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ANESTHESIA NERVE INJURIES: EVALUATING THE MAJOR CAUSES AND THE REMEDIAL STRATEGIES FOR A SAFETY ASSURANCE

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Abstract: Anesthesia nerve injuries remain a significant concern in perioperative care due to their potential to cause long-term sensory, motor, and functional impairments in patients. This study evaluates the major causes of anesthesia-related nerve injuries and examines effective remedial strategies essential for ensuring patient safety. The findings reveal that nerve injuries commonly arise from factors such as improper patient positioning, regional anesthesia techniques, prolonged surgical duration, anatomical variations, and the use of excessive mechanical pressure during procedures. Inadequate practitioner experience and insufficient preoperative assessments further heighten the risk. The study underscores the importance of early recognition and systematic evaluation to reduce the incidence and severity of such injuries. Remedial strategies identified include enhanced clinical training, adoption of ultrasound-guided regional anesthesia, and strict adherence to positioning protocols, improved monitoring systems, and timely postoperative neurological assessment. The study concludes that anesthesia nerve injuries remain a critical patient-safety concern, requiring continuous vigilance and evidence-based practice. Understanding their major causes ranging from patient factors to surgical positioning and anesthetic techniques is essential for effective prevention. One of the recommendations made was that comprehensive preoperative risk assessments should be implemented to identify patients with predisposing factors such as diabetes, obesity, neuropathies, or vascular diseases, ensuring customized preventive strategies are applied.

Key words: Anesthesia Nerve Injuries, Major Causes, Remedial Strategies, Safety Assurance.

Introduction

Anesthesia nerve injuries remain one of the most significant yet preventable complications associated with perioperative care, raising concerns about patient safety, clinical outcomes, and medico-legal implications. These injuries occur when peripheral nerves are damaged due to factors such as mechanical compression, traction, ischemia, or chemical toxicity during surgical and anesthetic procedures. Although the incidence is relatively low, the consequences can be debilitating, ranging from transient sensory deficits to long-term motor dysfunction and neuropathic pain. Recent evidence shows that the complexity of modern surgical interventions, combined with increasing patient comorbidities, continues to heighten the risk of nerve injuries, making a deeper understanding of their causes and prevention a priority in anesthesia practice (Jeng, 2020). As healthcare systems continue to advocate for improved patient safety and quality outcomes, evaluating anesthesia-related nerve injuries becomes an essential area of concern.

The major causes of anesthesia nerve injuries are multifactorial, involving patient-related, surgical, and anesthesia-related elements. Patient-specific risk factors such as diabetes mellitus, obesity, peripheral vascular disease, and anatomical variations have been identified as significant contributors to nerve susceptibility during anesthesia (Barrington, 2019). Surgical factors, including prolonged operation time and improper positioning, often increase pressure on peripheral nerves, leading to compression neuropathies. In addition, anesthesia-related causes—such as improper administration of regional anesthesia, needle trauma, high-pressure local anesthetic injection, and inadequate monitoring—have been reported as common determinants of perioperative nerve injury (Neal, 2021). These risk factors

emphasize the need for continuous vigilance and the adoption of evidence-based practices among anesthesia providers.

Given the potential severity of nerve injuries, the development and implementation of effective remedial strategies are fundamental. Modern anesthesia practice increasingly relies on multimodal preventive approaches such as the use of ultrasound guidance for regional anesthesia, patient-specific positioning protocols, neuromonitoring techniques, and enhanced postoperative assessment systems (Sites, 2018). These strategies aim to reduce the likelihood of nerve trauma and allow early detection and intervention should injuries occur. The evolution of ultrasound technology has significantly improved the accuracy of nerve localization, reducing incidences of intraneural injection and mechanical trauma. Furthermore, improved training and competency-based skill development among anesthesia personnel have been acknowledged as essential components of prevention and remediation (Kopp, 2020).

Concept of Nerves

A nerve is a bundle of nerve fibers (axons) that transmits electrical impulses between the brain, spinal cord, and other parts of the body, facilitating sensory perception, motor control, and autonomic functions (Fineable Content Team, 2025). Anzaku (2019) mentioned that a nerve is a cable-like structure within the body designed to conduct nerve impulses that relay information from one part of the body to another.

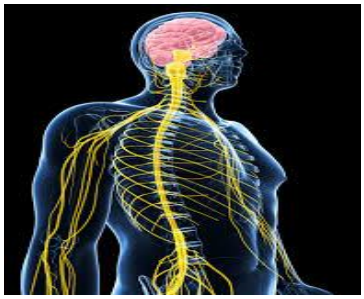

Fig.1: A picture of Nerves

However, Hall & Guyton (2016) noted that a nerve is a specialized conductor of electrochemical impulses that propagate through axons to transmit signals between different parts of the body. Depending on the axon's width and degree of myelination, these signals—known as action potentials—move at different speeds. A nerve is regarded as a functional component of the peripheral nervous system (PNS), which allows people to observe their surroundings, make judgments, and react in unison by sending information to and from the central nervous system (CNS). Touch, pain, temperature, pressure, and other sensory information are all integrated by nerves and transformed into signals that the brain can understand. By instructing muscles to contract in specific patterns, they also provide motor output. These functions make nerves central to learning, adaptation, cognition, and behavior (Cleveland Clinic, 2022).

As mentioned by Marieb & Hoehn (2018), they defined nerves as a functional unit of the peripheral nervous system that enables two-way communication between the brain, spinal cord, and the rest of the body. Nerves transmit motor commands that regulate muscle contraction and glandular production in addition to sensory data like touch, pain, and temperature to the central nervous system. According to Bear, Connors & Paradiso (2020), which noted that a nerve is a conductor of electrochemical impulses, carrying action potentials that allow the body to respond rapidly to internal and external stimuli. Depending on the thickness of the axon and the existence of myelin, these impulses go along axons at different speeds. Salutatory conduction, which is used by militated nerves, significantly speeds up impulse transmission and is necessary for quick reflexes, coordinated movement, and sensory perception.

Concept of Nerves Injury

Nerve injury refers to any structural or functional disruption in the peripheral or central nervous system that impairs the ability of neurons to transmit signals effectively. According to Chen and Li (2020), nerve injury arises when mechanical, chemical, ischemic, or metabolic factors damage the axon, myelin sheath, or surrounding connective tissues. Thus, nerve injury is a complex physiological and pathological event that affects the body's communication network.

Fig.2: A picture of Nerves Injury

According to Hand Surgeon (2023), nerves are the wires that carry messages back and forth between the brain and the rest of the body. Some nerves carry messages from the brain to muscles to make the body move. Other nerves transmit information from the body to the brain regarding temperature, pressure, and pain. Each nerve contains numerous tiny fibers that are bundled together to transmit messages. Certain nerves, known as motor nerves, exclusively contain fibers that regulate muscles. Other nerves, known as sensory nerves, solely contain fibers that transmit information about touch and feeling. Those that possess both are referred to as having mixed nerves. A nerve's outer layer protects its fibers.

As mentioned by Elsevier (2025), nerve injury refers to damage to peripheral nerves caused by physical trauma, which can lead to various degrees of functional impairment and disability. Nerve injury is one of the most serious complications of peripheral nerve block. Nerve injury risk factors for patients have been identified (48A). Nowadays, nerve damage is a prevalent ailment, and there has been a lot of interest in treating it. It has now been discovered that OEC transplantation can be used to cure injuries and restore function. Based on severity, it is divided into five grades, each of which has a different impact on recovery results and regeneration ability. Researchers emphasize that nerve injury often presents with sensory disturbances, motor impairments, autonomic dysfunctions, or a combination of these symptoms, reflecting the multifaceted role of nerves in regulating bodily activities (Kim et al., 2021).

Concept of Anesthesia Nerve Injuries

Anesthesia nerve injury refers to the damage that occurs to a peripheral nerve during or after the administration of anesthesia, especially during surgical procedures. It happens when a nerve is compressed, stretched, punctured by a needle, exposed to toxic levels of an aesthetic drugs, or deprived of adequate blood supply.

Anesthesia nerve injury refers to structural or functional damage to a nerve that occurs during the administration of regional, general, or local anesthesia. According to Hines and Warner (2020), nerve injury often arises from mechanical compression, stretching, ischemia, or chemical irritation during an aesthetic procedures. Temporary symptoms including numbness, tingling, or weakness, as well as long-term paralysis or chronic neuropathic pain, can result from anesthesia-induced nerve damage.

These injuries happen when a nerve is traumatized by a needle during regional anesthesia, stretched as a result of incorrect positioning, or crushed by surgical tools. Clinically, anesthesia-related nerve injury may cause numbness, weakness, paresthesia, or long-term neuropathic pain, and while most cases are temporary, severe injuries may lead to permanent deficits (Mogensen & Allen, 2021). Overall, the concept highlights that anesthesia nerve injury is a multifactorial event influenced by procedural

techniques, patient factors, and surgical conditions, making prevention through safe practice essential (Hadzic & Neal, 2024).

Major Causes of Anesthesia Nerves Injuries

Although rare, nerve damage following anesthesia can result in severe short-term or long-term impairment. An injury is frequently caused by a combination of mechanical, ischemic, chemical, surgical, and patient variables, which are typically multifactorial. (Brull et al, 2015)

Major causes

- **Direct mechanical trauma (needle or catheter contact)**: Focal axonal or fascicular damage may result from needle-nerve or catheter-nerve contact during regional blocks, particularly if the needle penetrates intrafascicularly or if forceful needle manipulation takes place. This risk is decreased by careful technique and gentle feedback.

- **Local anesthetic neurotoxicity/intrafascicular injection**: Dose-dependent neurotoxicity (axonal degeneration, apoptosis) can result from intrafascicular injection or high concentrations of local anesthetics. Injury risk is increased when injecting into a fascicle or at high pressure. Preventive measures include avoiding intramural injection and using the proper dose and volume (Hewson, 2018).

- **Ischemic injury (vascular compromise)**: Ischemia of nerve fibers can result via compression, the use of tourniquets, bleeding, or damage to the vasa nervous. Susceptibility is increased by prolonged surgical durations and systemic hypotension. Ischemia frequently coexists with other traumas (such as compression + neurotoxicity).

- **Compression and stretch (positioning):** One common perioperative cause of neuropathy (such as ulnar or personal neuropathy) is malpositioning on the operating table (long stretch, external compression at bony prominences). Periodic inspections and appropriate padding are crucial preventive measures (Neal, 2018)

- **Haematoma / bleeding around the nerve:** A perineural hematoma can cause ischemic damage by compressing the nerve or its blood supply. This risk is increased by vascular damage, traumatic needle passes, and anticoagulation status. Early identification is crucial since evacuation might be necessary.

- **Infection and inflammation:** Neural tissue can be harmed by infection (rare) or inflammatory responses close to the nerve, which can result in chronic neuropathic pain. This cause is lessened by using sterile techniques and paying attention to infection risk factors (Hogan, 2008).

- **Patient factors and preexisting neuropathy:** Diabetes, peripheral vascular disease, smoking, senior age, or prior neurological disease make nerves more vulnerable to minor shocks and may impair outcomes. These considerations should be considered during planning and consent.

- **Surgical trauma and confounding causes:** It can be difficult to distinguish between anesthesia-related and surgical neuropathy because the final cause is frequently surgical (retraction, direct nerve transection) or associated with the underlying illness (Bais, 2024).

Effects of Anesthesia Nerve Injuries

Because they can result in long-term sensory and motor deficits that impair patients' everyday functioning, anesthesia-induced nerve injuries continue to be one of the most serious consequences related to perioperative care. According to Ahmed (2021), nerve injuries may occur due to direct needle trauma, compression from patient positioning, or ischemia during prolonged surgical procedures. While many cases recover on their own in a matter of weeks, some patients develop more serious problems that necessitate prolonged therapeutic care. The immediate effects typically manifest as numbness, tingling, or transient weakening in the area supplied by the afflicted nerve.

Persistent neuropathic pain is one of the main consequences of anesthesia nerve damage, and it can seriously lower quality of life. As noted by Lee and Park (2020), neuropathic pain following

perioperative nerve injury arises from abnormal nerve signaling and can present as burning sensations, shooting pain, or hypersensitivity to touch. This type of discomfort frequently develops into a chronic condition that causes psychological distress, decreased movement, and disturbed sleep. Neuropathic pain has an effect that goes beyond only physical discomfort because chronic pain syndromes are closely associated with anxiety and depression, which makes recovery more difficult.

Another significant result is motor dysfunction, especially when motor fibers are directly affected. Motor deficits can cause muscle weakness, an uneven gait, difficulty grasping objects, and poor limb coordination. In a study by González-Suárez (2022), postoperative nerve injuries affecting motor pathways were associated with delayed return to work and reduced independence in daily activities. Long-term physical therapy is necessary for these deficits, and in complicated cases, they may not completely improve, leaving patients with residual disability.

Furthermore, loss of protective feeling brought on by anesthesia-induced nerve damage might raise the risk of subsequent injuries like burns, falls, and skin ulcers. According to Malik (2023), patients with diminished sensation in the hands or feet may inadvertently expose themselves to harmful situations because they cannot adequately perceive pain or pressure. In addition to endangering physical safety, this sensory loss can hinder movement and general functionality, particularly in elderly folks or those with long-term medical conditions.

Lastly, people and healthcare systems are affected economically and psychosocially by anesthesia nerve damage. Long-term reliance on medical care, decreased productivity, and emotional anguish can result from persistent neurological impairments. Research by Fernandes, (2024) found that unresolved nerve injuries significantly increase hospital visits, rehabilitation costs, and the need for specialized neurologic assessment. These burdens highlight the necessity of improved preventive measures, including precise regional anesthesia techniques and real-time nerve monitoring.

Treatment of Anesthesia Nerves Injuries

An organized, evidence-based strategy that emphasises early detection, conservative therapy, diagnostic assessment, and, if required, surgical or interventional treatment is needed for anesthesia-related nerve damage. Prompt neurological assessment, recording sensory or motor impairments, and limb protection are all part of immediate management. Early patient communication, stopping local anesthetic infusions where necessary, and ruling out compressive or vascular problems are all stressed in the guidelines. These steps, recommended in recent anesthesia safety guidance, are critical for preventing progression and aiding recovery. (Chang, 2023; El-Tallawy, 2025).

Since many anesthesia-related peripheral nerve lesions heal on their own, conservative measures are frequently used in the early stages of treatment. These consist of range-of-motion exercises, occupational therapy, physiotherapy, and limb splinting in cases of motor weakness. Contemporary surgical and rehabilitation literature emphasises that early physiotherapy improves functional outcomes and prevents secondary complications such as joint stiffness or muscle atrophy (Harhaus, 2024; Lopes et al., 2022).

Pharmacologic therapy is crucial, particularly for neuropathic pain. Tricyclic antidepressants, gabapentin, pregabalin, and duloxetine are often prescribed drugs. These medications are frequently used in the treatment of perioperative neuropathy because they have shown efficacy in neuropathic pain pathways. In certain patients, topical medications like lidocaine or capsaicin patches may provide supplemental benefits.

While clinical evidence specific to anesthesia-induced neuropathy is still emerging, reviews show that neuropathic pain agents significantly reduce synesthesia and discomfort (Varshney, 2021; Couch et al., 2024).

Electrodiagnostic tests, including electromyography (EMG) and nerve conduction studies (NCS), are recommended if nerve impairments last more than a few weeks, usually three to six weeks. These can aid in differentiating between neurotmesis, axonotmesis, and neurapraxia. High-resolution ultrasound

or MRI neurography can also be utilized to assess nerve integrity and find compressive lesions such as haematomas. Studies from 2024–2025 highlight that timely electrodiagnostic evaluation improves treatment planning and surgical outcomes (Seidel et al., 2025; Goldsmith et al., 2024).

Prevention of Anesthesia Nerve Injuries

➢ Comprehensive Pre-Anesthetic Assessment

A thorough assessment before anesthesia helps identify patients at high risk of nerve injury. According to Patel (2023), conditions such as diabetes, obesity, peripheral neuropathy, alcoholism, and vascular diseases reduce nerve resilience and increase susceptibility to injury. Clinicians must examine baseline motor and sensory function to compare postoperative changes. Mogensen and Allen (2021) explain that understanding pre-existing weaknesses allows anesthetists to customize techniques that minimize nerve compression or stretching. This phase is crucial because patients with undiagnosed neuropathic tendencies frequently sustain nerve damage.

➢ Use of Ultrasound Guidance During Regional Blocks

One of the best methods to lessen nerve damage caused by needles is ultrasound imaging. It makes it possible to see nerves, muscles, veins, and the precise needle path in real time. O'Connor and Brull (2022) note that ultrasound prevents accidental intramural injection, reduces injection pressure, and increases block accuracy compared to traditional blind techniques. Chang (2021) also reported that ultrasound significantly lowers the rate of nerve injury in peripheral nerve blocks by ensuring safe needle placement and controlled drug deposition. Thus, its use is essential in modern anesthetic practice.

➢ Safe Injection Techniques and Avoidance of High Injection Pressure

Slow injection, cautious needle handling, and appropriate medication delivery are necessary to prevent nerve damage. According to Hines and Warner (2020), high injection pressure can cause fascicular rupture and ischemia, leading to permanent nerve damage. In order to prevent intrafascicular deposition, anesthetists must aspirate before injecting and halt the injection if the patient feels severe pain or paresthesia. Chemical neurotoxicity is less likely when the right amounts and concentrations are used. Monitoring opening injection pressure with a pressure-limiting device is strongly recommended in recent studies (O'Connor & Brull, 2022).

➢ Proper Patient Positioning and Padding During Surgery

Proper posture is essential, particularly when the patient is under general or spinal anesthesia and cannot feel pain or discomfort. Hadzic and Neal (2024) highlight that incorrect positioning—such as excessive arm abduction, rigid leg rotation, or compression over bony prominences—can stretch or compress nerves like the brachial plexus, ulnar nerve, or personal nerve. Adequate padding, neutral limb alignment, avoiding prolonged pressure, and regularly checking positions during long procedures significantly reduce nerve injuries. Studies show that most positioning-related injuries are entirely preventable (Patel, 2023).

➢ Continuous Intraoperative and Postoperative Monitoring

Early diagnosis of aberrant placement, oedema, or reduced limb perfusion is made possible by monitoring both during and after anesthesia. Chang (2021) emphasises that early recognition of warning signs prevents temporary nerve irritation from progressing to severe neuropathy. Early detection of intramural needle insertion during regional anesthesia is facilitated by tracking injection resistance and patient reaction. Following surgery, routine neurological examinations enable prompt diagnosis and treatments like physical therapy or neurology referrals. According to Mogensen and Allen (2021), timely intervention improves outcomes and prevents long-term deficits.

Conclusion

Anesthesia nerve injuries remain a critical patient-safety concern, requiring continuous vigilance and evidence-based practice. Understanding their major causes—ranging from patient factors to surgical

positioning and anesthetic techniques—is essential for effective prevention. Modern technologies such as ultrasound guidance and neuromonitoring have significantly enhanced accuracy and reduced risk. Strengthened training, standardized protocols, and timely postoperative assessment further contribute to safety assurance. By integrating these remedial strategies, anesthesia providers can minimize complications and improve patient outcomes. Overall, a proactive, multidisciplinary approach is vital for reducing nerve-injury incidence and promoting safer anesthetic care.

Recommendations

1. Comprehensive preoperative risk assessments should be implemented to identify patients with predisposing factors such as diabetes, obesity, neuropathies, or vascular diseases, ensuring customized preventive strategies are applied.
2. Adopt strict intraoperative positioning protocols with continuous monitoring to prevent mechanical compression, traction, or ischemic injury to vulnerable peripheral nerves during surgical procedures.
3. Increase the routine use of ultrasound guidance for regional anesthesia to enhance needle accuracy, avoid intraneural injections, and minimize mechanical or chemical nerve trauma.
4. Strengthen provider training and competency development through simulation-based education, hands-on workshops, and periodic skill evaluations to enhance safe anesthetic delivery practices.

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