

$\mu\text{g/ml}$.¹³ Ecoffey *et al.*¹⁴ used 2.5 mg/kg of plain bupivacaine for caudal anesthesia and showed average peak serum bupivacaine concentrations of 1.25 $\mu\text{g/ml}$. Epinephrine may be responsible for the lower serum levels, despite a larger bupivacaine dose, by reducing systemic absorption. We believe epinephrine is necessary as an early indicator of inadvertent intravascular injection. We give incremental injections, aspirating intermittently, and monitor for changes in heart rate and arterial blood pressure. We did not observe any central nervous system or cardiovascular signs of local anesthetic toxicity in our patients.

In summary, we performed caudal anesthesia easily and safely in seven consecutive, awake or sedated, high-risk infants. An adequate level of block was obtained using 1.0–1.3 ml/kg of bupivacaine 0.25% with epinephrine 1:200,000, although one patient required a supplemental ilioinguinal/iliohypogastric block for deep exploration of the inguinal area on one side. Our observations indicate that caudal epidural anesthesia is a useful anesthetic technique for lower extremity, anorectal, and inguinal procedures in high-risk infants and obviates the necessity for general anesthesia and endotracheal intubation.

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Comparison of Lidocaine and Prilocaine for Intravenous Regional Anesthesia

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Intravenous regional anesthesia (IVRA) is an effective method of producing anesthesia of an extremity

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with rapid onset and recovery. There has been considerable controversy regarding the most appropriate drug for IVRA.^{1,2} Lidocaine is probably the local anesthetic most commonly chosen for this technique in the United States.

Prilocaine is better tolerated in terms of systemic toxicity than lidocaine.^{3,4} Circulating prilocaine concentrations are less than those of lidocaine when equal doses of the two agents are administered for regional blockades.⁵ This would suggest that prilocaine may be of particular advantage in an anesthetic technique in

TABLE 1. Patient Data

	Prilocaine	Lidocaine	
Sex M/F	4/7	3/7	
Age (years)	56 ± 19	50 ± 20	NS
Weight (kg)	70 ± 11	67 ± 18	NS
Dose (mg/kg)	3.7 ± 0.7	4.0 ± 1.0	NS
Hematocrit	41 ± 4	39 ± 4	NS

Values are expressed as mean ± standard deviation. NS indicates no statistical significance.

which the drug is injected intravenously. However, prilocaine has been associated with the formation of methemoglobin.⁶ Doses of prilocaine required to produce clinically significant blood levels of methemoglobin are much larger than the dose of prilocaine required for IVRA.

Previous studies comparing lidocaine and prilocaine for IVRA have not included simultaneous measurements of both circulating drug concentrations and methemoglobin concentrations.^{7,8} The current study was designed to compare the efficacy and safety of equal doses of prilocaine and lidocaine for IVRA. Patients were monitored for evidence of toxicity, and blood concentrations of methemoglobin and the local anesthetics were measured.

MATERIALS AND METHODS

The protocol for this study was approved by our Committee for the Protection of Human Subjects. Informed consent was obtained.

Twenty-one adult ASA I or II patients of both sexes scheduled for hand surgery under IVRA were admitted to the study and randomized. Patients were admitted through the Day Surgical Unit and were unpremedicated. The electrocardiogram was continuously monitored and arterial blood pressure measurements were recorded every 5 min. A 16-gauge intravenous catheter with stopcock was placed in a vein of the arm not requiring surgery and was used for blood sampling. A 20-gauge Vicra obdurator was placed in the arm requiring surgery. The limb was elevated and wrapped with a rubber esmarch bandage for effective exsanguina-

tion. The proximal cuff of a double tourniquet was then inflated and 50 ml of either 0.5% prilocaine or 0.5% lidocaine was injected in a double blind manner. After approximately 10 min, the distal cuff was inflated and the proximal cuff deflated, to provide analgesia under the tourniquet. A minimum tourniquet time of 20 min was required before tourniquet deflation.

Venous blood drug concentrations were determined before tourniquet deflation and at 1, 3, 5, 10, 30, 60, 90, and 120 min following tourniquet deflation. Samples were stored at -20° C in heparinized glass blood collection tubes until analyzed. Whole blood concentrations of lidocaine and prilocaine were determined using a gas chromatographic technique similar to that described by Tucker.⁹ The coefficients of variation of the assay at 0.1 mg/ml were 7% (lidocaine) and 8% (prilocaine) over the course of the study. Concentrations have been expressed as mg/ml of whole blood. Methemoglobin concentrations were measured as a percent of total hemoglobin using a standard blood gas analyzer. Samples were taken at 0, 30, 60, and 90 min following tourniquet deflation. Times to onset of anesthesia to pinprick following drug administration were recorded. Resolution of analgesia following tourniquet deflation was also assessed by pinprick. Signs and symptoms of toxicity, such as dizziness, lightheadedness, tremors, tinnitus, convulsions, arrhythmias, or any evidence of cyanosis were noted. An unpaired Student's *t* test was used for comparison of data between groups. A *P* value of <0.05 was considered to be statistically significant. Results are expressed as means ± the standard deviation.

RESULTS

Patients in both groups were comparable in age, sex, weight, and dose per kilogram of local anesthetic agent (table 1). Onset of anesthesia to pinprick was essentially the same for both drugs (table 2). Time to resolution of anesthesia, as well as total tourniquet times, were similar in both groups (table 2). One patient in each group received supplementation at the site of operation because of inadequate anesthesia. One patient in the lidocaine group reported dizziness and lightheadedness after tourniquet deflation (peak drug concentration of 2.17 mg/ml; total tourniquet inflation time 65 min).

A peak venous concentration of 1.60 ± 1.19 mg/ml of lidocaine was measured at 3 min following tourniquet deflation. In the prilocaine group, a peak venous concentration of 0.70 ± 0.21 mg/ml was measured at 5 min following tourniquet deflation. Prilocaine concentrations were significantly lower than those of lidocaine from 3 min to 120 min following tourniquet deflation (*P* < 0.05) (fig. 1).

TABLE 2. Intraoperative Data

	Prilocaine	Lidocaine	
Onset of anesthesia (min)	3.6 ± 1.1	2.7 ± 1.5	NS
Post-tourniquet analgesia (min)	6.3 ± 4.2	5.7 ± 2.2	NS
Tourniquet time (min)	48 ± 14	50 ± 14	NS

Values are expressed as mean ± standard deviation. NS indicates no statistical significance.

In patients receiving prilocaine, methemoglobin levels increased significantly from 0.5% to approximately 3% at 60 min post-tourniquet deflation (fig. 2). No significant change in methemoglobin was found in the lidocaine group. The highest methemoglobin level measured in any patient was 3.2%. No signs of cyanosis were seen in any of the patients. Methemoglobin levels were returning towards the control value at 90 min following tourniquet deflation.

DISCUSSION

Whole blood concentrations of prilocaine were significantly lower than those of lidocaine following tourniquet deflation. This is consistent with previous studies comparing blood concentrations of lidocaine and prilocaine after various forms of regional anesthesia.⁵ This difference in whole blood concentrations was present despite the use of equipotent doses. When tested *in vivo*, prilocaine is quite similar to lidocaine in terms of duration, latency, and efficacy of anesthesia.¹¹ The rapid tissue redistribution and more rapid hepatic metabolism of prilocaine are believed responsible for the enhanced disappearance rate from blood of this local anesthetic.⁶ Another explanation for the lower plasma levels of prilocaine seen following tourniquet deflation suggests that prilocaine is taken up to a greater extent by peripheral tissues following intravenous injection, and, therefore, is released at a slower rate following tourniquet deflation.¹² In terms of relative toxicity, no statistically significant differences could be demonstrated between plasma levels of lidocaine and prilocaine required to evoke seizures in Rhesus monkeys.¹³ Thus, prilocaine may have a greater margin of safety in a technique requiring an intravenous injection of local anesthetic. This is especially advantageous in a technique in which the tourniquet may accidentally be deflated too early, allowing a bolus of drug to enter the systemic circulation.

The peak methemoglobin level after prilocaine administration was significantly higher than that seen with lidocaine, but was still lower than the methemoglobin level that would be expected to cause cyanosis or other symptoms.^{14,15} Peak methemoglobin levels have been reported to occur between 60 and 150 min following administration of intravenous prilocaine, which is consistent with the results of our study.^{14,15}

Hydroxylated O-toluidine, a metabolite of prilocaine, is an oxidizing agent capable of converting hemoglobin (Hb^{2+}) to methemoglobin (Hb^{3+}). At least 1.5 gm/dl of methemoglobin would be needed to produce cyanosis. This corresponds approximately to at least 10% of the hemoglobin present being oxidized to methemoglobin. None of the patients in this study were found to have

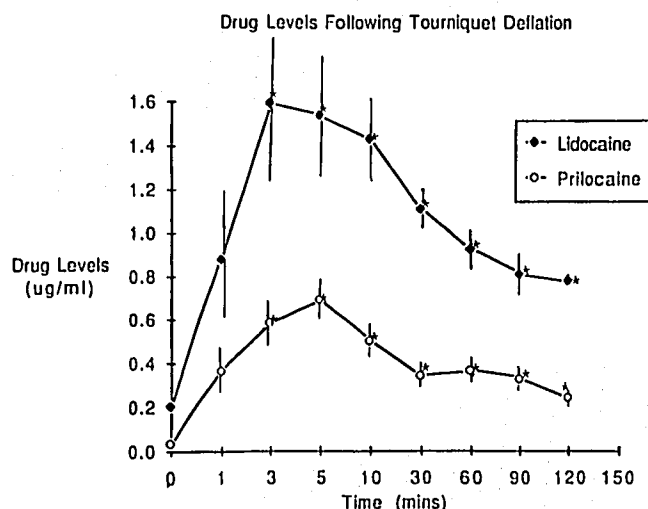


FIG. 1. Whole blood drug levels over time following tourniquet deflation. The asterisk indicates $P < 0.05$. Bars indicate standard error of the mean.

more than 3% of hemoglobin oxidized to methemoglobin. Thus, the increase in methemoglobin seen after the dose of prilocaine used in this study would not be expected to be clinically significant. Theoretically, the use of prilocaine for this technique may not be preferable in patients with severe anemia or clinical reasons for impairment in oxygen exchange.

In summary, both prilocaine and lidocaine were comparable in terms of onset, duration, and quality of anesthesia when used for intravenous regional anesthesia. With the dose used, the incidence of side effects was minimal. Whole blood concentrations of prilocaine were significantly lower than those of lidocaine between 3 and 120 min following tourniquet deflation. The degree of methemoglobinemia seen with prilocaine was

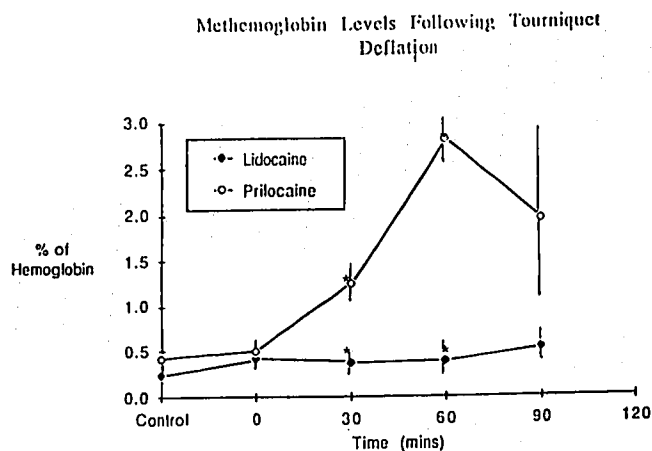


FIG. 2. Percent hemoglobin existing as methemoglobin over time following tourniquet deflation. The asterisk indicates $P < 0.05$. Bars indicate standard error of the mean.

not in a range expected to be clinically significant. The significantly lower prilocaine concentrations may indicate a greater margin of safety for prilocaine as compared to lidocaine in terms of potential systemic toxicity.

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Minimum Alveolar Concentration of Halothane for Tracheal Intubation in Children

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Deep inhalation anesthesia can be used for tracheal intubation in children when neuromuscular blockade is contraindicated. Gregory *et al.*¹ and Nicodemus *et al.*² have found age-related variations in the minimum alveolar concentration (MAC) that prevents movement after skin incision. Yakaitis *et al.*³ found that the minimum alveolar concentration of halothane permitting tracheal intubation in 50% of children between the ages of 2 and 6 yr (MAC-EI) was greater than the MAC for

skin incision (MAC-EI = 1.33%, MAC = 0.91%).^{1,3} Although MAC is known for various age groups, there are no data on MAC-EI except for children between 2 and 6 yr.³ Knowledge of MAC-EI is important for predicting the level of anesthesia that will permit laryngoscopy and tracheal intubation without patient movement or coughing. We, therefore, determined the MAC-EI in the age groups from 6 months to 12 yr. Patients under age 6 months were excluded from the study because of our inability to obtain precise and reproducible measurements of end-tidal gas concentrations.

MATERIALS AND METHODS

After obtaining institutional approval and written informed consent from the parent or legal guardian of the child, we studied 148 healthy ASA 1 and 2 children undergoing general endotracheal anesthesia for elective surgery. Patients were excluded if they had a history of prematurity or central nervous system disorders, or if they were receiving any drugs preoperatively.

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