Intravenous regional anesthesia (IVRA) is a well-recognized technique for producing anesthesia during surgical procedures of the extremities. It has been suggested that the application of a tourniquet to the forearm may improve the quality of the block. The purpose of this investigation was to determine whether the application of a forearm tourniquet would accelerate onset time and improve the density and quality of an intravenous regional block.

Twenty volunteer subjects were enrolled and randomly assigned in this crossover investigation. Control subjects received a standard IVRA technique; experimental subjects received IVRA technique with the application of a simple forearm tourniquet. Pain was elicited by means of an electrical stimulus, and assessments were performed using a 100-mm Visual Analogue Scale (VAS). Paired t tests were used to examine differences between groups on the variables studied. It was noted that the arm with the tourniquet had a shorter time for the onset of anesthesia \( (P = .0008) \) and had lower 10-minute VAS tolerance \( (P = .0469) \).

This investigation suggests that the application of a simple forearm tourniquet as an adjunct to IVRA provides a more rapid onset of anesthesia than when no tourniquet is applied and may improve the density and quality of the block.

Key words: Analgesia, Bier block, forearm tourniquet, intravenous regional anesthesia, lidocaine.
density and quality of an intravenous regional block or Bier block.

Methods
Twenty volunteers participated in a prospective randomized crossover comparison of 2 IVRA techniques. The technique involved placement of a venous catheter, extremity exsanguination by wrapping with an esmarch bandage, inflation of an upper arm tourniquet, and injection of local anesthetic solution. Exclusion criteria consisted of subjects with a history of chronic pain, hypersensitivity to study medications, and relative or absolute contraindications to IVRA (eg, sickle cell disease, cellulitis, fever, severe hypertension, and a history of certain cardiac diseases such as untreated heart block). Before initiating the IVRA study technique, subjects gave written informed consent, and their baseline pain threshold and tolerance were established and recorded. Subjects were also instructed on the use of the Visual Analogue Scale (VAS) for measuring pain. A VAS was administered whenever a threshold or tolerance was being recorded. A 100-mm VAS was used, with zero indicating no pain and 100 indicating the worst pain imaginable.

An electrical stimulation model of surgically induced pain was used to determine surgical anesthesia. Electrical stimulation has been demonstrated to provide a stimulus equivalent to the mental and physical stresses of surgery. A single monophasic square wave pulse at 100 Hz was provided by the Nicolet Viking IV, model DA9940469, through a pair of silver electrodes applied to the tip of the subject's middle finger. Stimulation was increased in steps of 0.2 mA every 5 seconds. The stimulus began at 0.6 mA until threshold was reached, and then increased in 0.4-mA increments to an upper limit of 25 mA. The subject's pain threshold was defined as the point at which the subject stated the sensation first became apparent. The subject's pain tolerance was defined as the point at which the subject indicated that he or she did not want to receive the next higher stimulus. A 20-gauge heparin lock was placed in the operative extremity and an 18-gauge heparin lock was inserted into the subject's contralateral arm for drawing blood samples to determine serum lidocaine levels. Volunteers were monitored continuously with noninvasive blood pressure measurements, an electrocardiogram, and pulse oximetry.

A standard technique for performing the IVRA block was incorporated as follows:

1. A pneumatic double-cuffed tourniquet was placed on the upper arm.
2. A 20-gauge butterfly was used to cannulate a dorsal hand vein.

3. The extremity was elevated and exsanguinated with an esmarch bandage. A tourniquet was inflated to 250 mm Hg. The esmarch bandage was then removed.

4. The venous compartment of the upper extremity was injected with 40 mL of 0.5% (200 mg) lidocaine. After the removal of the esmarch bandage, a simple forearm tourniquet (penrose drain) of the type typically used to draw blood was applied to the middle of the forearm of members of the experimental group. No attempt was made to standardize or control the resulting tension on the forearm tourniquet. After the penrose forearm tourniquet was applied, 20 mL of the 0.5% lidocaine solution was injected during 60 seconds. Immediately after this initial injection, the forearm tourniquet was removed, and the remaining 20 mL of 0.5% lidocaine solution was injected for another 60 seconds.

After the injection of the total volume of lidocaine in each group, the anesthesia onset time was determined. Onset time was quantified by applying half the patient's baseline pain tolerance stimulus, measured in milliamperes, until the subject indicated that he or she could no longer feel the presence of the stimulus. Pain threshold, pain tolerance, and the VAS were again recorded at 10 minutes and at 20 minutes after lidocaine injection.

Thirty minutes after the initial inflation of the pneumatic, double-cuffed, upper arm tourniquet, the tourniquet was released. Ten seconds were counted off with a stopwatch, and the tourniquet was reinflated. After reinflation, signs and symptoms of central nervous system (CNS) toxicity were evaluated and 3 mL of blood were drawn from the preexisting 18-gauge heparin lock in the contralateral arm, to determine serum lidocaine levels. The samples were immediately sent to the institutional laboratory and were refrigerated at 4°C. The pneumatic upper arm tourniquet was released a second time, and another CNS toxicity evaluation was performed. Demographic data collection included age, weight, height, sex, and ASA class. Paired t tests were used for baseline pain threshold, baseline VAS threshold, baseline pain tolerance, baseline VAS tolerance, and anesthesia onset time. Paired t tests were also used for measurements after the onset of anesthesia, including pain threshold at 10 minutes, 10-minute VAS threshold, pain tolerance at 10 minutes, 10-minute VAS tolerance, pain threshold at 20 minutes, 20-minute VAS threshold, pain tolerance at 20 minutes, 20-minute VAS tolerance, tourniquet pain, and lidocaine levels. By means of a chi-square analysis, CNS toxicity data of the 2 groups were compared. Sample size calculation was based on a power of
Results
No significant differences between groups were found on the demographic variables evaluated (Table). Onset of anesthesia occurred significantly more rapidly in the experimental group ($P = .0008$) than in the control group (Figure 1). The 10-minute VAS tolerance scores of pain were also significant between the experimental group and the control group ($P = .0469$) (Figure 2). The 20-minute threshold for pain approached significance ($P = .0720$). The 20-minute VAS tolerance scores for pain also approached significance ($P = .0798$).

Serum lidocaine levels were not significantly different (control group = 0.8579 µg/mL ± 0.5824; experimental group = 0.7900 ± 0.5004). No significant differences between the 2 groups were noted in CNS toxicity evaluations. CNS toxicity was evaluated by the presence or absence of distinct parameters, including (1) circumoral numbness, (2) tongue numbness, (3) lightheadedness, (4) tinnitus, (5) visual disturbances, and (6) muscular twitching. Cardiotoxic events, such as hypotension or arrhythmias, were not observed. On completion of the study, a comparison of tourniquet pain tolerance between the groups found no significant differences.

Discussion
This investigation demonstrated that the addition of a simple forearm tourniquet (penrose drain) to the standard IVRA technique hastened the onset time of anesthesia and improved the density and quality of the block. This observation is supported by the fact that the experimental group lost sensation to the stimulus more rapidly than the control group (6 minutes and 51 seconds vs 9 minutes and 40 seconds, respectively). In addition, the experimental group had a significantly higher subjective tolerance to pain early in the procedure, as evidenced by lower 10-minute VAS scores (19.35 mm vs 28.45 mm, respectively). These data suggest a rapid onset of anesthesia in the experimental group, which is important in the clinical setting.

After anesthetic injection during IVRA, it takes roughly 12 to 15 minutes for adequate analgesia to occur. Any maneuver that speeds the progression of anesthesia before the surgical incision will potentially increase patient comfort and decrease stress. The find-

Table. Demographics

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ings of this investigation suggest that this simple modification will more rapidly establish anesthesia and improve the density and quality of the block. The 20-minute pain threshold and VAS tolerance scores approached significance, which suggests that this simple modification may improve the density and quality of the block throughout the procedure.

The results of this investigation are consistent with the experimental effects of retrograde intravenous pressure infusion. The application of a tourniquet to the forearm prevents proximal seepage of the anesthetic and promotes retrograde perfusion. A preferential distribution of the local anesthetic occurs more quickly and extensively.

Lidocaine levels were similar for both techniques, and CNS side effects occurred in all volunteers regardless of technique used. However, side effects were mild and well tolerated by our volunteers. CNS side effects during IVRA may be underreported, since the reliability of subjective symptoms of local anesthetic toxicity is decreased when patients are medicated. Because our volunteers were not medicated, their ability to detect the CNS effects of lidocaine was not impaired.

The use of a simple forearm tourniquet as an adjunct to IVRA is both safe and effective. It can be used whenever IVRA is applicable, causes no untoward effects, and requires no additional time or resources. Our findings suggest that this simple modification has clinical value because it resulted in a decrease in time to onset of anesthesia and an increase in both pain tolerance and threshold. However, this study failed to demonstrate a significant difference in all parameters tested at the 20-minute time mark. No single explanation for this disparity in findings could be found. It was surmised that the 20-minute parameters might have been improved by extending the time of the forearm tourniquet beyond 60 seconds, or simply by injecting the entire 40 mL of local anesthetic solution with the penrose tourniquet applied. To determine this, a future study will have to be performed incorporating these changes into the research design. Although the addition of a simple forearm tourniquet did not show evidence of increased safety based on lidocaine levels, we did not examine the potential for adverse effects after shorter tourniquet times or in cases of tourniquet failure.

A possible limitation of this study is the use of volunteers. Subjects undergoing repair of traumatic soft tissue and bone injury, in which the inflammatory process and pain pathways have been established, may respond differently to this technique. Future researchers may want to incorporate operative subjects in the clinical setting. On the basis of the results of this investigation, we recommend that all anesthesiologists incorporate this technique clinically.

REFERENCES

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