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Optimizing First-Pass Success in Subarachnoid Block: A Comprehensive Narrative Review

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ABSTRACT

Subarachnoid block (SAB), or spinal anesthesia, is a foundational technique in modern regional anesthesia, providing rapid, dense, and reliable surgical anesthesia for lower abdominal, obstetric, urological, and orthopedic surgeries. Traditionally relied upon as a landmark-guided, tactile procedure, the first-pass success (FPS) rate of SAB historically ranges from only 60% to 70% in unselected patient populations. Multiple needle passes, bony contacts, and redirections significantly escalate the risk of patient discomfort, post-dural puncture headache (PDPH), spinal hematoma, epidural vein puncture, and transient neurological symptoms. Achieving a high FPS rate has therefore evolved from a metric of clinical efficiency into a primary safety parameter.

This narrative review examines contemporary, Evidence-Based strategies designed to maximize FPS in subarachnoid blocks. It evaluates the impact of patient-related predictors of difficulty, examines advanced mechanical positioning aids and multimodal instructions, contrasts structural approaches (midline vs. paramedian), explores needle design variations, and presents the definitive role of preprocedural and real-time neuraxial ultrasound. By integrating technology with refined clinical ergonomics, anesthesia providers can transition SAB from an empirical, blind procedure into a high-precision, highly successful intervention on the first pass.

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Introduction

Subarachnoid block (SAB) is celebrated for its rapid onset, dense motor and sensory blockade, and minimal systemic drug requirements. However, its traditional execution relies heavily on the tactile recognition of deep structures through a blind, landmark-guided technique based on the intercristal (Tuffier's) line. When landmarks are altered by obesity, pregnancy, advanced age, degenerative joint disease, or spinal deformities like scoliosis, this landmark-guided approach often deteriorates into a series of trial-and-error needle redirections.

The clinical consequences of repeated needle passes are well-documented. Each deviation of the needle tip increases the risk of damaging regional microvascular structures, lacerating the dura mater excessively, or inducing paresthesia via nerve root contact. Furthermore, multiple skin punctures and prolonged procedure times significantly degrade patient satisfaction and elevate perioperative anxiety.

First-Pass Success (FPS) defined precisely as the successful placement of the spinal needle into the subarachnoid space with a single skin puncture and a single forward needle advancement without redirection has emerged as a vital benchmark for quality in regional anesthesia. Consequently, minimizing technical failures and optimizing the ergonomics of the initial pass has driven substantial clinical research into predictive modeling, ergonomic positioning, needle bioengineering, and neuraxial imaging.

Anatomical and Clinical Predictors of Difficult Neuraxial Access

A critical step in maximizing FPS is the early identification of the 'difficult neuraxial airway.' Clinical intuition alone is frequently insufficient to predict technical difficulties during spinal anesthesia. Instead, targeted pre-anesthetic screening must isolate specific independent demographic and anatomical predictors[1].

Demographic Factors

- **Body Mass Index (BMI):** Elevated BMI and morbid obesity are strongly correlated with a reduced FPS rate. Excessive subcutaneous fat masks the underlying bony landmarks, rendering the spinous processes unpalatable and obscuring the midline.
- **Advanced Age:** Aging induces predictable degenerative alterations in the axial skeleton, including osteophyte formation, calcification of the interspinous and flaval ligaments, and narrowing of the intervertebral disc spaces. These changes constrain the available interlaminar window, leading to frequent bone-on-needle contact during traditional landmark approaches.

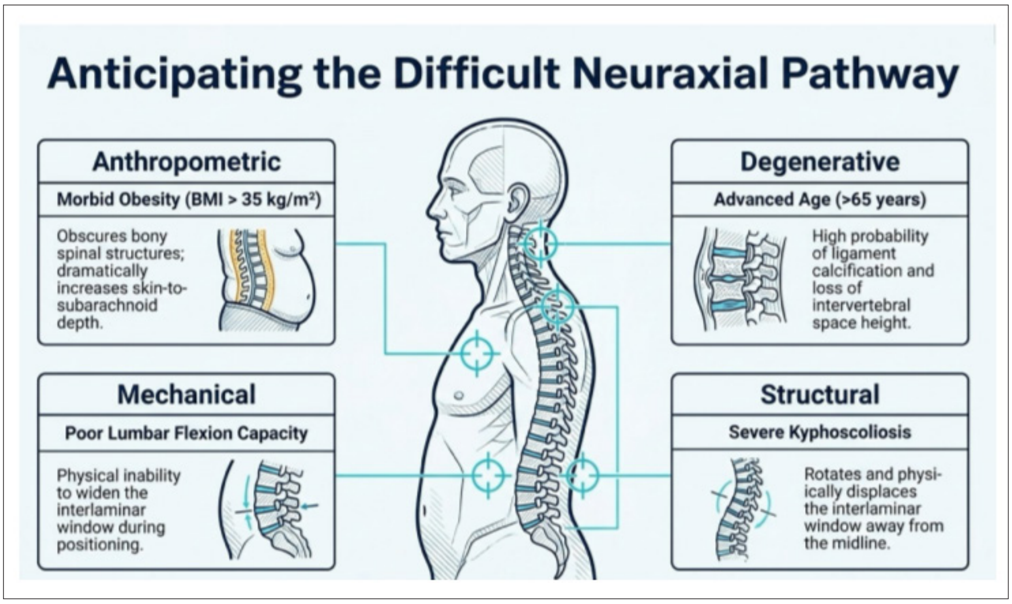
Physical and Structural Markers

Observational evidence highlights several examination findings that directly threaten FPS:

- **Impaired Spinal Flexion:** The inability of the patient to adequately reverse lumbar lordosis narrows the acoustic and mechanical pathways to the subarachnoid space.
- **Poorly Palpable Spinous Processes:** When the intervertebral

spaces cannot be manually delineated by palpation, the probability of first-pass failure rises drastically.

- **Spinal Deformities:** Manifestations of advanced scoliosis, kyphosis, or prior spinal fusion surgery alter standard anatomical relationships, rendering conventional geometric trajectory assumptions invalid.



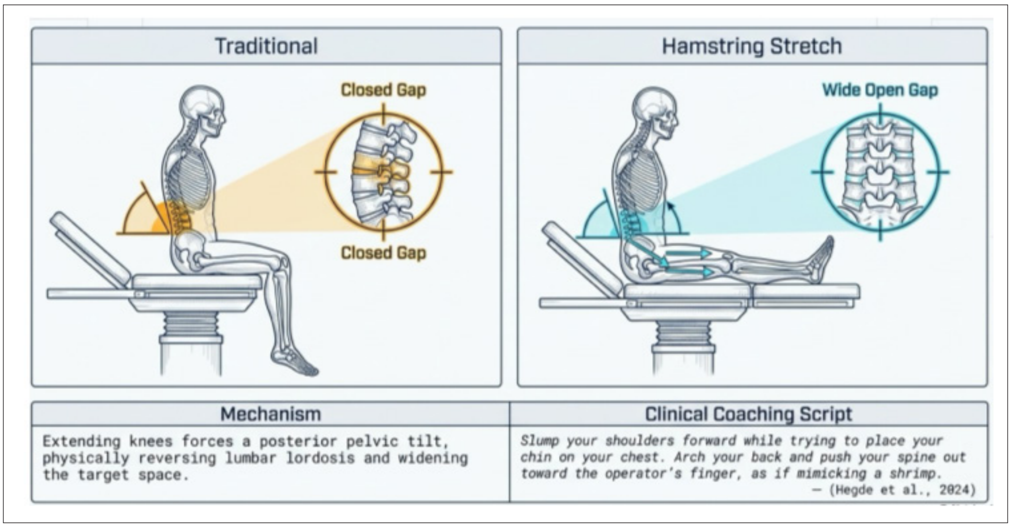
Ergonomics and Patient Positioning Strategies

Optimal patient positioning is widely considered the most effective non-technological intervention to enhance FPS. Maximizing the dimensions of the interlaminar space requires maximum flexion of the lumbar spine, which separates the adjacent spinous processes.

The Traditional Sitting Position vs. Modified Approaches

While the sitting position is routinely favored for its ease of implementation, traditional instruction ('slouch like an angry cat') often results in hip flexion rather than isolated lumbar flexion.

To overcome this, the modified sitting position-utilizing a footstool to elevate the knees above the hips-or the hamstring stretch position (sitting with knees fully extended on the operating table) can be employed. Extending the knees stretches the hamstring muscles, which pulls the pelvis into a posterior tilt. This mechanical shift directly forces a reversal of lumbar lordosis, significantly widening the interlaminar gap compared to sitting with the legs dangling [2].



Visual Aids and Multimodal Communication

Standardized verbal commands frequently fail to help anxious, pregnant, or cognitively impaired patients achieve the correct posture. Combining explicit verbal directions with visual aids (such as showing the patient a photograph of an ideally positioned individual before the procedure) significantly improves compliance.

Patients who receive combined visual and verbal instructions achieve superior lumbar flexion, which reduces total needle redirection maneuvers, shortens insertion time, and increases FPS rates.

Technical Approaches: Midline versus Paramedian

The choice of needle trajectory plays an important role in avoiding structural obstructions, particularly when facing calcified ligaments or narrowed spaces.

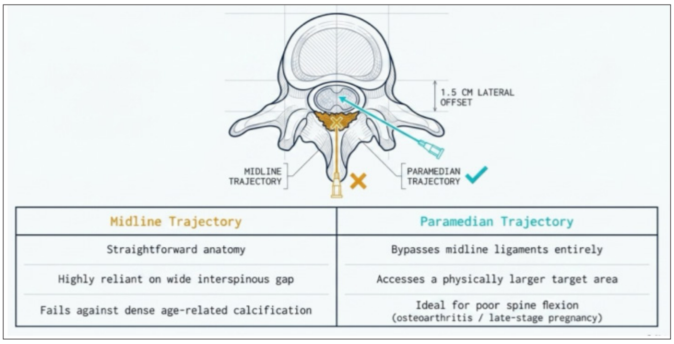
The Midline Approach

The midline approach is the standard entry path for most clinicians. It requires the needle to pass sequentially through the skin, subcutaneous tissue, supraspinous ligament, interspinous ligament, ligamentum flavum, and epidural space before puncturing the dura-arachnoid mater. While anatomically straightforward, its success depends entirely on a wide interspinous gap and an unobstructed path through the midline ligaments. In patients with dense calcification of these interspinous structures, the midline path can become virtually impassable [3].

The Paramedian Approach

The paramedian approach bypasses the supraspinous and interspinous ligaments entirely. The needle is inserted approximately 1–1.5 cm lateral and 1 cm inferior to the superior aspect of the chosen spinous process. It is then directed medially and cephalad, angling inward toward the midline.

- **Advantages in Difficult Anatomy:** Because it bypasses the midline interspinous structures, the paramedian approach avoids the primary site of age-related ligamentous calcification and spinal compaction.
- **Larger Target Area:** The paramedian approach provides a larger anatomical target area by accessing the wider posterolateral aspect of the interlaminar space. This trajectory makes it highly effective for patients who cannot flex their spines adequately, such as those with severe osteoarthritis or late-stage pregnancy.
- **Impact on FPS:** In patients with poorly palpable landmarks, combining a preprocedural ultrasound scan with a paramedian trajectory delivers a higher FPS rate and fewer needle passes than traditional landmark-guided midline approaches.

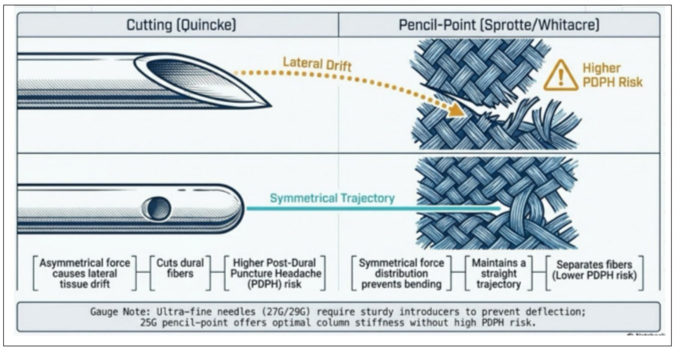


Needle Selection and Bioengineering Dynamics

The physical profile of the spinal needle affects both the tactile feedback transmitted to the operator and its tendency to deviate as it passes through deep tissue layers.

Cutting (Quincke) vs. Pencil-Point (Sprotte, Whitacre) Needles

- **Quincke Needles:** These feature a sharp, beveled tip that easily cuts through dense fibrous tissues. However, this sharp bevel creates an asymmetrical cutting edge that causes the needle to drift or bend when passing through deep tissue planes. This drift can misalign the needle tip from its intended midline path, leading to unintended bone contact and lowering the FPS rate.
- **Pencil-Point Needles (Sprotte/Whitacre):** These feature a rounded, blunt tip with a lateral opening for drug delivery. Because the tip design distributes forces symmetrically as it advances, pencil-point needles resist lateral drift and maintain a straighter path through tissue. This predictable trajectory directly supports a higher FPS rate. Furthermore, pencil-point needles separate rather than cut the dural fibers, which substantially reduces the incidence of PDPH.



Needle Gauge Options

While ultra-fine needles (such as 27G or 29G) minimize dural trauma and reduce the risk of PDPH, their thin shafts lack structural rigidity. As a result, they are highly prone to bending or deflecting when encountering dense subcutaneous tissue or fascial planes.

To prevent this deflection and maximize FPS, fine-gauge needles should always be placed through a sturdy introducer needle. Alternatively, a slightly heavier gauge needle (such as a 25G pencil-point needle) can be used to balance optimal column stiffness with a low risk of post-procedure headache.

The Technological Shift: Ultrasonography in Neuraxial Blockade

The integration of ultrasound guidance represents a major advancement in central neuraxial anesthesia, shifting SAB from a blind, tactile technique to a visually guided procedure [4].

Preprocedural Ultrasound-Assisted SAB (UA-SAB)

Preprocedural ultrasound imaging serves as a valuable diagnostic and mapping tool before needle insertion. The clinician uses a low-frequency curvilinear transducer (2–5 MHz) to perform a systematic survey of the lumbar spine in two anatomical planes:

- **Paramedian Sagittal Oblique (PMSO) View:** This view identifies the key sonographic landmarks of the spine: the 'sawtooth' pattern of the lamina and the deeper, flat 'interrupted line' representing the anterior complex (anterior dura mater, posterior longitudinal ligament, and vertebral body).
- **Transverse Interlaminar View (TILV):** Obtained by rotating the probe 90 degrees, this view displays the 'flying bat' configuration of the spinous process and lamina. This orientation allows the clinician to look through the interlaminar space and visualize the posterior complex (ligamentum flavum-dura mater mix) and the anterior complex.

By optimizing the ultrasound image of the TILV, the operator can mark the precise skin entry site and measure both the depth to the ligamentum flavum and the optimal cephalad angle for the needle.

Large systematic reviews and network meta-analyses confirm that preprocedural ultrasound guidance significantly increases first-pass success, reduces total needle redirections, and lowers overall failure rates compared to traditional landmark guidance. It is particularly effective for patients with anticipated technical difficulties, such as those with poorly palpable landmarks, obesity, or advanced structural spine pathology.

Real-Time Ultrasound-Guided Spinal Anesthesia

Real-time guidance involves advancing the spinal needle while continuously imaging the lumbar spine. This approach can be performed by a single operator using an in-line needle guide or via a two-person technique.

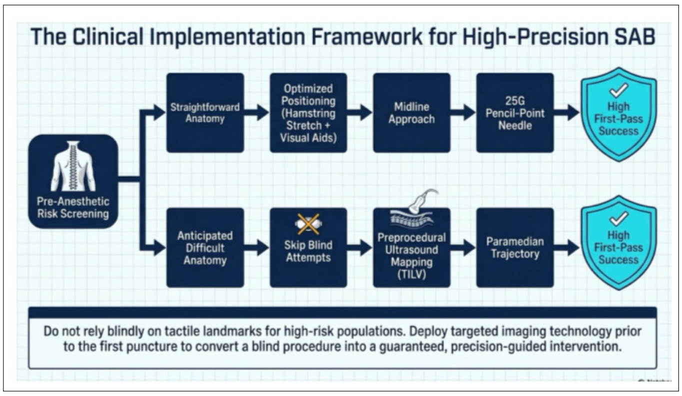
While real-time guidance ensures continuous visualization of the needle tip as it enters the intrathecal space, it is technically demanding and requires a high level of manual dexterity. Current clinical evidence indicates that for adult patients, real-time ultrasound guidance does not offer a significant advantage in FPS rates over a well-executed preprocedural ultrasound scan.

Discussion and Clinical Implementation Framework

Maximizing first-pass success in subarachnoid blocks requires a systematic approach that combines preoperative assessment, optimized positioning, appropriate equipment selection, and advanced technology. Clinicians can improve their procedural success by moving away from a uniform, one-size-fits-all strategy and instead adopting a structured, step-by-step framework tailored to each patient's anatomy.

When managing patients with straightforward anatomy, high FPS rates can be consistently achieved through precise manual landmark identification, optimized lumbar flexion using visual and verbal aids, and the use of directional pencil-point needles. However, when an anticipated difficult neuraxial space is identified during the pre-anesthetic evaluation, clinicians should skip the traditional blind approach and move directly to preprocedural ultrasound mapping.

Using ultrasound to establish an accurate entry point and projection angle saves time, preserves local tissue integrity, and prevents the patient from enduring multiple painful needle passes. This structured approach helps ensure that advanced technical resources are deployed efficiently where they will have the greatest impact on patient safety and comfort [5].



Conclusion

Achieving a high first-pass success rate during a subarachnoid block is a key indicator of clinical excellence, directly enhancing patient safety, comfort, and overall satisfaction. While the basic landmark-guided technique remains a valuable core skill, relying on it blindly in challenging patient populations can lead to unnecessary technical complications and procedural delays.

Modern strategies offer a reliable path to consistently higher FPS rates. Clinicians can improve their results by using structured risk screening to identify difficult anatomy early, employing enhanced positioning techniques like the hamstring stretch or visual aids, and choosing stable, predictable pencil-point needles. Most importantly, preprocedural neuraxial ultrasound has fundamentally changed how clinicians approach difficult access, converting a blind procedure into a precise, targeted intervention.

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