ANESTHESIOLOGY™ 2014
OCTOBER 11-15 | NEW ORLEANS, LA

Session: L030
Session: L101

My Ulnar Neuropathy Has Resolved. Now I Have to Go for Spine Surgery in the Prone Surrender Position

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Disclosures: This presenter has no financial relationships with commercial interests

Stem Case and Key Questions Content

A 53-year-old male, 182 cm tall and weighing 87 kg, presents for lumbar laminectomy and fusion with neuromonitoring. He has history of hypertension, diabetes mellitus, smoking, bilateral ulnar neuropathy and spinal stenosis. The patient is complaining of severe back and lower extremity pain. He is a carpenter. Three years earlier he developed bilateral perioperative ulnar neuropathy after knee surgery in the supine position. The patient reports that he had tingling, pain, and motor weakness after the procedure. Motor weakness was incapacitating as he lost his grip and could not hold things. Patient noticed slow and gradual improvement of his sensory symptoms during the first six months after surgery. Motor weakness of both hands slowly improved, but persisted beyond the first postoperative year and completely resolved after fourteen months postoperatively. He was on disability for fifteen months until his symptoms completely resolved.

1. Is perioperative peripheral nerve injury (PPNI) a significant problem in the practice of anesthesiology?
2. How frequent is perioperative ulnar nerve injury? What are the risk factors? Is this patient at risk?
3. Which surgical procedures are considered high-risk for PPNI?
4. What are the mechanisms of PPNI? What is the etiology of PPNI?
5. Why are men more prone to develop perioperative ulnar neuropathy than women?
6. What is the mechanism of perioperative ulnar nerve injury?

A year ago the patient had endoscopic sinus surgery without any complications. The patient mentions that he notified the anesthesiologist of his previous history of ulnar neuropathy and the anesthesiologist padded his elbows during the surgery, and that is why it “went fine”. The patient is very concerned that he may develop ulnar neuropathy again, especially when positioned in the prone surrender position under general anesthesia.

7. The patient relates the uneventful endoscopic sinus surgery to the fact that the anesthesiologist padded his elbows. Is this the only reason he did not develop ulnar neuropathy? What would you tell the patient?
8. What is the clinical presentation of perioperative ulnar nerve injury? Is it common for patients to develop bilateral ulnar neuropathy? What is the prognosis of perioperative ulnar neuropathy?
9. During preoperative evaluation you notice that the patient is very muscular and he has limited

range of motion of the upper extremity. Is this concerning? Why?

Induction of general anesthesia and endotracheal intubation was uneventful. The patient is positioned in the prone surrender position. The neuromonitoring team will monitor somatosensory evoked potentials (SSEP) while stimulating both the ulnar and the median nerves.

10. Does the prone surrender position pose any risk to the brachial plexus or the ulnar nerve? Why?
11. How would you position the patient's head and neck, Shoulders and arms? Why?
12. Is the forearm position relevant to perioperative ulnar nerve injury? How would you position the forearm?
13. How would you pad the patient's upper extremity?
14. After placement of the arterial line, how would you position the wrist?

During the procedure, the right upper extremity SSEP signals show a 70% decrease in amplitude and 40% increase in latency. Is this concerning?

15. Is the right upper extremity SSEP change concerning? How would you modify the position of the upper extremity?
16. Does mean arterial pressure (MAP) affect nerve conduction and SSEP signals? What is the best MAP for the patient?
17. In the post-anesthesia care unit (PACU) the patient reports no symptoms of ulnar neuropathy. Examination reveals no change from preoperative neurological evaluation. Is the patient still at risk for perioperative ulnar neuropathy? What is the usual onset time for perioperative peripheral ulnar neuropathy?
18. What instructions would you give to the patient for the post-operative period?

The patient had L2-L5 laminectomy and fusion with cage instrumentation. Four days postoperatively the patient experienced severe radicular pain and lower extremity weakness. The diagnosis of cage malposition was made, and the patient is coming back for revision of the instrumentation in the lateral decubitus position under general anesthesia.

19. What are the mechanisms of perioperative upper extremity nerve injury in the lateral decubitus position?
20. Would you place a chest (axillary) roll? Why? How would you place it?
21. What would you use for a chest roll? Does it make a difference?
22. How would you position the dependent upper extremity?
23. How can you monitor perfusion in the dependent upper extremity to detect hypoperfusion due to compression of the dependent neurovascular bundle?
24. How would you position the non-dependent upper extremity?
25. How would you position the head and neck?
26. Is documentation of perioperative anesthetic management important in this case?

Model Discussion Content
Perioperative peripheral nerve injury (PPNI) is a rare but significant perioperative complication that can result in significant patient disability. The reported incidence of PPNI is 0.03-0.1% [1,

2]. According to the closed claims study, PPNI is the second leading cause of anesthesia malpractice litigation accounting for 16% of cases [3]. The incidence of perioperative peripheral ulnar nerve injury in surgical patients is 0.5% [2]. Ulnar neuropathy is the most common site of PPNI [2] and it comprises 28% of all anesthesia-related nerve injury malpractice claims [3].

Risk Factors

Risk factors for ulnar neuropathy include very thin and very obese patients, male gender, and prolonged hospitalization [4]. Pre-existing asymptomatic abnormal conduction in the contralateral ulnar nerve has been observed in patients who developed postoperative ulnar neuropathies [5]. Pre-existing subclinical neuropathy may manifest clinically in the perioperative period when patients are subject to certain predisposing factors [4, 6]. Induced and prolonged hypotension has been associated with perioperative ulnar nerve injury [7]. Positioning during anesthesia has been related to ulnar neuropathy [2]. Hypertension (Hazard ratio (HR) 2.2), diabetes mellitus (HR 2.4), renal disease (HR 1.9), coronary artery disease (HR 1.7), and smoking (HR 2.1) have been associated with PPNI injury [1]. This patient is considered high-risk for the development of perioperative ulnar nerve injury because of the previous history of ulnar neuropathy, existing co-morbidities, and his gender. In addition to patient related risk factors, he will be placed in the prone surrender position for a prolonged period of time under general anesthesia. Orthopedic and neurosurgical procedures are considered high-risk for PPNI injury [1].

Etiology of PPNI

The main mechanism of PPNI is peripheral nerve ischemia leading to disruption of the physiologic functions and slowing of conduction. Persistence of ischemia for prolonged periods of time will lead to PPNI. Mechanisms of PPNI include:

Stretch: Stretch of the peripheral nerve 5-15% beyond the resting length can cause ischemia due to compression of intraneural capillaries and stretch of the fibers.

Compression: Compression leads to damage of the nerve fibers and compression of blood supply.

Direct trauma: Direct trauma leads to disruption of nerve fibers.

Inflammation: Recent evidence suggests an inflammatory etiology of ulnar neuropathy with a favorable response to high-dose steroids [8].

Males have significantly less fat content on the medial aspect of the elbow and significantly larger tubercle of the coronoid process (1.5 times) compared to females [9]. Women have a significantly higher fat content (2-19 times) on the medial aspect of the elbow than men; while men have a thickened and more developed flexor retinaculum [2]. Men are more susceptible to direct pressure on unmyelinated ulnar nerve fibers than women [10]. The mechanism of perioperative ulnar neuropathy is multifactorial and not clearly understood. In the ASA closed claims study, the mechanism of ulnar neuropathy was explicitly stated in only 9% of malpractice claims [3]. Patient predisposition plays an important role as mentioned above. Predisposed individuals may develop ulnar neuropathy when subject to perioperative precipitating factors. The ulnar nerve has a superficial path along the medial epicondyle of the humerus. The ulnar collateral artery and vein run in close proximity to the ulnar nerve and may be affected by external pressure leading to reduced perfusion, ischemia and nerve injury [11]. Compression of

the ulnar nerve and its blood supply at the area of the tubercle of the coronoid may lead to ischemia. The ulnar nerve is relatively more sensitive to ischemia compared to the median and the radial nerves. Flexion of the elbow leads to elongation (stretch) of the ulnar nerve. Flexion of the elbow is associated with a decrease in the cross-sectional area of the cubital tunnel and ulnar nerve resulting in a significant increase in the intraneural and exteneural pressures causing a reduction in the perfusion pressure which can lead to ischemia [12]. Stretch of the ulnar nerve by elevation of the shoulder, flexion of the elbow, and dorsiflexion of the wrist, leads to a marked increase in the intraneural pressure [13]. Prolonged and profound hypotension can lead to peripheral nerve ischemia, especially in the presence of nerve stretch or compression in predisposed individuals.

The ulnar nerve runs a superficial course around the elbow and is vulnerable to compression. Padding the elbows is helpful but is not the only mechanism to protect the ulnar nerve. Perioperative ulnar nerve injury can occur despite of appropriate padding. Compression of the ulnar nerve can occur if the forearm is in the prone position. Flexion of the elbow stretches the ulnar nerve. The supine arms tucked position used in endoscopic sinus surgery is a low-risk position for PPNI because of the lack of elbow flexion and direct pressure on the ulnar nerve at the elbow. Usually the forearm is in the neutral position and minimal direct pressure against elbow exists.

Clinical Presentation and Prognosis

Perioperative ulnar neuropathy presents as a sensory deficit in 47% of the cases, while 53% of the deficits are mixed sensory and motor. Bilateral symptoms of ulnar neuropathy develop in 9% of the cases [4]. Fifty-three percent of patients with perioperative ulnar neuropathy regain complete recovery of sensory and motor functions by the first postoperative year. Six percent regain complete recovery of sensory and motor function but still complain of pain. At one year, 41% of patients have persistent deficits. Patients with sensory deficits have a better chance of complete recovery (80%) compared to patients with mixed motor and sensory deficits (35%) [4].

Preoperative Evaluation

Identifying the pattern of PPNI during preoperative evaluation of the patient is important because patients with motor symptoms have worse prognosis compared to those with sensory symptoms. Assessment of the range of motion and what positions can be tolerated by the patient is important, especially in high-risk patients. Because the patient is muscular, it is important to check the range of elbow extension that would be tolerated by the patient [14]. Extension of the elbow may overstretch the median nerve, leading to injury. Muscular patients and patients with limited elbow extension range may be at risk for median nerve injury if the arm is fully extended under general anesthesia. The reduced range of extension in these patients may lead to similar contraction of median nerve, making it more prone to overstretch. Overstretch of the median nerve under general anesthesia may occur when the arm is extended beyond the position tolerated by the awake patient [14, 15]. It is important to explain to the patient that the etiology of ulnar neuropathy is multifactorial and not completely understood. The prone surrender position is a high-risk position that stresses upper extremity peripheral nerves including the ulnar nerve. Patient predisposition plays a role in the development of perioperative ulnar neuropathy. Given his history, he is considered high-risk for perioperative ulnar nerve injury.

The prone Surrender (Superman) Position

In the prone surrender (superman) position, injury can occur along the entire length of the brachial plexus. Patients placed in the prone surrender (superman) position had a significantly higher incidence of position-related impending upper extremity nerve injury detected by SSEP compared to patients positioned in the supine arms tucked, supine arms out, and prone arms tucked positions [16]. Stretch is the main mechanism of injury. If the head is directed away from the arm, this can stretch the brachial plexus. Abduction of the shoulder greater than 90°, depression of the shoulder girdle, and elbow flexion can stretch the brachial plexus. Pronation of the forearm can increase direct pressure over the ulnar nerve at the elbow. The head of the humerus may compress the neurovascular bundle in the axilla thus leading to nerve damage. In a steep, prone Trendelenburg position the brachial plexus may be compressed between the clavicle and the first rib, especially with use of shoulder braces. Forearm supination significantly minimizes direct pressure over the ulnar nerve at the elbow (2 mmHg) compared with the neutral (69 mmHg) and prone (95 mmHg) forearm positions. Neutral forearm position resulted in significantly less pressure compared to the prone forearm position, however more pressure compared to the supine forearm position [11].

When patients are placed in the prone surrender position, the head and the neck should be in the neutral position. Extreme head flexion and extension can stretch the brachial plexus and should be avoided. If the head is directed away from the arm, this can stretch the brachial plexus; therefore lateral neck rotation should be avoided. Although patients may comfortably tolerate arm abduction greater than 90° in the prone surrender position [15], it is advisable to limit the shoulder abduction to less than 90° in order to avoid overstretching of the brachial plexus. Depression of the shoulder girdle should be avoided. Lateral rotation of the arm should be avoided as it can stretch the brachial plexus. The longitudinal axis of the forearm should be parallel to the longitudinal axis of patient to avoid outward rotation of the arm. Extreme elbow flexion should be avoided. The forearm should be placed in a neutral position to minimize the direct pressure on the ulnar nerve at the elbow. The forearm should be at or below the table mattress surface. The elbow and the inner aspect of the upper arm should be padded with foam to avoid direct pressure on the nerves. Foam padding around the elbow should not be tight (e.g. due to tight Velcro straps) to avoid compression of the ulnar nerve. The medial aspect of the upper arm should be padded to avoid direct pressure caused by the frame supporting the chest (e.g. Wilson frame). Prolonged overextension of wrist over the wrist board placed for arterial lines should be avoided as it may stretch the median nerve [15, 17].

Neuromonitoring

Somatosensory evoked potential (SSEP) monitoring has been used to detect peripheral nerve conduction abnormalities under general anesthesia. Conduction abnormalities indicate peripheral nerve stress and impending injury during surgery in variable intraoperative positions [16, 18-24]. Conduction changes detected by SSEP may indicate position-related impending peripheral nerve injury. In a retrospective study of 1000 consecutive spine cases, position modification of the upper extremity led to resolution of 92% of upper extremity SSEP changes [16].

Significant SSEP change indicating impending upper extremity nerve injury is usually defined as a reduction in amplitude of 50% or more, and/or an increase in latency of 10% or more [16]. Significant SSEP changes indicate abnormal conduction and impending nerve injury. If the changes persist for a prolonged period of time, permanent nerve injury may occur [11]. The use

of SSEP to monitor extremity nerve function and guide position modification of the upper extremity into a more favorable position for the peripheral nerve may protect peripheral nerves from injury under general anesthesia. The incidence of position related significant upper extremity SSEP changes during spine surgery ranges from 1.8 % to 15% depending on the type of spine surgery, the operative position, and patient group [16, 18-24].
Position modification strategies include: correcting extreme elbow flexion and extension, decreasing shoulder abduction, releasing tight safety straps, releasing tight foam pad straps, releasing shoulder traction on tucked arms (caused by taping down the shoulder), and moving the upper extremity into the original position if the position has been modified. After position modification of the upper extremity, the SSEP signal should be rechecked for resolution of SSEP change (usually after 10 minutes) [16].

Mean arterial blood pressure (MAP)
Perfusion of the peripheral nerve depends on perfusion pressure. Perfusion pressure is the difference between the MAP and local tissue pressure, in this case the intraneural and extraneural pressures. Increased intraneural and extaneural pressures due to operative positioning, will lead to a reduction of the perfusion pressure. Maintaining MAP and avoiding hypotension will help maintain tissue perfusion to the nerve. Appropriately increasing MAP can lead to the resolution of significant SSEP conduction change. The MAP within the physiologic range that leads to resolution of the SSEP conduction changes is considered the best for the patient. Before adjusting MAP, attempts should be made to modify the upper extremity position, which usually results in resolution of the SSEP change.

Postoperative Evaluation
Most cases of perioperative ulnar nerve injury do not manifest immediately postoperatively. Fewer than 10% of ulnar neuropathies are noted in the PACU. Initial symptoms are usually noted more than 24 hours after the procedure, and appear within 2-7 days in 90% of patients (median 3 days) [3, 4]. Ulnar nerve injury has been associated with prolonged hospitalization. New onset ulnar nerve injury occurred in hospitalized patients admitted to the internal medicine service. During hospitalization, the patients are usually lying in the supine position in bed with the elbows flexed and the forearms placed on the chest or the abdomen. Elbow flexion can stretch the ulnar nerve, and the prone position of the forearm leads to compression of the ulnar nerve by increasing direct pressure at the elbow. Patients should be advised to avoid this position and avoid keeping their arm in one position for prolonged periods of time during the postoperative period [25].

The lateral Decubitus Position
Patients placed in the lateral decubitus position had a significantly higher incidence of position-related impending upper extremity nerve injury detected by SSEP compared to patients positioned in the supine arms tucked, supine arms out, and prone arms tucked positions [16]. The lateral decubitus position may lead to nerve injury through stretch and compression. The dependent neurovascular bundle can be compressed between the head of the humerus and the chest. Compression of the brachial plexus can lead to direct nerve injury while compression of the axillary artery can lead to decreased perfusion and ischemia of the peripheral nerves. The stretch of the non-dependent brachial plexus can lead to injury. Direct pressure on the ulnar nerve at the non-dependent elbow may lead to nerve compression and injury. Overextension of the dependent elbow can stretch the median nerve.

A chest roll is useful to prevent compression of the dependent brachial plexus between the thorax and the humeral head. The roll is placed under the chest and not the axilla. It is a chest roll-not an axillary roll. The anesthesiologist can place his or her hands in the axilla while placing the chest roll to make sure it is appropriately positioned under the chest and not in the axilla. Intravenous fluid 1000 ml bags are usually used as chest rolls. However, the use of an inflatable pillow beneath the dependent chest was associated with significantly less pressure beneath the dependent shoulder and chest compared to a 1000 mL intravenous fluid bag or gel-pads [26]. Padding the dependent elbow while avoiding overextension to prevent stretching of the median nerve is important. The metal bars supporting the non-dependent arm should be clear of the dependent arm to avoid radial nerve compression. The forearm should be in the supine position to minimize pressure on the ulnar nerve at the elbow. If an arterial line is in place in the dependent extremity, it can be used to monitor and assess the perfusion. If an arterial line is unavailable, monitoring perfusion using pulse oximetry in the dependent arm is a good alternative.

The non-dependent arm should be positioned on an elevated arm rest. The arm rest should be padded with a soft pad. In addition, gel or foam padding should be placed under the elbow. The arm should be horizontal and at the same level of the non-dependent shoulder joint. Shoulder abduction greater than 90° should be avoided.
The head and neck should be in the neutral position. Extreme flexion and extension of the head can stress the brachial plexus and should be avoided. Lateralization of the cervical spine can stretch the contralateral brachial plexus.

Documentation
In general, it is very important to document key aspects and details of perioperative patient management. The anesthetic record and preoperative evaluation form should clearly reflect the anesthesiologist's perioperative management. In high-risk cases, like this case, details of preoperative anesthesia evaluation and discussion should be well documented. This includes documentation of preoperative neurological deficits, history of ulnar neuropathy, and key points discussed with the patient while obtaining informed consent. One of the most common causes of litigation in the practice of medicine is not informing the patient of the possible perioperative complications preoperatively. Details of intraoperative positioning should be clearly and legibly documented in the anesthetic record. Although the is no guarantee that PPNI can be completely prevented-especially in high-risk patients-anesthesiologists should apply current knowledge, guidelines, recommendations, and practice standards. It is imperative that the anesthesiologist documents what was done, because if it is not documented it was not done.

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