly → hematoma risk), obesity, spinal deformity, pre-existing neurologic disease, antithrombotic therapy, infection/coagulopathy.
- **Technique:** needle type (cutting vs. atraumatic), gauge, bevel orientation, number of puncture attempts, baricity and dose of local anesthetic, patient position during injection. Use of hyperbaric high-concentration solutions and intrathecal catheter use have been implicated in some adverse outcomes historically.
- **Provider:** experience, sterile technique adherence, and timely recognition of complications.

6. Prevention: evidence-based strategies

6.1. Needle and technique selection

- Prefer atraumatic pencil-point needles (Whitacre/Sprotte) to reduce PDPH. Multiple studies and guideline statements recommend this where feasible.

6.2. Hemodynamic prophylaxis

- For high-risk populations (especially cesarean delivery), prophylactic vasopressor infusion (phenylephrine; increasing data for norepinephrine) with coloading of crystalloids is recommended to reduce maternal hypotension and its sequelae. Continuous monitoring and protocols for rescue therapy (ephedrine/epinephrine) should be in place.

6.3. Anticoagulation management

- Follow contemporary ASRA/ESAIC timing recommendations for holding antiplatelet and anticoagulant medications prior to neuraxial procedures. Document timing of last doses and lab coagulation status where relevant. Avoid neuraxial procedures if coagulopathy is uncontrolled.

6.4. Aseptic technique and infection control

- Use chlorhexidine-alcohol skin prep, sterile gloves, drapes, and masks to minimize meningitis/abscess risk. Guidelines emphasize universal mask use and minimizing breaks in sterility.

6.5. Ultrasound assistance

- Pre-procedural (and where feasible, real-time) ultrasound mapping of lumbar anatomy improves identification of midline and interspace, reduces needle passes and redirections, and decreases traumatic punctures in patients with difficult anatomy (obesity, scoliosis, prior spine surgery). While trials vary in magnitude of effect,

systematic reviews support ultrasound as a useful adjunct to improve technical success and potentially reduce complications related to multiple traumatic passes.

7. Recognition and management of key complications

7.1. Immediate intraoperative problems

- **High/total spinal**-anticipate if rapid ascent of block with respiratory compromise or marked hypotension occurs: secure airway, ventilatory support, aggressive vasopressors, and treat as a critical event.
- **Refractory hypotension/bradycardia-**follow local algorithms: phenylephrine/norepinephrine for hypotension; atropine/epinephrine for severe bradycardia or asystole.

7.2. Postoperative neurologic concerns

- **Acute new motor deficit/sensory change, severe localized back pain, or urinary retention→** urgent neurological exam and MRI. If epidural/spinal hematoma is identified, emergent decompressive laminectomy is typically required; outcomes are time-sensitive.

7.3. PDPH

- **Initial**: conservative measures (analgesia, hydration, caffeine) can be used for mild cases.
- **Persistent/moderate severe**: **epidural blood patch (EBP)** remains the gold standard for symptomatic relief; guidelines suggest the technique and typical volumes (commonly 15–20 mL or more based on clinical response) and recommend EBP when functionally significant.

7.4. Infections

- New fever with meningeal signs after neuraxial block → urgent lumbar puncture (if safe) and initiation of empirical antimicrobial therapy pending cultures; neurosurgical consultation if abscess suspected. Maintain high index of suspicion in immune-compromised patients.

8. Special populations

8.1. Obstetric patients

Obstetric physiology increases SAB-related hypotension risk; prophylactic vasopressor regimens and left uterine displacement are standard. PDPH remains more likely in parturients with fewer options to tolerate severe headaches; EBP is effective when indicated.

8.2. Elderly / hip fracture patients

Elderly patients have greater risk of bleeding complications if anticoagulated; careful pre-procedural assessment of coagulation status and cautious dosing/technique are needed. Ultrasound may help in difficult anatomy.

8.3. Patients on antithrombotic therapy

Individualized risk–benefit assessment is required. Follow ASRA/ESAIC timing windows for holding and resuming drugs; multidisciplinary planning (surgery, hematology, and anesthesia) is often helpful.

9. Medico-legal and documentation considerations

Given the potential seriousness of rare complications, thorough informed consent (including discussion of common and rare complications), careful documentation of needle type/gauge/level/number of attempts, timing of anticoagulants and post-procedure neurological monitoring are important medico-legal safeguards. Institutions should have protocols for rapid imaging and neurosurgical escalation when red-flag neurologic signs appear.

10. Research Gaps and Future Directions

1. **High-quality comparative trials** of norepinephrine versus phenylephrine regimens for maternal hemodynamic control and neonatal outcomes.
2. **Optimizing PDPH prevention and conservative management** randomized comparisons of early EBP timing, prophylactic vs therapeutic blood patching, and non-invasive neuromodulation techniques.
3. **Defining safe neuraxial timing** with newer antithrombotic agents (DOACs) in diverse surgical and frail populations through prospective registry data and trials.
4. **Standardizing ultrasound training and workflows** to maximize benefit and make ultrasound-guided neuraxial techniques accessible globally; evaluate cost-effectiveness and learning curves.

11. Conclusion

Spinal anesthesia is one of the oldest and most dependable anesthesia techniques, with a history spanning nearly three centuries. Its introduction holds a remarkable historical significance. Despite the passage of more than 100 years, the fundamental technique has remained largely unchanged. Advances have primarily involved improvements in needle and catheter designs, along with the development of safer and longer-acting local anesthetics. Additionally, the practice of combining opioids with local anesthetics has become common, offering enhanced pain relief but also increasing the spectrum of potential complications.

The phenomenon of transient radicular irritation (TRI) or transient neurologic symptoms (TNS) remains intriguing and not fully understood. Over the past five decades, substantial progress has been made in understanding the physiology of spinal anesthesia, largely due to the pioneering work of experts like Sir Robert Macintosh and Professor Nicholas Greene. Given its proven effectiveness and adaptability, spinal anesthesia is expected to remain a vital technique in anesthesiology well into the next century. The pioneering efforts of Bier and Hildebrandt are gratefully acknowledged for introducing this invaluable technique that continues to benefit patients worldwide.

Recent advances also include better safety protocols, refined drug combinations, and sophisticated monitoring techniques, which have collectively contributed to reducing complications and improving patient outcomes. These improvements sustain spinal anesthesia's role as a cornerstone in perioperative care.

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