

1,001 Subclavian Perivascular Brachial Plexus Blocks: Success With a Nerve Stimulator

Carlo D. Franco, M.D., and Zairo E.G. Vieira, M.D.

Background and Objectives: Among the supraclavicular approaches to the brachial plexus, the subclavian perivascular technique is a well-established method of anesthesia of the upper extremity. Ever since Kulenkampf described his technique, eliciting a paresthesia has been almost mandatory ("no paresthesia, no anesthesia"). Lately, nerve stimulators have become more popular. However, up to the present time, clinical studies involving the nerve stimulator have failed to show success rates comparable to paresthesia techniques.

Methods: Data from 1,001 consecutive, subclavian perivascular blocks were prospectively gathered over 2.5 years. All blocks were performed according to Winnie's technique, but using a nerve stimulator instead of a paresthesia. When an adequate response was obtained, 35 to 40 mL of local anesthetic solution was injected.

Results: Nine hundred seventy-three blocks (97.2%) were completely successful; 16 blocks (1.6%) were incomplete and needed supplementation; and 12 blocks (1.2%) failed and required general anesthesia, giving a success rate for regional anesthesia of 98.8%.

Conclusions: The subclavian perivascular block consistently provides an effective block for surgery on the upper extremity. At the site of injection with this technique, the plexus is reduced to its smallest components and the sheath is reduced to its smallest volume, which explains in great part the success obtained with this block. We believe that we have demonstrated a nerve stimulator technique that is both highly successful and safe; no clinical pneumothorax was found nor did any other major complications develop. *Reg Anesth Pain Med* 2000; 25:41-46.

Key Words: Subclavian perivascular brachial block, Nerve stimulator, Success rate, Upper extremity.

Techniques for blocking the brachial plexus at different levels, both above and below the clavicle, are well established and commonly used to provide anesthesia for surgery on the upper extremity. The level at which the plexus is approached and the technique selected varies with the surgical site and with the training and experience of the anesthesiologist. Furthermore, when one of the supraclavicular techniques has been chosen, even the procedure itself varies: with earlier techniques the exact site for insertion of the needle was determined using visual, topographic landmarks (i.e., 1 cm above the midpoint of the clavicle),¹ whereas with more recent techniques, palpable landmarks (i.e., the scalene muscles and the interscalene groove) have

been utilized.^{2,3} Regardless of which landmarks have been used to determine the point of needle insertion, even the endpoint determining the site of local anesthetic injection varies. Until recently, most techniques have used a paresthesia to indicate the point at which local anesthetic is injected. Ever since Kulenkampf's original publication,¹ eliciting a paresthesia has been an integral part of most techniques of brachial plexus block, and particularly those performed above the clavicle. This practice was reinforced and perpetuated by the often quoted dictum of Moore, "no paresthesia, no anesthesia."⁴ Selander has raised the possibility that paresthesias might be associated with an increased risk of nerve damage.⁵ However, to date, there are no data confirming this theory.

An alternative to the use of a paresthesia as an endpoint involves the use of a nerve stimulator. A nerve stimulator was first utilized to perform a supraclavicular brachial block as early as 1912.⁶ However, the equipment was clumsy, and its use was soon forgotten. The first practical and portable nerve stimulator was introduced into clinical practice by Greenblatt in 1962,⁷ and newer and better nerve stimulators have been developed since then.^{8,9} The use of the nerve stimulator has the theoretical advantage over the use of a paresthesia in that it

From the Department of Anesthesiology, Cook County Hospital, Chicago, Illinois; and the Department of Anesthesiology, Rush Medical College, Chicago, Illinois.

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Reprint requests: Carlo D. Franco, M.D., Department of Anesthesiology and Pain Management, Cook County Hospital, 1835 West Harrison St, Suite 7308, Chicago, IL 60612-3789.

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should minimize the possibility of neuropathy by avoiding actual physical contact with a nerve. However, even with careful technique (such as the one used in this study), unintentional paresthesias cannot be avoided. When a mixed nerve is stimulated by an electrical current, the motor fibers are depolarized by a lower current than the sensory fibers,¹⁰ which allows the anesthesiologist to obtain a painless visible muscle contraction without eliciting a paresthesia. Nonetheless, this technique remains somewhat controversial,^{11–15} undoubtedly because in the few clinical studies that have been reported the nerve stimulator has not been proved to provide results comparable to those achieved with the paresthesia technique.^{16–19} It has been our impression at Cook County Hospital that the nerve stimulator technique is highly successful. Therefore, the purpose of our study is to validate this impression by presenting these observational results obtained using a nerve stimulator in performing 1,001 subclavian perivascular brachial plexus blocks.

Materials and Methods

All consenting, consecutive, ASA I–III patients scheduled for surgery on the upper extremity under regional anesthesia are included in the study. Exclusion criteria included patient refusal, clinically significant coagulopathy, infection at the injection site, and pneumothorax or previous pneumonectomy on the opposite side. Chronic pulmonary disease, obesity, and pregnancy were not exclusion criteria. Data pertaining to 1,001 blocks were prospectively gathered between February 1996 and July 1998. This protocol was approved by the Institutional Review Board.

All of the patients were told (in lay terms) that they would receive a subclavian perivascular brachial plexus block as their anesthetic, and the details of the procedure were explained to them. After informed consent had been obtained, the patients were brought to the operating room where standard monitors (noninvasive blood pressure monitoring, electrocardiography, and pulse oximetry) were applied, and supplemental oxygen via nasal cannula was administered. When indicated, light sedation consisting of intravenous midazolam 0.01 to 0.03 mg/kg and/or fentanyl 0.3 to 3.0 µg/kg was titrated so that the patients remained awake and cooperative throughout the procedure. The protocol also let the operator use sedative doses of propofol on 2 conditions: (1) the dose could not exceed 50 µg/kg/min (ideal body weight) and (2) propofol could only be started after surgery had begun and the block had already been qualified. The anesthetic technique

used was that previously described by one of the authors,² with the addition of a nerve stimulator. The nerve stimulator utilized was the Stimuplex DIG (B. Braun, Allentown, PA)—a unit found to be accurate in a recent, comparative study.⁹ A 22-gauge, 2-inch, short-bevel insulated needle (Stimuplex; B. Braun) was used for most blocks, although a few blocks were performed with an unsheathed, 22-gauge short-bevel needle. A skin wheal was raised 1 finger breadth over the lowermost palpable portion of the interscalene groove, and the block needle was inserted through it. Then, with the nerve stimulator output set at 0.9 mA at 1 Hz, the needle was advanced directly caudad (parallel to the table) until a flexor or extensor response of all the fingers was obtained, at which point the output was reduced to 0.5 to 0.7 mA. If the response was still visible at this level of stimulation, the local anesthetic solution was injected in 5-mL increments, with repeated aspirations between each increment. The operators were allowed to use up to 40 mL of local anesthetic solution, but were free to use less at their discretion, mainly based on the patient's age, size, and general condition. Visual and verbal contact with the patient was maintained during and after the injection. The local anesthetic solutions utilized varied depending on the expected duration of the surgical procedure, and included 1% mepivacaine; 1% mepivacaine plus 1:200,000 epinephrine; or a combination of 1% mepivacaine, 0.2% tetracaine, and 1:200,000 epinephrine. When a tourniquet was expected to be used for more than 1 hour, an additional injection of 3 to 5 mL 1% mepivacaine plain was made subcutaneously over the axillary artery pulse to block the intercostobrachial and medial brachial cutaneous nerves in the axilla. At their discretion, the operators could perform this block later if surgery had prolonged for more than 1 hour and if this block was feasible. All blocks were performed by residents under the direct supervision of one of the authors or by one of the authors themselves.

Because the subclavian perivascular block usually has a very fast onset, a preliminary test for onset of anesthesia was performed within 5 minutes of the injection by checking the response to pinprick in the radial, median, ulnar, and musculocutaneous nerves distribution in the distal arm. Subjective sensations of numbness and tingling as well as their location were also noted. This preliminary testing let us decide whether a supplemental injection by the anesthesiologist was going to be necessary to provide complete anesthesia. If objective and subjective signs indicated the onset of anesthesia in all dermatomes (as was usually the case), surgical preparation proceeded.

Before the surgical incision (usually 10 to 15 minutes after the injection), the surgeon was asked to test the block with a clamp in all dermatomes, C5 through T1, regardless of the surgical site. For the purpose of our study, a block was considered complete only if all dermatomes of the brachial plexus (C5 to T1) were blocked by the original injection. If a supplemental injection was needed for complete anesthesia, the block was considered incomplete. If dermatomes outside the surgical field were not blocked and supplementation was not necessary for the surgery, the block was still considered incomplete. A block was considered a failure if general anesthesia was required—either because a supplementary block did not complete the anesthesia or because a supplementary block was not considered feasible by the surgeon.

After the surgical procedure, the patient was followed until normal sensation had returned, and a postanesthesia visit was made 24 hours later to ensure that there were no immediate complications related to the block. The hand surgeons were asked to evaluate the patients thereafter and refer to us any patient who they suspected might have developed any kind of neurologic deficit or other complication associated with a brachial block.

At the time the study was initiated, it was agreed that for the findings to be considered clinically significant the study should be continued until a considerable number of blocks had been performed. Ultimately, when 1,000 blocks had been performed, it was agreed that this represented “a considerable number.”

Results

Demographic Data

The 1,001 subclavian perivascular brachial plexus blocks were performed in 947 patients—652 males (68.8%) and 295 females (31.2%). Patient age ranged from 9 to 94 years (mean, 36 years); height ranged from 135 to 211 cm (mean, 170 cm); weight ranged from 27 to 191 kg (mean, 163 kg). Table 1 shows the population demographics. Obesity was not an exclusion criterion. In fact, in the present study, 318 (31.8%) of the patients were considered

Table 1. Population Demographics

| | Mean | SD | Minimum | Maximum | Range | Median |
|-------------|-------|------|---------|---------|-------|--------|
| Age (y) | 36.2 | 13.8 | 9 | 94 | 85 | 34 |
| Height (cm) | 171.3 | 10.3 | 134.6 | 210.8 | 76.2 | 170.2 |
| Weight (kg) | 77.8 | 16.9 | 27.2 | 190.5 | 163.3 | 75.3 |
| BMI | 26.5 | 5.3 | 13.5 | 55.4 | 42.0 | 25.8 |

Table 2. Location of Surgery

| | | |
|---------|-----------|-------|
| Arm | 42 Cases | 4.2% |
| Elbow | 108 Cases | 10.8% |
| Forearm | 160 Cases | 16.0% |
| Wrist | 199 Cases | 19.9% |
| Hand | 492 Cases | 49.2% |

NOTE. If surgery was performed in more than one location, the operator arbitrarily allocated a region based on area mostly affected.

obese (Body mass index [BMI] more than 28) and 69 (6.9%) were considered morbidly obese (BMI 35).

The duration of surgery ranged from 15 minutes to 6½ hours, and the surgery included a wide variety of orthopedic procedures (complicated fractures, arthroplasties, arthrodesis, tendon repairs, and transpositions), as well as soft tissue procedures (drainage of fascial abscesses, debridement of traumatic wounds, and microscopic repair of vessels and nerves). Table 2 shows the surgeries according to their location.

Four patients were known to be pregnant at the time of the block (cases 42, 63, 410, and 530). All of these blocks were successful and uneventful. Three different solutions were used (Table 3). The operator was free to make a choice of anesthetic solution based on expected time of surgery.

Forty-nine patients returned to undergo a similar or different procedure under a brachial plexus anesthesia, for a total of 103 blocks. Thirty-one of those patients were males who received 65 blocks and 18 were females who received 38 blocks. The minimum time elapsed between blocks was 2 days and the maximum was 18 months. Five patients received up to 3 blocks in as little as 9 days and as long as 16 months. A “tourniquet” block in the axilla was performed in 730 cases (73%).

Most blocks were performed using 35 to 40 mL of local anesthetic solution. However, 15 patients received a block with 30 mL or less. The reasons given by the operator ranged from size of patient to emaciation (39-kg AIDS patient whose block was done using 25 mL of local anesthetic solution). This group included our youngest patient (9-year-old boy) and our oldest patient (94-year-old woman). In 3 patients, the reason given was “bilateral block.”

Table 3. Type of Local Anesthetic Solution

| | | |
|---|-------|-------|
| Mixture* | 867 | 86.6% |
| 1% Mepivacaine plain | 91 | 9.1% |
| 1% Mepivacaine plus 1:200,000 epinephrine | 43 | 4.3% |
| Total | 1,001 | 100% |

* 1% mepivacaine plus 0.2% tetracaine plus 1:200,000 epinephrine.

These were cases in which a subclavian perivascular block was combined with an axillary block on the opposite side for bilateral procedures. All 15 blocks were successful.

Outcome Data

Of the 1,001 blocks, 973 (97.2%) provided complete anesthesia (i.e., they provided a complete sensory blockade in all of the dermatomes of the arm, without the need for supplemental blocks or general anesthesia). Sixteen (1.6%) blocks were considered incomplete, because one or more dermatomes were missed by the initial injection, but the block became complete after a supplemental block. General anesthesia was not necessary in this group either. Twelve (1.2%) blocks were considered failures because general anesthesia was necessary. Thus, in 989 of 1,001 patients (98.8%), regional anesthesia was successful, and general anesthesia was necessary in only 12 (1.2%). Results are listed in Table 4. In 2 cases, the block was abandoned before the injection of local anesthetic because we were unable to elicit an adequate response. Both patients received successful axillary blocks. If these 2 blocks were counted as "failures," the success rate would be 97% (973/1,003).

We identified obesity as a possible factor contributing to either an incomplete or failed block. However, when compared among themselves, the groups were not found to be statistically different (Table 5). Only when failed and incomplete blocks were considered together as a group was a level of significance obtained compared with the overall or good groups.

Complications

Although we did not routinely perform chest radiographs to document the presence of subclinical pneumothorax, none of the patients had signs or symptoms indicative of a clinically significant pneumothorax. Three patients had transient and mild signs of local anesthetic toxicity (tinnitus and tachycardia), but none required treatment. Five patients developed small hematomas at the puncture site—all of which resolved without any treatment. Our nerve stimulator technique was performed to prevent unintentional paresthesias. However, paresthe-

Table 5. Results According to Body Mass Index

| | Overall | Good | Incomplete | Failure | Incomplete + Failure |
|--------------------|---------|-------|------------|---------|----------------------|
| Sample size | 1,001 | 973 | 16 | 12 | 28 |
| Mean | 26.45 | 26.39 | 28.78 | 29.01 | 28.88 |
| Standard deviation | 5.26 | 5.22 | 5.13 | 6.66 | 5.72 |

Overall versus good not significant $P > .05$. Overall versus incomplete not significant $P > .05$. Overall versus failure not significant $P > .05$. Overall versus incomplete + failure $P < .05$. Good versus incomplete + failure $P < .05$.

sias were elicited in 2.8% (28/1,001). These paresthesias were usually the result of a technical error (e.g., the nerve stimulator had not been turned on, the skin electrode was not attached). Whenever a paresthesia was produced, albeit unintentionally, the needle was withdrawn, and the problem was identified before reinitiating the technique. None of the patients had signs or symptoms of postanesthetic neuropathy; although 1 patient, who had experienced a paresthesia during the performance of the intercostobrachial block in the axilla without a nerve stimulator, developed a burning sensation postoperatively in the medial aspect of the upper arm that persisted 3 to 4 weeks.

Discussion

Our experience has been that the subclavian perivascular technique of brachial plexus block provides a consistent, reproducible and effective anesthesia of the upper extremity. We believe that a major reason for the success of this technique is that the local anesthetic is injected at the point where the plexus is reduced to its fewest components and size. For years, it was believed that the only way to place the needle close to the nerves was to contact the nerves and produce a paresthesia.⁴ We believe that the nerve stimulator technique can provide a high degree of success and safety as shown by the results of our study. As we have already mentioned, unintentional paresthesias cannot be totally eliminated. But, we disagree with those who consider the nerve stimulator technique not as a viable alternative to the paresthesia technique, but rather as a "crutch"¹¹ compensating for lack of anatomic knowledge or dexterity. We believe that anatomy is the most important factor for success in regional anesthesia, regardless of the technique. For accurate needle positioning, the nerve stimulator technique relies on the production of a visible muscle twitch seen when the needle is in proximity to the nerve.

Several features of our technique using the nerve stimulator may explain our results and safety. First,

Table 4. Results

| | No. | Percentage |
|------------|-----|------------|
| Complete | 973 | 97.2% |
| Incomplete | 16 | 1.6% |
| Failure | 12 | 1.2% |

although a larger initial setting can produce an earlier response, we believe it is unnecessary when anatomic landmarks are properly utilized.^{10,13} Secondly, when the desired response is obtained at the initial setting, it is frequently recommended that the current should be lowered to a point “as low as possible,” and outputs of less than 0.5 mA are frequently mentioned.^{20,21} This practice might be unnecessary. In our experience, it is far more important to get the desired response (i.e., flexion or extension of the fingers at an output of 0.5 to 0.7 mA) than to look for the minimum output possible in an effort to get closer to the nerve. This approach may also explain the relatively low number of unintentional paresthesias in our study. It is also important that an appropriate response must be elicited to get a profound and effective block.

For the purpose of this study, our definition of a “complete” block included only those blocks in which all dermatomes (C5 to T1) had been anesthetized, regardless of the surgical site. As a result, a few blocks were considered “incomplete,” even though they did not need supplementation because the dermatome that was not blocked was outside the surgical field. Also, blocks that were developing slowly might have become “failures” because of operating room time constraints.

The only factor that we identified as possibly associated with a result other than complete was BMI. However, as shown in Table 5, a level of significance is only reached when incomplete and failed blocks are grouped together. This lack of significance might be explained by the small number of incomplete and failed blocks. Currently, we are completing a study in our institution on the subclavian perivascular block in the obese population.

Although we performed our blocks during light sedation to relieve anxiety, all of our patients remained awake during the performance of the block. We do not recommend performing this block in either heavily sedated or unconscious patients. The protocol also called for the use of propofol at the discretion of the operator during the case. However, it is important to mention that during this study propofol could not be used in doses higher than 50 µg/kg/min (ideal body weight) nor could it be started before the block had been characterized. As a result, no propofol “rescue” could be performed in any of the cases.

Most blocks were performed with 35 to 40 mL of local anesthetic solution. However, 15 patients received 30 mL or less (7 received 20 to 25 mL). These patients were either small in size, emaciated, or received contemporaneously a contralateral axillary block. All these blocks were successful. However,

the small number does not allow us to draw any conclusions. A few blocks were performed with an unsheathed, 22-gauge short-bevel needle. Again, the number was too small to arrive at any valid conclusion.

Another implication of the high success rate achieved in this study is that because only a single injection was made in every case, multiple injections are unnecessary. Multiple injection advocates claim that they are necessary because of the presence of septa which extend inward from the sheath and between neural components, subdividing the perivascular space into compartments and interfering with the circumferential spread of injected local anesthetics. Although there is certainly good anatomic and radiologic evidence that such septa do exist²²⁻²⁴ there is equally good clinical evidence that the septa do not interfere with the spread and diffusion of injected local anesthetics. Finally, and equally importantly, the present study documents not only the efficacy but also the safety of the subclavian perivascular technique of brachial plexus block performed using the nerve stimulator technique. The absence of significant systemic toxicity, either during or after the injection, the absence of respiratory difficulty during anesthesia and for 24 hours thereafter, and the absence of clinical pneumothorax document the safety of this technique. Historically, the most feared complication of any supraclavicular technique of brachial plexus block has been pneumothorax, with a reported incidence of 0.5% to 6.0%.²⁵ However, these were reports of cases where traditional, multiple injection techniques were utilized, not the subclavian perivascular technique, in which only a single injection is made.

We followed our patients for 24 hours and had our surgical colleagues check our patients thereafter. They were supposed to refer to us any patient who might have shown any sign of a neurologic deficit or other complication believed to be associated with a brachial plexus block. Although we cannot rule out subtle degrees of neuropraxia that might have gone unnoticed, we are confident that our patients did not experience any major neurologic damage.

In summary, the high success rate and absence of complications achieved when the nerve stimulator is used in performing the subclavian perivascular technique of brachial plexus block indicate that our technique is safe and effective.

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