Pro-Con Debate: Peripheral Nerve Blockade Should Be Provided Routinely in Extremity Trauma, Including in Patients At Risk for Acute Compartment Syndrome

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In this Pro-Con commentary article, we discuss the controversial debate of whether to provide peripheral nerve blockade (PNB) to patients at risk of acute extremity compartment syndrome (ACS). Traditionally, most practitioners adopt the conservative approach and withhold regional anesthetics for fear of masking an ACS (Con). Recent case reports and new scientific theory, however, demonstrate that modified PNB can be safe and advantageous in these patients (Pro). This article elucidates the arguments based on a better understanding of relevant pathophysiology, neural pathways, personnel and institutional limitations, and PNB adaptations in these patients. (Anesth Analg 2023;136:855–60)

GLOSSARY

ACS = acute compartment syndrome; **APS** = acute pain service; **CPNB** = continuous peripheral nerve blockade; **ERAS** = enhanced recovery after surgery; **LA** = local anesthetic; **PNB** = peripheral nerve blockade

Acute pain in extremity trauma and surgery can be severe and challenging to manage. There is a growing utilization of peripheral nerve blockade (PNB) in trauma care given its superiority in pain control, decreased use of opioids and opioid-related side effects, and facilitation of earlier mobilization.[1] Despite the benefits, there remains significant objection to PNB in acute extremity trauma with concerns PNB analgesia may mask a developing acute compartment syndrome (ACS).[2–4] Recent case reports and expert opinion suggest to the contrary claiming tailored PNB does not delay ACS diagnosis compared to other modalities, and may enable a developing ACS to be discovered earlier.[5–12] This Pro-Con article presents the arguments and contrasts the evidence and philosophy for and against PNB in patients at risk for ACS.

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BACKGROUND

Extremity trauma encompasses a continuum of injuries from simple lacerations to severe trauma. Reported pain is dependent on the extent of the patient's injury, level of sensorium, innate tolerance to pain, surgical intervention, and response to analgesic treatments. Inadequate pain control leads to human suffering, quality-of-life impairment, increases in morbidity, and higher health care costs.[13] Traditionally, systemic opioid analgesia has been used for severe trauma-related pain despite numerous side effects and the risk of creating opioid dependence when pain is uncontrolled.[14] Alternative analgesic modalities have been introduced with PNB providing superior analgesia and improved range of motion tolerance with minimal to no side effects.[1]

High-energy injuries, fractures (particularly tibial plateau, tibial shaft, and radial fractures), or vascular trauma also predispose the patient to a greater likelihood of developing ACS.[15] The pathophysiology begins with tissue injury and swelling that elevate interstitial pressures in closed fascial compartments. Regional perfusion decreases and local tissue hypoxia ensues. Without surgical release of the fascial compartments, cell death and muscle necrosis follow. Irreversible nerve damage and loss of limb function may occur, and amputation of the extremity may be necessary.[15] Systemic alterations of hyperkalemia, acidosis, myoglobinuria, and acute renal

and multiorgan failure can also manifest in severe cases.[16,17] Early recognition of developing ACS and surgical decompression of the involved fascial compartments remain the most essential means to prevent irreversible sequelae and optimize the chance of a full recovery.[3,15]

Unfortunately, there are no reliable diagnostic parameters that identify early ACS. While the 5 "P"s of disproportionate pain and pain on passive stretch, paresthesias, paralysis, pallor, and pulselessness combined with increased intracompartmental pressures are considered the hallmark symptoms and signs of ACS, detection of all these findings portend a late diagnosis with a high chance of irreversible damage.[18] Identifying early signs, such as increasing pain and analgesic requirements or pain out of proportion than expected, remains symptoms that trigger clinical suspicion and prompt further investigation.[19] "Disproportionate" pain, however, is highly variable and subjective and can be difficult to differentiate from "expected" pain due to injury or surgery.

Historically, managing pain in patients at risk for extremity ACS demands a delicate balance as effective analgesia must be weighed against masking unexpected pain foreshadowing a developing ACS.[17] Multiple case reports attribute missed diagnosis of ACS to various analgesic modalities, with the preponderance implicating neuraxial anesthesia and nerve blocks.[20–23] Yet, recent literature shows that PNB analgesia enables detection of sudden changes in ischemic pain with potentially an earlier diagnosis of ACS considered.[5–12] Amid increasing administration of PNB in trauma patients, the controversial role of PNB in patients at risk for ACS is herein discussed (Table).[4,19,24]

PRO: MODIFIED PNB SHOULD BE USED ROUTINELY IN EXTREMITY TRAUMA PATIENTS, INCLUDING IN PATIENTS AT RISK FOR ACS

PNB is emerging as an incredibly effective and safe modality of treating injury and surgical pain. The targeted pain relief improves pain scores while decreasing opioid use, side effects from systemic medications, lengths of stay, and health care costs.[14] Many enhanced recovery after surgery (ERAS) and injury protocols include regional anesthetics in multimodal care.[25] In patients at risk for ACS, PNB may provide added benefits by limiting catecholamine release and enhancing blood flow through the extremity via sympathetic blockade.[26] For these reasons, PNB should be added to multimodal analgesics in the at-risk ACS population as well.[24] Opponents argue, based on a few case reports, that PNB in this cohort is too risky. Their concern is dense analgesia via PNB blocks even disproportionate pain and alters the baseline nerve examination, thereby masking early ACS symptomology.[4] This argument is flawed for several reasons.

First, precluding PNB in extremity trauma leaves opioids and other multimodal agents as alternatives for analgesic therapies. To date, though, no studies compare PNB to standard therapy to determine which modality is better at detecting early ACS symptoms in this population.[24] In fact, opioid therapy in these patients seems no more protective than PNB with case reports pointing to systemic opioids as the cause of a missed ACS.[27]

The fear of PNB masking an early ACS assumes that all nerve blocks induce dense motor and sensory blockade for a long duration. However, advances in PNB techniques have seen many modifications that allow for satisfactory analgesia without compromising acceptable and timely neurologic examinations. Dilute local anesthetics, continuous nerve block infusions that can be paused, and direct targeting of sensory nerves often provide sufficient steady-state analgesia without impairing mental status or adequate nerve function.[5,7,28] Hence, a developing ACS with breakthrough pain might be more easily detected, as reported in several instances.[5,8,11]

Similar unfair generalization occurs when certain injuries are labeled substantial risk for ACS regardless

Table. Summary of Pro and Con Arguments

Pro	Con
PNB provides superior analgesia	PNB masks disproportionate pain, the key symptom of early ACS
Opioid-based therapy is no more protective	Multimodal analgesic approaches that exclude PNB allow for adequate analgesia without neurologic compromise
PNB with dilute LA via CPNB may prevent false ACS diagnosis and unnecessary fasciotomies as well as aid in earlier diagnosis of true ACS	If PNB is allowed, inexperienced providers may still use dense long-acting LA solutions
Appropriate risk stratification allows for PNB in the majority of cases without ACS risk	Many centers lack resources for appropriate patient selection and vigilant ACS monitoring protocols
APS manages patients after PNB and provides frequent assessments	Full-time APS is rare, costly, and may complicate provider response times
PNB can theoretically be used without impairing ACS ischemic transmission pathway	Ischemic transmission pathway unproven to be spared in standard PNB techniques
No data exists comparing PNB to other modalities	Evidence will be needed to change practice and medicolegal ramifications

Abbreviations: ACS, acute compartment syndrome; APS, acute pain service; CPNB, continuous peripheral nerve blockade; LA, local anesthetic; PNB, peripheral nerve blockade.

of patient demographics or mechanism of injury, which vary quite significantly. Some patients are at negligible risk for ACS (eg, frail elderly female after a ground-level fall with distal tibial fracture scheduled for plating), while others may be at significantly higher risk (eg, muscular young male with ballistic tibial diaphyseal injury with large tissue and vascular injuries requiring an intramedullary rod and vascular repair).[29–31] Those with minimal to no risk of ACS are still denied PNB, due to generalization of their fracture with the high-risk group.[4,32,33] Moreover, patients in the latter group at times undergo prophylactic fasciotomies during their initial surgery and should thereby become PNB candidates as the compartments are now open. Appropriate ACS risk stratification with a validated evidence-based scoring system, as recommended by Nathanson et al,[24] would allow for liberal PNB in the low-risk patients with thoughtful consideration in high-risk patients.[33,34]

For case-specific risk and management of these patients, the value of a dedicated regional anesthesia and acute pain service (APS) must also be recognized. Large hospitals and trauma centers have incorporated an APS with expertise in PNB in the trauma patient. APS clinicians assess patients for proper risk stratification, have knowledge and experience with PNB modifications and other multimodal analgesics, and enhance ACS monitoring protocols.[12,24] The APS team can also educate nursing staff, patients, and their families about ACS and how to observe for the earliest signs and symptoms of ACS.[6]

Dissent for PNB in these patients stresses the importance of maintaining a patient's ability to voice worsening pain as the ACS worsens. However, reliance on subjective complaints in many trauma patients is not feasible. Some have an altered sensorium due to systemic medications, intoxication, or traumatic brain injury hindering their ability to report subjective pain or demonstrate an accurate neurological examination.[19,35] PNB in these patients may offer better analgesia and would not alter the need to perform periodic objective assessments of the extremity, including pulse checks, capillary refill, and compartment pressures, if indicated. Even among isolated extremity injuries in patients who are alert and communicative, Bae et al[36] found that up to 10% of ACS cases in a pediatric cohort presented as pain-free. Moreover, disproportionate pain is insensitive and nonspecific, with most patients simply experiencing increased trauma- or surgery-related pain without other clinical signs of an ACS.[37] PNB analgesia can theoretically prevent nociceptive trauma pain from escalating to the degree that a negative decompressive fasciotomy is performed due to subjective pain complaints. Additionally, patients may tolerate repeated invasive intracompartmental pressure checks when partial sensory block is present.

Several cases have reported patient complaints of disproportionate pain despite intact dense PNB.[8,38] Kucera and Boezaart[8] proposed that ACS-induced ischemic pain may be transmitted via a different anatomical pathway than common motor and sensory nerves normally targeted by PNB. The ischemic pathway, rather, travels via perivascular sympathetic fibers and can remain unaffected with patients retaining the capacity to detect ACS ischemic pain.[39,40] Recent microscopic analysis of the femoral artery revealed sympathetic nerve fibers in vascular adventitia.[41] A better scientific understanding of ACS ischemic pain transmission may enable targeted PNB without the risk of masking ACS.

The argument that PNB will mask a developing ACS is based on several published cases that are outdated, lack proper monitoring protocols, and generalize patients and their conditions. The alternative of providing opioid-based analgesia is no more protective and can lead to more severe complications. With many advances in acute pain management, modifications in PNB technique, and new discoveries of neural pathways, PNB provides superior analgesia and can improve detection of early ACS in trauma patients. It is paramount that large registries or data sets be reviewed to compare the true risk of various analgesic modalities in this population.

CON: PNB REMAINS A RISKY INTERVENTION IN PATIENTS AT RISK FOR ACS AND SHOULD BE AVOIDED TO PREVENT CATASTROPHIC COMPLICATIONS

ACS of the extremities is uncommon. Even when it occurs, it is often detected early, and emergent surgical fasciotomies prevent permanent sequelae.[15] Missed ACS, however, is rare but can be devastating. Currently, disproportionate pain complaints with paresthesias and mild changes in motor and sensory function remain the first harbinger for developing ACS.[17] Blockade of nerve fibers via PNB removes these additional important prognostic symptoms in detecting ACS early and can lead to a missed diagnosis. Case reports and expert opinion have established a norm disapproving PNB in patients at risk for ACS.[3,4,20,22] Long-lasting single injections or continuous PNB often provide prolonged dense analgesia and an insensate extremity with patients and their care providers unaware of a developing ACS before irreversible damage occurs.[42] Short-acting PNB can lead to rebound pain, which may be confused with disproportionate pain and lead to either an unnecessary fasciotomy or to rapid administration of multiple analgesics that again risk masking a developing ACS.

PNB advocates often note superiority of PNB to opioid-only therapy.[1] However, in recent years, multimodal analgesia has replaced opioid-only treatments. Ice, elevation, acetaminophen, nonsteroidal

anti-inflammatories, gabapentinoids, intravenous lidocaine, ketamine, muscle relaxants, and other nonopioid agents can contribute to improved pain scores and significantly limit systemic opioid administration.[25]

While training in the performance of regional anesthetics has increased, PNB application in trauma patients requires more experience and modifications to local anesthetic concentrations, adjuncts, and infusions. Use of higher concentrations of local anesthetics without dilution may decrease the ability to detect breakthrough pain.[43] Even with more vigilance, unintentional intraneural administration of local anesthetics during ultrasound-guided PNB occurs in 17% of blocks and can cause even dilute concentrations of local anesthetic to last longer and provide a dense block.[44]

Proponents argue that an APS with dedicated staff can more reliably assess patients, potentially allowing for earlier detection of ACS. However, an APS that provides round-the-clock in-house coverage, including on nights and weekends, is not universal even in some busy trauma centers and can be cost-prohibitive in smaller centers. As reported in several cases, even when the APS team evaluates a patient with increased pain complaints, the initial response is often to bolus the PNB catheter with a dense anesthetic to attenuate pain rather than rule out a developing ACS.[7,8] This negates the very argument that an APS can better detect an ensuing ACS. Finally, adding an additional consulting service can at times lead to more confusion as to whom the nurses should contact and can decrease provider responsiveness.

Regardless of personnel, monitoring protocols are critical to ensure the early detection of a developing ACS especially in the setting of good analgesic provisions. Unfortunately, strict diagnostic protocols, monitoring equipment, and adequate training of all stakeholders including the patient, family members, nurses, advanced care providers, therapists, and even physicians are inconsistent.[4,45] Patient selection to allow PNB in low-risk patients or in those unable to communicate effectively is well-meaning, but without well-defined institutional protocols, the risk of a missed ACS with catastrophic consequences likely outweighs the benefits of PNB analgesia.

Recent data suggest that ACS pain is ischemic in nature and is transmitted via nerve pathways that do not routinely travel with motor and sensory nerves are intriguing but not proven at this time.[8,39,41] Even if true, most sympathetic nerve fibers travel in vascular adventitia, which run adjacent to the large nerves or plexi that transmit sensation from the extremities. In most brachial plexus, femoral or popliteal sciatic blocks, it is likely that local anesthetic infiltration in the area will also block the sympathetic pathways that transmit ischemic pain.[41] Fine nuances in pain transmission then become academic, as most clinical blocks maintain the risk of masking ischemic pain. According to this theory, femoral nerve block with periarterial spread may block ischemic transmission and mask a lower leg ACS despite sparing the sciatic innervation of the affected compartments.[20]

Given current concerns, the lack of standardized multidisciplinary protocols, an unproven theory of ischemic pain pathways, multiple multimodal analgesic agents available, an incomplete understanding of the nuances of PNB in these patients, and literature implicating PNB in masking early ACS, it remains unwise to provide PNB to patients at risk of ACS.

CONCLUSIONS

Current teaching advises against PNB in patients at risk for ACS. However, this is based on old, anecdotal cases and unscientific conservative management. The Pro argument for PNB in this patient population recognizes improved analgesia with dilute local anesthetics, emerging data that differentiate ischemic pain pathways, and vigilant protocols that may allow for earlier detection of ACS. The Con argument remains skeptical of modifying current standards especially when most systems are ill equipped to retrain multidisciplinary providers in new protocols, and questions if the addition of PNB in this population translates to clinically meaningful analgesic benefit. Future direction depends either on large data sets (ie, a national registry or multicentered trial) comparing PNB versus other modalities in at-risk patients or on promising research that quantifies objective metabolic compromise (eg, local tissue pH, glucose, and tissue oxygenation) in developing ACS.[23,35] Until then, expert opinion will argue theory while clinical decision-making is relegated to individual providers.[46,47]

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