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COMMENTARY

The Phenomenon of Rebound Pain After Peripheral Nerve Block

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ABSTRACT

Peripheral nerve blocks provide highly effective postoperative analgesia for limb surgeries. But the complete resolution of the blockade is frequently followed by an abrupt and severe escalation in pain intensity that significantly exceeds baseline levels. This acute hyperalgesic response is termed ‘rebound pain’. Despite affecting nearly one half of all ambulatory orthopedic patients, standardized clinical protocols for its prevention remain unfound.
The paper focuses on the pathophysiological mechanisms, patient-specific demographics, surgical risk factors, and pharmacological management strategies regarding severe rebound pain following peripheral nerve blockade.
We investigated few studies focusing on the occurrence of rebound pain following peripheral nerve blocks for upper and lower limb surgeries. The debate included studies focusing particularly on pathophysiology, risk factors, and pharmacological adjuvants used, while central neuraxial techniques were excluded.
Rebound pain represents a distinct physiological state driven by the silent peripheral accumulation of inflammatory mediators, coupled with a central nervous system unprepared for sudden nociceptive input. Risk stratification identifies younger patients, females, and individuals undergoing major osseous procedures as highly susceptible. Regarding pharmacological intervention, prioritizing maximum block duration does not necessarily improve the patient's functional recovery. Although perineural dexamethasone demonstrates a statistically significant prolongation of sensory effects, it fails to improve postoperative sleep quality or reduce peak rebound pain severity when compared to systemic intravenous administration. Perineural particulate steroids also carry theoretical risks of neurotoxicity.
Mitigating the escalation of rebound pain requires shifting clinical focus away from maximizing sensory block duration toward optimizing the transitional analgesic phase. Current evidence supports the integration of preemptive, timed multimodal bridging analgesia combined with intravenous dexamethasone. Future research should prioritize functional patient outcomes, specifically sleep quality, over block duration
Keywords: Nerve Block; Pain, Postoperative; Dexamethasone; Hyperalgesia; Pain Management.

INTRODUCTION: Peripheral nerve blocks are known to routinely provide effective, opioid-sparing analgesia for limb surgeries, aimed at facilitating early discharge. Upon the resolution of these blocks, however, a distinct clinical challenge presents itself. Once the local anesthetic effect eventually wears off, many patients often experience rapidly increasing pain intensity. This phenomenon is called ‘rebound pain’. A sudden nociceptive spike can precipitate more acute distress than the steady levels of background pain patients would have experienced, as a baseline, without regional anesthesia. In the practice of ambulatory anesthesia, this remains a difficult and challenging phenomenon to address. [1].

From current literature, most focus is made on an intent to extend block duration by using novel adjuvants. The underlying assumption is quite simple: Maximizing analgesic time, after all, should directly improve patient outcomes. Unfortunately, enough, this approach completely ignores the nature and quality of the transition

itself. Current data increasingly shows that if we extend block duration without catering to its resolution phase (i.e the time of the day when it wears off), we may not be able to improve patient recovery. In fact, by delaying the onset of pain, we risk causing the block to abruptly wear off during sleep. In this state, the patient might go on to experience what Lavand'homme describes as a failure of 'predictive coding' [1]. Sudden nociceptive input strikes that overwhelm a central nervous system psychologically unprepared to modulate those signals. The scope of this issue is thus substantial. Retrospective data indicates up to one half of patients undergoing orthopedic procedures, who might undergo severe rebound pain, particularly within their first 24 hours [2]. Current clinical practice focuses heavily on prolonging block duration, often neglecting the quality of recovery once the block recedes. This review proposes that shifting the focus toward the transitional phase of analgesia is essential for improving patient outcomes.

The commentary focused on the risk factors and pathophysiological correlations of rebound pain and also critically evaluated the comparative efficacy of intravenous versus perineural dexamethasone proposed a safe multimodal management strategy.

1.PATHOPHYSIOLOGY: MECHANISMS OF THE REBOUND PHENOMENON: Rebound pain is not merely a matter of local anesthetic clearance and cessation of block's effects. The actual cause runs deeper and probably involves complex underlying physiological shifts taking place during the comfortable period of successful neural blockade. We may extract from evidence several principle mechanisms occurring, which involve distinct alterations within both the peripheral and central nervous systems.

1.1. PERIPHERAL SENSITIZATION AND SILENT ACCUMULATION: An important contributing factor here is the silent accumulation of inflammatory mediators at the surgical site. The process is silent because of complete lull of the successful nerve blockade, putting mask onto it. The local anesthetics have certainly blocked sodium channels to stop nociceptive transmission. But they cannot attribute the local tissue response to surgical trauma. Throughout the duration of this block, the incision site will continuously and generously pour a mixture of prostaglandins, histamine, bradykinin, and inflammatory cytokines, such as IL-6.

Since the afferent transmission is now suspended, the central nervous system will remain entirely blinded of this ongoing inflammatory process. To the contrary, peripheral nociceptors are undergoing a prolonged exposure to these algogenic substances, all the while. As the local anesthetic concentration eventually drops below the minimum blocking threshold, nerve conduction resumes quickly, waking the central nervous system up. The afferent pathway begins to transmit signals from a surgical tissue bed already in a state of peak inflammation [1]. This sudden influx of massive nociceptive input to the spinal cord often manifests clinically as severe, tearing sensation, reported by patients on very high pain scales.

1.2. CENTRAL DEAFFERENTATION AND MISMATCH: Central maladaptation is the second phenomenon, and it plays a critical role. Acute deafferentation is the name of a process where the central nervous system is completely deprived of sensory input from a limb for long period of time. This has shown to trigger transient neuroplastic changes, resulting ultimately in heightening regional sensitivity, such as to nociception. This idea shares a very mechanistic similarity with transient phantom limb pain. Lavand'homme categorizes this physiological mismatch, calling it a failure of 'predictive coding' [1]. During normal recovery, where no block has been performed, pain intensity will escalate gradually, providing the central nervous system, able to receive signals from surgical tissue bed, time to activate endogenous descending inhibitory pain pathways in response. This is the awake and aware central nervous system helping the patient to engage in psychological coping strategies. Conversely though, after a dense regional block is done, the patient will experience profound comfort for many hours, in addition to their central nervous system rendered asleep. Neither physiological nor psychological defenses could be primed. The subsequent, abrupt arrival of severe pain strikes on an unconditioned central nervous system will be ready to wreak havoc. This stark discrepancy between the sudden physical nociception and the lack of mental preparation significantly amplifies the patient's subjective distress.

1.3. LOCAL ANESTHETIC-INDUCED HYPERALGESIA: There is also Emerging evidence from animal models showing local anesthetics themselves to trigger transient receptor sensitization [1]. During the washout phase, affected nerve membranes often exhibit a brief period of hyperexcitability. This will effectively lower the depolarization threshold. Therefore, the local anesthetic agent administered to prevent nociception may have proved counterintuitive and primed the peripheral nerves for an exaggerated, hypersensitive response immediately following block resolution.

2. INCIDENCE AND RISK STRATIFICATION: The clinical presentation of rebound pain exhibits significant interpatient variability. Risk stratification will allow for targeted analgesic planning.

2.1. INCIDENCE: Literature reports on incidence consistently vary due to discrepancy in stated definitions. One way to define it is a transition from mild to severe pain within the first 24 postoperative hours. In its light, recent data explores the incidence between 40% and 50% in the ambulatory orthopedic population [2]. This demonstrates that It is a frequent complication rather than just an outlier.

2.2. PATIENT-RELATED RISK FACTORS: Multiple patient-specific factors correlate with increased risk:

- **Younger Age:** Increased basal metabolic rates, as found amongst young patients, will facilitate faster local anesthetic clearance from blood. These patients also demonstrate increased physiological reactivity and lower acute pain thresholds compared to the elderly [2].
- **Female Sex:** Female sex is seen in multiple models as an independent predictor of rebound pain. Perhaps, hormonal influences on nociceptive pathways as well as gender-based differences in acute pain coping strategies mediate this effect.
- **Pre-operative Pain and Anxiety:** Prior to surgery, patients with elevated pain scores are strongly predisposed to undergoing severe rebound hyperalgesia. Patients exhibiting pain catastrophizing also show higher susceptibility. Their over-sensitized nervous systems will amplify the subsequent nociceptive input.

2.3. SURGICAL RISK FACTORS: It is well known fact that the type of surgical trauma will directly influence the postoperative trajectory of pain. Osseous procedures involving bone resection or extensive internal fixation (for example, complex ankle fractures, anterior cruciate ligament reconstructions etc) consistently generate the highest intensity of rebound pain yet. In contrast, purely soft-tissue operations produce significantly milder transitions. The disparity is clearly anatomically driven. The highly innervated periosteum effectuates an aggressive, localized inflammatory response. And hence the sensory return is not gradual but abrupt and sudden. The analgesic block failing rapidly leads to a steep and abrupt onset of pain.

2.4. CLINICAL IMPLICATION: The above mentioned Risk stratification facts dictate that standardizing a single block protocol across all demographics is simply inadequate. It is the clinical profile which should dictate the necessary intervention needed. A 70-year-old male scheduled for a minor soft tissue release may only require a standard transitional care. But a 25-year-old female presenting for major open reduction and internal fixation will represent the highest risk tier. A standard single-shot peripheral nerve block may be too insufficient for this demographic. This patient should mandate a pre-planned, multimodal analgesic bridge to manage her resolution phase safely.

3. PHARMACOLOGICAL STRATEGIES AND THE ADJUVANT DEBATE: Pharmacological management of rebound pain, thus far, focuses on modifying the regional block profile to ensure a more gradual and controlled resolution of sensory deficits of block. This objective is primarily achieved through the use of adjuvants which are specific pharmacological agents added to the local anesthetics so that they can alter their pharmacokinetic or pharmacodynamic properties. While various drugs have been tested, dexamethasone remains the most extensively evaluated adjuvant. But its optimal route of administration should require careful clinical consideration.

3.1. DEXAMETHASONE: THE GOLD STANDARD ADJUVANT: Dexamethasone is a well-known potent glucocorticoid. It prolongs analgesic duration and significantly reduces overall postoperative opioids

requirement. Its mechanism of action appears to be multimodal. It directly inhibits nociceptive C-fiber transmission through the potassium channel modulation and exerts a systemic anti-inflammatory effect that attenuates the localized surgical immune response [3].

3.2. THE ROUTE CONTROVERSY: PERINEURAL VS. INTRAVENOUS: Whether dexamethasone should be injected intravenously or perineural is a point of extensive ongoing debate. Efficacy data is clear regarding its effect on block duration. A comprehensive Cochrane review by Pehora et al. confirmed that perineural dexamethasone provides a statistically significant prolongation of sensory blockade [3]. If the metric is duration of blockade, then the perineural route is a superior choice. But in real clinical practice, it is important that we balance this extended duration against potential morbidity and harm. Williams et al. had raised significant neurotoxicity concerns, demonstrating that particulate steroids can crystallize when combined with local anesthetics. This creates a theoretical risk for chemical neuritis or direct nerve injury [4]. Recent noninferiority trials by Kim et al. once again contextualize this skewed risk-benefit ratio. Their data indicates that the prolonged sensory block achieved via the perineural route does not necessarily translate to superior functional outcomes: That is, they found no significant difference in rebound pain severity or objective sleep quality between the intravenous and perineural groups [5]. If intravenous administration delivers comparable recovery quality while eliminating the neurotoxic risks of perineural crystallization, does it not present as the safer, pragmatic standard of care?

3.3. OTHER ADJUVANTS: There are several alternative adjuvants as well. For one thing, dexmedetomidine. This Alpha-2 agonist effectively extends analgesic duration. However, its pharmacodynamic profile restricts it's utility in the ambulatory setting. This drug frequently causes hemodynamic instability, most specifically Bradycardia and Hypotension. It also causes profound sedation which can delay patient discharge from the post-anesthesia care unit. That is why its routine application for rebound pain prophylaxis is questionable. Investigations into other additives have been conducted, such as magnesium or clonidine, but the yielded evidence is currently too inconsistent to support routine clinical implementation.

3.4. THE CONCEPT OF BRIDGING ANALGESIA: Adjuvant selection addresses only a part of the clinical dilemma. Effective prevention relies heavily on the implementation of bridging analgesia. Instead of waiting for the patient to be hit with barrage of nociceptive strikes and then respond reactively, clinicians must employ preemptive pharmacology. A standard protocol may utilize a timed multimodal regimen—typically administered 10 to 12 hours after the block, irrespective of whether the patient reports pain or not. The objective here is to achieve therapeutic plasma concentrations of oral non-opioid analgesics (e.g., acetaminophen and NSAIDs) prior to the resolution of the regional blockade. This establishes a preexisting analgesic foundation before the central nervous system registers the sudden onset of surgical nociception.

CLINICAL RECCOMENDATION: Mitigating rebound pain requires a proactive approach and intervention. The concept of bridging analgesia should be standardized. The patients must receive a dose of oral combination analgesic (e.g., NSAIDs and acetaminophen) approximately one hour prior to anticipated resolution of the block. Intravenous dexamethasone at the dose of (4–10 mg) should be preferred over perineural administration, as it provides comparable systemic analgesic duration with a superior safety profile, avoiding the theoretical risks of neurotoxicity. Preoperative patient education also remains vital and essential. Clinicians must explicitly warn patients about hyperalgesia and rebound phenomenon to manage the expectations and reduce psychological distress when sensation ultimately returns.

CONCLUSION: The clinical success of regional anesthesia depends heavily on the resolution phase. Rebound pain is a specific form of hyperalgesia that can undo all benefits of regional anesthesia if the transition phase is not properly managed. The updated and latest evidence supports using dexamethasone to extend the block, but this must be combined with timed oral analgesics to bridge the gap effectively. Future studies may need to shift focus on functional recovery, specifically quality of sleep, rather than just recording the duration of sensory loss.

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