# The Risk of Persistent Paresthesia Is Not Increased with Repeated Axillary Block

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Neurologic deficits are noted on physical examination in approximately 0.2%–19% of patients after regional anesthetic techniques. Laboratory and clinical studies suggest that a subclinical neuropathy occurs much more often. Performing a regional anesthetic technique during this period may result in additional nerve trauma. We evaluated the frequency of neurologic complications in patients undergoing repeated axillary block. A total of 1614 blocks were performed on 607 patients. The median number of blocks per patient was two (range 2–10 blocks). The median interval between blocks was 12.6 wk, including 188 (31%) patients who received multiple blocks within 1 wk. Sixty-two neurologic complications occurred in 51 patients for an overall frequency of 8.4%. Of the 62 nerve injuries, 7 (11.3%) were related to the anesthetic technique; the remaining 55 (88.7%) were a result of the surgical procedure. Patient age and gender, the presence of preexisting neurologic conditions, a surgical procedure to a nerve, and total number of blocks did not increase the risk of neurologic complications. No regional anesthetic technique risk factors, including elicitation of a paresthesia, selection of local anesthetic, or addition of epinephrine, were identified. The success rate was higher with the paresthesia technique than with nerve stimulator technique or transarterial injection, and with use of mepivacaine versus bupivacaine. We conclude that the frequency of neurologic complications in patients undergoing repeated axillary block is similar to that in patients receiving a single regional technique. These patients are not likely to be at increased risk of neurologic complications. **Implications:** The risk of neurologic complications was not increased in patients who underwent multiple axillary blocks, even within a 1-wk interval. No risk factors for anesthetic-related complications were identified. However, block success rate was increased with the paresthesia technique and the injection of mepivacaine versus bupivacaine.

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Historically, the frequency of neurologic complications after axillary brachial plexus block has varied from 0.2% to 19% (1–4). Nerve injury related to regional anesthetic technique may be caused by direct trauma, local anesthetic toxicity, ischemia, or a combination of factors (5–7). Additional patient and surgical variables, such as the presence of a preexisting neurologic disorder, prolonged tourniquet time, and surgical approach may also contribute to the development and severity of postoperative nerve dysfunction (4,8–11). Although neurologic deficits are often identified in the immediate postoperative period, clinical studies have reported that the onset of neurologic sequelae may be delayed for days or even weeks after regional blockade (2,12). In addition, subclinical nerve injury as detected by nerve conduction studies may be present before the onset and after the recovery of clinical symptoms. Performing a regional anesthetic technique during the period of subclinical neuropathy may result in additional nerve injury and may increase the risk of neurologic complications. In the present retrospective study, we evaluated the frequency and risk factors for the development of neurologic complications in patients undergoing repeated axillary block. Factors affecting the success rate of axillary block—such as regional technique, selection of local anesthetic, and addition of epinephrine—were also studied.

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## Methods

After approval of our institutional review board, the medical records of all patients undergoing repeated axillary block over a 10-yr period from 1985 to 1994 were retrospectively reviewed. Patient demographics, including age at first block, gender, height, and weight, were recorded. The presence of a preexisting neurologic condition, such as cervical myelopathy or radiculopathy, mononeuropathy, or sensorimotor peripheral neuropathy on the operative extremity, and the preoperative




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neurologic examination (by the orthopedic surgeon and/or neurologist) were noted. Surgical procedures and total tourniquet times were reviewed. The regional technique used to locate the brachial plexus (elicitation of paresthesias, electrical nerve stimulation, transarterial injection) and the neural distribution of all paresthesias or motor responses during needle placement were recorded. Needle gauge and bevel, local anesthetic concentration, and the addition of epinephrine were noted. These data are routinely reported on our anesthesia block record. Axillary blocks were performed by attending staff and residents. Block success rate, defined as the ability to proceed without supplemental local anesthetic injection or the administration of general anesthesia, was noted. General anesthesia was defined as the administration of nitrous oxide, volatile anesthetics, or propofol infusion $>75\ \mu g \cdot kg^{-1} \cdot min^{-1}$. Factors potentially associated with successful block (regional technique, local anesthetic, addition of epinephrine, total tourniquet time) were assessed univariately using the two-sample rank sum test for continuous variables and the $\chi^2$ test for categorical variables.

The patient's hospital record was reviewed for worsening of preexisting neurologic deficits or new neurologic symptoms, such as persistent pain or alterations in sensation or motor function present after resolution of the axillary block. Neurologic status of the operative limb is evaluated by the surgical service and recorded daily for all hospitalized orthopedic hand patients. In addition, a neurologic examination is also performed and documented during follow-up visits by the surgeon, typically scheduled for 2 and 4 wk after hospital discharge. The etiology of the neurologic sequelae was judged to be surgery- or anesthesia-related on the basis of the level and distribution of the nerve injury. Other complications associated with axillary block, including infection and hematoma, were also recorded. Subsequent outpatient and inpatient registrations were reviewed to evaluate neurologic recovery. Duration of neurologic complications and length of follow-up were noted.

Potential factors associated with the development of neurologic complications (preexisting neurologic diagnosis, surgery to a nerve, total tourniquet time, number of previous blocks, interval between blocks, regional technique, local anesthetic, addition of epinephrine) were assessed using the two-sample rank sum test for continuous variables and Fisher's exact test for categorical variables. Separate analyses were performed to compare patients who experienced surgical- and anesthetic-related complications versus patients who did not develop neurologic complications. To analyze anesthetic and surgical variables between patients who experienced complications and those who did not, an index block was defined for each patient. For patients with neurologic complications, the index block was defined as the block before the diagnosis of the neurologic complication. For patients without neurologic complications, the index block was defined as the last block in the study period. In all cases, two-sided tests were used with $P \leq 0.05$ used to denote statistical significance.

## Results

Six hundred seven patients underwent 1614 axillary blocks. Eleven patients received multiple blocks bilaterally. Mean patient age at the time of first block was 42 ± 18 yr. There were 226 (37.2%) female and 381 (62.8%) male patients. A preexisting neurologic condition was present in 247 (40.7%) patients, including 234 (38.6%) patients with a mononeuropathy, 18 (3.0%) patients with a sensorimotor peripheral neuropathy, and 12 (2.0%) patients with a radiculopathy. The mononeuropathy involved the ulnar nerve in 127 (21%) or the median nerve in 118 (19%) patients. Multiple neurologic diagnoses were present in 17 patients preoperatively. Diabetes requiring treatment with oral drugs or insulin was diagnosed in 27 (4.4%) patients. An operation on a nerve occurred as the primary surgical goal or as a part of another surgical procedure in 162 (10.0%) of the cases. A tourniquet was used in 1158 (71.7%) procedures; the mean total tourniquet time in these was 71 ± 52 min (range 4 to 488 min).

The median number of blocks per patient was two (range 2–10 blocks). The median interval between blocks was 12.6 wk (range 2 days to 10 yr). However, 188 (31%) patients received multiple blocks within 1 wk, including 51 patients who underwent three or more blocks within a 1-wk period. Within 2-, 4-, and 8-wk time intervals, multiple blocks were performed on 222 (37%), 251 (41%), and 285 (47%) patients, respectively.

A long-beveled needle was used in 947 (58.6%), a short-beveled needle was used in 542 (33.6%), and an unspecified needle type was used in 129 (7.9%) of blocks (Table 1). Epinephrine was added to the local anesthetic solution in 1155 (71.6%) of blocks. Local anesthetic volume was 47 ± 8 mL. Fourteen blocks were performed before an anticipated general anesthetic; these blocks were not included in the analysis of success rate. Inadequate anesthesia requiring supplementation was reported in 239 (14.9%) of cases. Regional technique significantly affected block success rate. Success rate was higher with the paresthesia technique compared with the nerve stimulator technique or transarterial injection (Table 1). In addition, the success rate with mepivacaine (88.6%) was significantly higher than that with bupivacaine (83.4%) ($P = 0.007$). Total tourniquet time was increased in patients with failed blocks (75 ± 65 min) compared with those with successful blocks (47 ± 50 min) ($P < 0.001$).

**Table 1.** Regional Technique and Success Rate

| | Total blocks *n* (%) | Successful block (%) | *P* value |
|---|---|---|---|
| Technique | | | 0.018 |
| Paresthesia | 222 (13.9) | 89.6 | |
| Combination[a] | 686 (42.9) | 86.9 | |
| Nerve stimulator | 318 (19.9) | 83.0 | |
| Transarterial | 316 (19.8) | 81.3 | |
| Other/unspecified[b] | 58 (3.6) | 77.6 | |
| Local anesthetic | | | 0.007 |
| Bupivacaine | 584 (36.5) | 83.3 | |
| Mepivacaine | 718 (44.9) | 88.6 | |
| Other/unspecified[b] | 298 (18.6) | 79.8 | |
| Epinephrine | | | NS |
| Yes | 1143 (71.4) | 85.5 | |
| No | 457 (28.6) | 83.8 | |

Of the 1614 blocks that were performed before an anticipated general anesthetic, 14 were not included in the analysis of success rate ($n = 1600$).
NS = not significant.
[a] Paresthesia or nerve stimulator combined with transarterial injection.
[b] This group not included in comparison.
Using pairwise comparisons, success rate with paresthesia technique is significantly higher than that with nerve stimulator ($P = 0.030$) or transarterial injection ($P = 0.008$); the combination technique is more successful than transarterial injection ($P = 0.022$).

There were 62 neurologic complications in 51 of the 607 patients, for an overall frequency of 8.4%. There were also five patients with postoperative neuroma formation related to surgery. Neuromas were not considered neurologic complications. Only 7 of 62 (11.3%) nerve injuries were related to the anesthetic technique; the remaining 55 (88.7%) were a result of the surgical procedure. Three patients experienced both surgical and anesthesia-related neural injuries. Nerve injuries associated with the surgical procedure included direct surgical trauma or stretch injury in 40 cases, inflammation or infection in 6 cases, hematoma or vascular compromise in 4 cases, cast irritation in 3 cases, and tourniquet ischemia in 2 cases. Fourteen patients underwent subsequent surgery to restore nerve function.

A single nerve was involved in 42 patients. The remaining nine patients had multiple neural complications, including three patients with symptoms that occurred after different surgical procedures. The ulnar nerve was the most often involved (Table 2). Symptoms were pain or hypersensitivity in 33 (48.5%), numbness in 27 (39.7%), and weakness in 8 (11.8%) patients; nerve injuries may have resulted in more than one symptom. The seven neuropraxias associated with regional technique consisted of pain/hypersensitivity in four patients and numbness in three patients. In addition, the postoperative nerve deficit occurred in the distribution of an elicited paresthesia or nerve stimulator response in five of the seven patients (Table 3). All complications involving motor deficits were surgical (Table 2). Despite postoperative neurologic complications, only 15 of 51 patients (11 with surgical and 4 with anesthetic-related complications) did not undergo subsequent blocks.

Patient, anesthetic, and surgical variables were analyzed to assess associations with the development of neurologic complications. Patient age and gender; the presence of preexisting neurologic conditions or diabetes; a surgical procedure to a nerve; tourniquet time; or performance of repeated blocks within 1, 2, 4, or 8 wk did not increase the risk of anesthesia-related complications. In addition, no regional anesthetic technique risk factors—including elicitation of a paresthesia or nerve stimulator response, use of epinephrine, the use of a long-beveled needle, and selection of bupivacaine—were significantly associated with anesthesia-related neurologic complications. Maximal total tourniquet time was significantly longer among patients with surgical complications versus those with no complications ($P < 0.01$) (Table 4). There were two patients with axillary hematomas; neither resulted in neurologic symptoms or required surgical drainage. No patient developed infection at the needle insertion site.

## Discussion

Perioperative nerve injuries have long been recognized as a complication of regional anesthesia. Kroll et al. (13) examined the ASA Closed Claims database to determine the role of nerve damage in malpractice claims filed against anesthesia care providers. Of the 1541 claims reviewed, 227 (15%) were for anesthesia-related nerve injury. Injuries to the brachial plexus or the ulnar, radial, and median nerves accounted for nearly two thirds of all nerve injuries. The use of regional anesthesia was significantly more common in claims involving nerve damage (82 of 227 claims) compared with the incidence of regional anesthesia in claims not involving nerve damage (296 of 1314 claims). The potential risk of nerve injury from needle trauma, local anesthetic toxicity, or neural ischemia during regional anesthetic techniques increases the probability that the neurologic deficit will be attributed to the anesthetic.

Neurologic deficits that arise within the first 24 h most likely represent extra- or intraneural hematoma, intraneural edema, or a lesion involving a sufficient number of nerve fibers to allow immediate diagnosis (14). However, in many cases of persistent paresthesias after regional anesthesia, the symptoms of nerve injury do not develop immediately after the injury, but have their onset days or weeks later (2,4,12,14). The presentation of late disturbances in nerve function suggests an alternative etiology, such as tissue reaction or scar formation, although it is not possible from the existing data to determine whether this reaction is due to mechanical trauma, chemical trauma, or both. Löfström et al. (12) evaluated late disturbances in nerve conduction after ulnar nerve block at the elbow. The technique was varied to produce different degrees

**Table 2.** Neurologic Complications

| Etiology | *n* | Nerve injured: Ulnar | Radial | Median | Other | Onset of symptoms (wk) | Duration of symptoms (wk) |
|---|---|---|---|---|---|---|---|
| Surgical | 55 | 20 | 19 | 14 | 2 | 3.0 (0.0–45) | 12.0 (0.1–364) |
| Anesthetic | 7 | 4 | 1 | 1 | 1 | 1.3 (0.1–5) | 4.0 (0.1–20) |

There were 62 neurologic complications in 51 patients.
Data are median (range)

**Table 3.** Patients with Anesthesia-Related Neurologic Complications

| Age (yr)/gender | Preexisting neurologic disease | Time of previous block (mo) | Regional technique during block before development of complication | Local anesthetic | Nerve(s) involved | Symptoms | Onset of symptoms | Duration of symptoms | Subsequent axillary blocks | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| 53 M[a] | None | None | Unknown | Bupivacaine 0.5% | Ulnar | Pain | 13 days | 14 days | 2 | Concomitant surgical complication |
| | | | | | Superficial radial | Numbness | 13 days | 14 days | | |
| 22 F[a] | None | None | Paresthesia (radial, ulnar) | Mepivacaine 1.0% with epinephrine | Radial | Numbness | 41 days | 12 wk | 3 | Subsequent surgical complication |
| | | | | | Ulnar | Numbness | 33 days | 20 wk | | |
| 27 M | None | 9 | Combination (ulnar, median paresthesias) | Bupivacaine 0.5% with epinephrine | Ulnar | Numbness | 1 day | 9 wk | 0 | |
| 29 M | Ulnar Neuro-pathy | 4 | Combination (ulnar, median paresthesias) | Bupivacaine 0.5% with epinephrine | Ulnar | Pain | 1 wk | 4 wk | 0 | |
| 22 F | None | 12 | Combination (median paresthesia) | Mepivacaine 1.25% with epinephrine | Median | Numbness | 1 day | 1 day | 0 | |
| 26 F | None | 6 | Nerve stimulator (ulnar, median, radial responses) | Bupivacaine 0.5% with epinephrine | Radial | Pain | 9 days | 4 wk | 0 | |
| 36 F[a] | None | None | Paresthesia (ulnar, median, and radial) | Bupivacaine 0.5% with epinephrine | Musculo-cutaneous | Pain | 27 days | 20 wk | 7 | Concomitant sugical complication |
| | | | | | Ulnar | Weakness | 27 days | 12 wk | | |

[a] Three patients with anesthesia-related neurologic complications also reported concomitant or subsequent surgical neurologic complications.

of mechanical trauma: intra- and extraneuronal injection, single and multiple injections of local anesthetic, and speed of injection were investigated. Although ulnar nerve action potential returned to normal within 24 h after injection in all subjects, subsequent examinations at weekly intervals detected abnormally low amplitudes in 3 of 28 subjects, although only 1 complained of neurologic dysfunction. All three subjects with decreased nerve action potential had undergone a traumatic injection technique characterized by rapid intraneuronal injection. Extraneuronally injected local anesthetic, intraneuronally injected saline, and needle puncture alone (without injection) did not produce electroneurographic signs of nerve damage in any subject. The decrease in amplitude reached a maximum at approximately 3 wk and demonstrated regression 2–3 mo after the block. Late disturbances in nerve function have also been reported after human microneurography, a technique involving percutaneous electrical stimulation of a nerve (15).

Laboratory studies demonstrate that a subclinical neuropathy is present before clinical dysfunction is noted. After sciatic nerve impalement with an axillary block needle in rats, histologic changes consistent with axonal injury persisted for 28 days. However, clinical evidence of hind leg hyposensitivity was present for only 2 wk (16). Performing a regional anesthetic technique during the period of subclinical neuropathy would theoretically result in additional nerve injury and increase the risk of neurologic complications. Although it is impossible to definitively determine during what time period patients would be at increased risk of neurologic complications if additional nerve trauma occurred, several laboratory studies reported at least partial resolution of trauma-induced nerve injury within 1 mo (16,17). Therefore, our analysis

**Table 4.** Risk Factors for Neurologic Complications

| Risk factor | Patients without complications ($n$ = 551) | Patients with anesthesia complications ($n$ = 7) | Patients with surgical complications ($n$ = 47) |
|---|---|---|---|
| Age (yr) | 43 ± 18 | 30 ± 11 | 42 ± 17 |
| Gender | | | |
| Male | 348 (63) | 3 (43) | 28 (60) |
| Female | 203 (37) | 4 (57) | 19 (40) |
| Preexisting neuropathy | 227 (41) | 2 (29) | 17 (36) |
| Diabetes | 25 (5) | 0 (0) | 2 (4) |
| Index block/surgery characteristics[a] | | | |
| Surgery to a nerve | 43 (8) | 1 (14) | 7 (15) |
| Elicitation of paresthesia or nerve stimulator response[b] | 432 (80) | 6 (100) | 31 (67) |
| Total tourniquet time for index surgery (min) | 45 ± 49 | 49 ± 39 | 66 ± 51* |
| Block/surgical characteristics of 1-wk period ending on date of index block[a] | | | |
| More than one block performed | 127 (23) | 0 (0) | 7 (15) |
| Surgery to a nerve | 52 (9) | 1 (14) | 7 (15) |
| Any elicitation of paresthesia or nerve stimulator response[b] | 447 (81) | 6 (100) | 34 (74) |
| Maximal total tourniquet time for any surgery (min) | 51 ± 49 | 49 ± 39 | 71 ± 49* |
| Block/surgical characteristics of 4-wk period ending on date of index block[a] | | | |
| More than one block performed | 182 (33) | 0 (0) | 6 (13) |
| Surgery to a nerve | 61 (11) | 1 (14) | 7 (15) |
| Any elicitation of paresthesia or nerve stimulator response[b] | 456 (83) | 6 (100) | 34 (74) |
| Maximal total tourniquet time for any surgery (min) | 56 ± 51 | 49 ± 39 | 74 ± 48* |

Of 607 patients, there were 551 with no complications and 51 with neurologic complications. Three patients had both surgical and anesthesia-related neurologic complications and are included in both groups. There were five patients who developed neuromas related to surgery; these were excluded from the risk factor analysis.

Values are mean ± SD or $n$ (%).

* Significantly greater than those patients who did not experience neurologic complications ($P < 0.01$, two-sample rank sum test).

[a] The block performed before the diagnosis of neurologic complication. In patients without neurologic complications, the index block is the last block the patient underwent in the study.

[b] Data on block technique were incomplete for 10 patients without complications and 1 patient who experienced surgical and anesthesia-related complications.

evaluated the risk of neurologic complications for patients undergoing multiple blocks within 1-, 2-, 4-, and 8-wk periods.

We reported a 1.2% (95% confidence interval 0.5%–2.4%) frequency of anesthesia-related neurologic complications in patients undergoing repeated axillary block. Multiple blocks performed within a 1-, 2-, 4-, or 8-wk period did not increase the frequency of neurologic complications among our patients. Nearly one third of all patients underwent multiple blocks within a 1-wk period, and >40% underwent multiple blocks within a 4-wk interval. However, none of the seven patients with anesthesia-related neurologic complications underwent more than one block in the 4-wk period ending on the date of their index block.

The development of a neurologic complication did not necessarily preclude performance of subsequent axillary blocks; three of seven patients with anesthesia-related nerve injury underwent additional regional techniques uneventfully (Table 3). We did not include a group of control patients undergoing a single axillary block because the frequency of neurologic complications reported was so low and the number of patients undergoing repeated blocks is limited.

Our study identified tourniquet time as a risk factor for the development of surgery-related neurologic complications. Prolonged tourniquet time has historically been associated with neural ischemia and dysfunction (8). However, the amount and duration of pressure required to produce persisting paralysis are extremely variable (9). In our study, the correlation of total tourniquet time with neurologic complications was noted not only for the index block (the block immediately preceding the diagnosis of the neurologic dysfunction), but also for the maximal total tourniquet time of any single surgery performed within 1 and 4 wk of the index block (Table 4). These data suggest that reversible and/or repeated neural ischemia from tourniquet inflation may contribute to postoperative neurologic deficits.

Regional technique may affect the frequency of neurologic complications. Theoretically, the elicitation of a paresthesia during axillary block may represent direct needle-induced trauma and increase the risk of persistent paresthesia. Selander et al. (2) reported a higher incidence of postoperative nerve injury in patients in whom a paresthesia was sought during axillary block (2.8%) compared with that in patients undergoing a transaxillary artery technique (0.8%), although the difference was not significant. The neurologic deficits ranged from slight hypersensitivity to severe paresis and persisted for 2 wk to >1 yr. Additional regional anesthetic factors that may influence the degree of nerve injury include needle gauge and type, needle bevel configuration, local anesthetic, and addition of epinephrine, although the findings are controversial (5–7,16). There are no clinical studies that report a significant increase in nerve injury related to a regional anesthetic technique, needle type, local anesthetic solution, or addition of vasoconstrictors.

We did not note an increase in neurologic complications associated with regional anesthetic approaches that involved identification of one or more nerves with a paresthesia or nerve stimulator techniques. However, we cannot definitively rule out the regional technique as a possible risk factor. Although a paresthesia was elicited in nearly 60% of blocks in our study, analysis of the regional technique used to perform the block immediately preceding the diagnosis of a neurologic complication reveals that one or more paresthesias was elicited in five of seven patients with a persistent paresthesia. The postoperative nerve deficit occurred in the distribution of an elicited paresthesia in four of the five patients (Table 3). These results agree with those of Auroy et al. (14), who reported that all cases of persistent paresthesia after spinal, epidural, or peripheral blockade occurred in the same topography as the associated paresthesia.

The possible association between elicitation of a paresthesia, intentional or accidental, during regional block has lead some anesthesiologists to conclude that nerve blocks should be performed without seeking paresthesias (2,18). However, serious and disabling neurologic complications may follow an axillary block using nerve stimulator or transarterial techniques (4,19). In addition, the paresthesia technique is associated with a significantly higher success rate than other approaches, which emphasizes the need to consider potential risks and benefits when selecting an anesthetic technique.

In summary, anesthetic-related neurologic complications were noted in 7 of 607 patients undergoing 1614 axillary blocks. Most neurologic complications (88.7%) were related to the surgical procedure. Performance of multiple regional techniques, even within 1 wk, did not increase the risk of neurologic complications. These results affirm the safety of regional anesthesia, as well as the need to thoroughly evaluate patients with a postoperative deficit for all possible etiologies of neural injury. Documentation of preexisting deficits is also advantageous. Although postoperative neurologic complications may present immediately after surgery, some may require days or even weeks to emerge. Should neurologic dysfunction occur, timely evaluation with a multidisciplinary approach involving neurology, radiology, internal medicine, and surgery will allow appropriate evaluation and treatment.

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