Injection Pressures by Anesthesiologists During Simulated Peripheral Nerve Block

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Background and Objectives: Anesthesiologists typically rely on a subjective evaluation ("syringe feel") of possible abnormal resistance to injection while performing a peripheral nerve block (PNB). A greater force required to perform the injection is believed to be associated with intraneural injection. The hypothesis of this study is that anesthesiologists vary in their perception of "normal" injection force, that the syringe feel method is inconsistent in estimating resistance, and that needle design may affect the injection force.

Methods: Thirty anesthesiologists were asked to inject a local anesthetic, as they would in their everyday practice, through a commonly used syringe and needle assembly. Injection force was measured using an in-line manometer coupled to a computer via an analog-to-digital conversion board. In addition, injection force at clinically relevant injection speeds was determined using 3 differently sized needles from 4 different manufacturers.

Results: During a steady injection rate, all anesthesiologists perceived an increase in the force required to inject, even with minor pressures changes (0.6 ± 0.3 psi). However, the 30 anesthesiologists, 21 (70%) initiated injection using a force that resulted in pressures greater than 20 psi; 15 (50%) used a force greater than 25 psi, and 3 (10%) exerted pressures greater than 30 psi. Pressures varied as much as 20-fold among needles of the same gauge/length from different manufacturers ($P < .01$).

Conclusions: Anesthesiologists vary widely in their perception of appropriate force and rate of injection during PNB. The syringe-feel method of assessing injection force is inconsistent and may be further affected by variability in needle design. *Reg Anesth Pain Med 2004;29:201-205.*

Key Words: Regional anesthesia, Peripheral nerve block, Neurologic complications, Needle.

Permanent neurologic injury from intraneural injection is a rare but potentially devastating complication during peripheral nerve block (PNB).[1] Because a greater force required to perform the injection (injection force) may be associated with intraneural injection, anesthesiologists often rely on a subjective evaluation ("syringe feel") to determine abnormal resistance to injection.[1] Although there is a paucity of clinical data, educational material on regional anesthesia, including major textbooks, suggests that patient pain and high injection pressure may portend intraneural injection of local anesthetic and perhaps increase the potential for nerve injury.[2-6] Indeed, studies performed in animal models indicate that greater force is required to inject a local anesthetic intraneurally than perineurally.[2] In clinical practice, anesthesiologists typically use a syringe-feel method to estimate what may be an abnormally high resistance to injection. However, the force perceived by a practitioner is subjective and may be influenced by such factors as the size of the syringe, the speed of injection, and needle design. We hypothesized that anesthesiologists would vary in their perception of "normal" injection force during a simulated PNB, that the syringe-feel method is inconsistent in estimating resistance, and that needle design may affect the injection force.

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Methods

Thirty attending anesthesiologists, having diverse experience with peripheral nerve blocks and unaware of the purpose of the study, were evaluated. All subjects had between 2 and 10 years clinical experience and performed between 5 and 10 PNBs a month. Because the subjects have been de-identified by the nature of the enrollment and type of the data collected, institutional review board approval was not required.

In the first phase of the experiment, the subjects were presented with a hypothetical clinical scenario in which they were asked to assist in performing a PNB by injecting local anesthetic for another practitioner. They were asked to inject the anesthetic at the same speed and force they use in their own clinical practice and to stop the injection if they thought the force being used was greater than "normal." All subjects were tested on the same apparatus, and all tests were done in triplicate. Injections were performed using a 50-mm, 22-gauge needle (Stimuplex, B. Braun, Inc, Bethlehem, PA) connected via flexible tubing and a 3-way stopcock to a pair of 20-mL syringes containing local anesthetic. The needle was submerged in a beaker filled with local anesthetic. Pressure data were acquired using an in-line manometer (PG5000, PSI-Tronics Technologies Inc, Tulare, CA) coupled to a computer via a DAQ 6023 analog-to-digital conversion board (National Instruments, Austin, TX) and analyzed using the BioBench version 1.2 data analysis software package (National Instruments, Austin, TX). Pressure data points greater than 1 second in duration were analyzed.

In the second phase of the study, subjects were again asked to inject a local anesthetic, this time at a steady rate consistent with what they would use in their own clinical practices. Using an in-line flow restrictor (Abbott Laboratories, North Chicago, IL), the resistance was gradually increased in a stepwise fashion to achieve an increase in injection pressure of approximately 0.1 psi/s. The subjects (unaware that the resistance was being increased) were asked to report when they felt that the injection force required was greater than "normal." All measurements where recorded in triplicate; mean pressure at which subjects reported a change in perceived injection force required was recorded.

In the final phase of the experiment, 3 needle sizes (50-mm/22-gauge, 100-mm/21-gauge; 150-mm/20-gauge) from 4 different manufacturers were tested. Three needles of each length and diameter were tested. For each needle size, the pressure generated during a constant rate of injection was measured using a PHD 2000 automated infusion pump (Harvard Apparatus, Holliston, MA). Pressures were recorded at injection speeds of 10, 15, 20, and 25 mL/min. These rates were chosen to reflect the range of injection rates commonly used in clinical practice.[7-10]

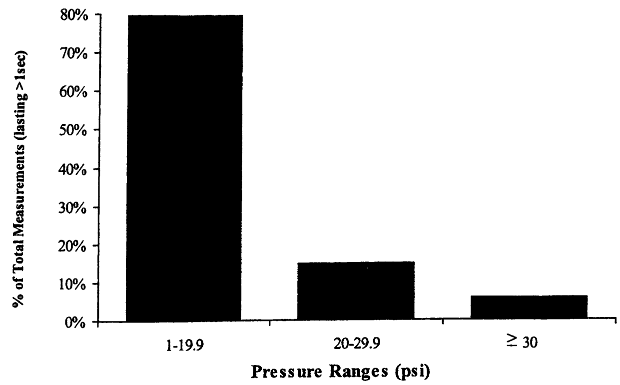

Fig 1. Injection pressure generated by anesthesiologists (n = 30) during simulation of interscalene brachial plexus block injection.

Statistical Analyses

Thirty anesthesiologists were required for the power of 0.80 to detect a moderate difference in pressures at $\alpha = 0.05$ for paired analyses.[11] Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 5.0.2 for Windows. All measurements were performed in triplicate, and results are expressed as the mean ± standard deviation (SD) for normal distributed data and as the median and range for data not normally distributed. One-way analyses of variance were applied to evaluate differences in injection pressures in the 3 phases of the study. Correlation analysis was used to study the relationship of speed of injection to pressure. A P value $\leq .05$ was considered to be significant.

Results

None of the subjects reported the injection force as unusually high. The number of occurrences where a pressure was maintained for at least 1 second is indicated in Fig 1. Of the 1,394 measurements, 79.5% occurred between pressures of 1 and 19.9 psi, 14.7% occurred between pressures of 20 and 29.9 psi, and 5.6% occurred at pressures exceeding 30 psi (Fig 1). Twenty-one (70%) subjects exerted force in excess of 20 psi at some time during the injection, 15 (50%) exerted force greater than 25 psi, and 3 (10%) exerted force greater than 30 psi. Of note, higher pressure measurements (>20 psi) occurred mostly (95% of the time) at the

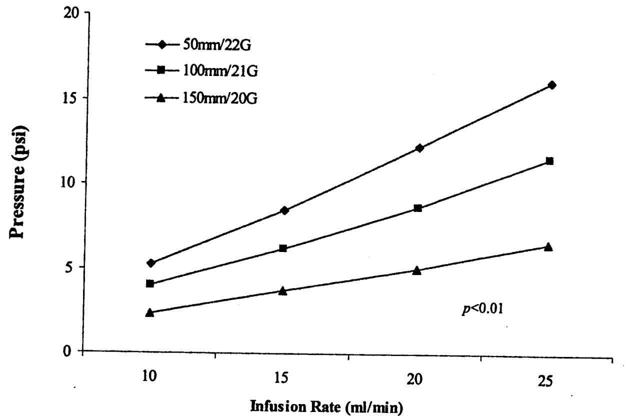

Fig 2. Effects of the needle diameter (gauge) and length on force (pressure) require to inject using 4 different injection rates. Needles used were Stimuplex 50 mm/22-gauge, 100 mm/21-gauge, and 150 mm/20-gauge (B. Braun, Inc., Bethlehem, PA).

beginning of the injection (during the first 5 seconds).

The time required to inject 40 mL of local anesthetic ranged from 87 to 250 seconds (median, 130 seconds). Five subjects (17%) injected at a rate >25 mL/min, 15 (50%) injected at 15 to 25 mL/min, and 10 (33%) injected at <15 mL/min. Subjects perceived a change in injection force of 0.6 ± 0.3 psi (range, 0.3 to 1.2 psi) when a stepwise resistance was applied to the tubing. Whereas all subjects detected subtle changes in injection force as resistance was applied to the tubing during a steady injection, none of them aborted the injection at any time because of high pressure.

Injection pressure correlated with speed of injection and varied with type of needle tested ($r^2 = 0.95$)(Fig 2). Higher injection pressures were recorded with faster injection rates (Fig 2). Surprisingly, injection pressure varied among needles of the same gauge and length but from different manufacturers. For instance, for an injection rate of 15 mL/min through a 50-mm, 22-gauge needle, the highest pressure (36.3 psi) was recorded with needle from manufacturer A, and the lowest pressure (1.8 psi) was recorded with a needle from manufacturer B ($P < .01$) (Fig 3).

Discussion

Subjective assessment of injection force is often used by practitioners during initiation of a PNB.[5,6,12] because a greater injection force may be associated with an intraneural injection and consequent mechanical injury to the nerve.[2] During this assessment, clinicians are typically trying to sense the resistance to injection (ratio of force divided by flow), or how much force is required to generate a given flow, using a syringe-feel method. Perception of the force required to initiate a nerve block injection is influenced by the internal resistance of the needle, the density of the tissue into which the needle is inserted (resistance), and the size of the contact surface between the thumb (or hand) and the plunger. Once the injection has begun, clinicians then continuously assess the applied force relative to the flow of the injectate.

Although no current data prove the relationship of excessive injection force to nerve injury in humans, slow administration, gentle injection, and avoiding high pressures are widely recommended when performing a PNB.[2-6] However, the subjects of our study had widely divergent perceptions of what constitutes a "normal" versus an "abnormal" injection force when using a syringe-feel method. In addition, they often exerted forces that resulted in injection pressures in excess of those that may be associated with intraneural injection in experimental models.[2] For instance, some 5% of the recorded pressure data were in excess of 30 psi, yet none of the subjects perceived this pressure as being abnormally high, and none of them aborted the injection. Instead, they controlled the rate of injection to keep the force of injection under what they felt was abnormally high. Interestingly, once the injection was initiated, changes in pressure as small as 0.2 to 1.2 psi were easily detected by all subjects. This finding perhaps might explain why most trainees quickly master the loss-of-resistance technique for identifying the epidural space. However, perception of what constitutes abnormal pressure at the beginning of the injection varied widely among our sub-

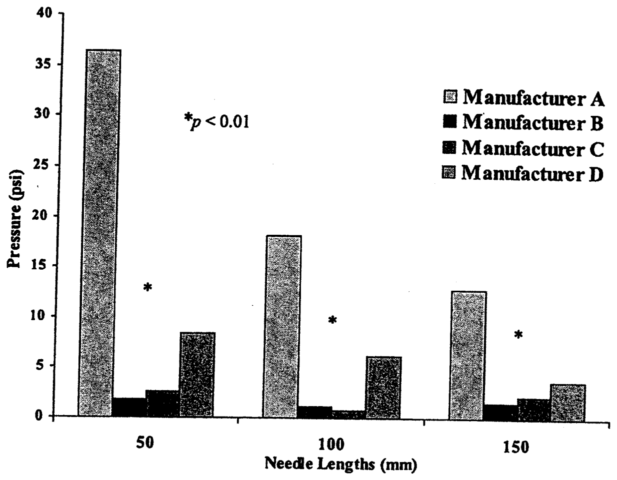

Fig 3. Force (pressure) required to inject at 15mL/min through needles of different lengths and diameters (50 mm/22-gauge, 100 mm/21-gauge, and 150 mm/20-gauge).

jects. Therefore, if the assessment of injection force required to initiate and complete a PNB injection is indeed important in clinical practice, some objective means of monitoring injection pressure is needed to help document and standardize injection technique.

Little published information exists on the mechanisms of neurologic complications after PNBs and how injection technique might influence the risk of nerve injury. Although many experts agree that the etiology of neurologic injury with PNB is likely multifactorial, mechanical needle and injection trauma are thought be important risk factors.[4,12,13] Such trauma can result from a single or repeated mechanical injury to the fascicles by the advancing needle, from an intraneural injection of local anesthetic, or both. Fortunately, nerve injuries after PNB are rare, and high injection pressure resulting from a rapid, forceful administration of local anesthetic during PNB is unlikely to result in a mechanical injury to the nerve, as long as the needle is not placed intraneurally. Higher resistance to injection could also result from a needle obstruction or injection into less compliant tissues. However, forceful injection against resistance of the tissues when a needle is inserted intrafascicularly could cause mechanical injury to the nerve, rupture of the perineurium, escape of the injectate extraneurally, and reduced resistance to injection thereafter.[2] For instance, in a model of nerve injury by Selander and Sjostrand,[2] generally pressures greater than 11 psi were required to initiate an injection solution into a fascicle of a rabbit sciatic nerve. Histologic examination of nerves after such injections demonstrates disruption of the nerve architecture, with rupture of the fascicles and their connective tissue sheath, the perineurium.[2] In contrast, perineural injections in the animal model result in significantly lower injection pressures (0.5 to 1.2 psi).[2]

Not surprisingly, the force required to inject varied significantly among needles of different gauges and lengths. More importantly, pressure attained during injection varied among needles of the same gauge and length from different manufacturers. This lack of consistency is most likely caused by differences in the internal diameters of the needles tested, although gauge and length were similar. This finding may have clinical implications for anesthesiologists who change to needles made by a new or unfamiliar manufacturer.

No clinical studies have addressed the importance of the rate of local anesthetic injection (mL/min) during administration of PNB. However, case reports describing systemic complications of local anesthetic injections with PNB detail the injection techniques used and imply that the rate of injection, force of injection, or both may affect the risk of systemic toxicity.[7-10] Our data indicate that the rate at which anesthesiologists inject varies widely. Studies are needed to determine the relevance of this finding to clinical practice.

Extrapolation of our findings to clinical practice may have limitations. First, injection was made into a needle that was submerged in a beaker. In clinical practice, pressures could be even greater than those measured by us because of the resistance of body tissues. Alternatively, the anesthesiologist could slow the rate of injection to control (reduce) the force of injection. Nonetheless, using the same equipment from one practitioner to another, we have demonstrated that the speed and force with which anesthesiologists inject local anesthetic through commonly used PNB equipment varies widely. Moreover, even a single clinician likely varies the speed and force of injection day to day, depending on the timing of the PNB procedure, local clinical activities, and operating room turnover pressures. Second, we measured injection pressure proximal rather than distal to the needle for two reasons: (1) it reflects current clinical syringe-feel assessment of force, and (2) this method was used in the experimental studies comparing pressure using an intraneural injection with pressure using a perineural injection.[2] Third, we may have underestimated the magnitude of the problem because of a possible "halo effect" among the test subjects. That is to say, the anesthesiologists in this study, even though they were unaware of the details of the experiment, injected more carefully than they would have in their own practices simply because they were being observed. Conversely, they may have been less careful because they injected into a beaker instead of an actual patient. Finally, the results of our study could have been different had we used syringes of a different size than 20 mL.

In summary, anesthesiologists typically rely on a subjective evaluation of what may be a high resistance to injection while performing a PNB because it is believed that a greater injection force may be associated with an intraneural injection. However, under the conditions of the current in vitro study, anesthesiologists varied widely in what they perceived as "normal" pressure and speed during a simulated injection for a PNB. Force required to inject varied significantly among needles of the same gauge and length from different manufacturers, which may negatively influence the accuracy of the syringe-feel method of assessing the injection force. Further studies are needed to establish whether avoiding forceful injection is associated with lower risk of complications. If so, objective means of monitoring injection force or pressure may help to quantify and document injection techniques as compared with the currently used syringe-feel method.

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Appendix

Manufacturer A–Neuro_Trace II; HDC Corporation, San Jose, California

Manufacturer B–Uniplex; Pajunk, Gesingen, Germany

Manufacturer C–Stimuplex; Braun, Inc, Bethlehem, Pennsylvania

Manufacturer D–Pro-Bloc II; LifeTech, Inc., Stafford, Texas