Effects of Local Anesthetics on Pulpal Blood Flow in Dogs

S. KIM, L. EDWALL*, H. TROWBRIDGE**, and S. CHIEN

*Division of Circulatory Physiology and Biophysics, Department of Physiology, College of Physicians and Surgeons, and Department of Endodontics, School of Dental and Oral Surgery, Columbia University, New York, New York 10032; *Karolinska Institute, Stockholm, Sweden; and **Department of Pathology, University of Pennsylvania, School of Dental Medicine, Philadelphia, Pennsylvania 19174*

Effects of 2% lidocaine with epinephrine (1:100,000) administered by the various local anesthetic techniques – i.e., infiltration, mandibular block, and intraseptal injection – on pulpal blood flow in dogs were determined using the 15 μm radioisotope-labeled microsphere injection method. The pulpal blood flow decreased significantly with all three techniques; however, the most drastic reduction occurred in the molar teeth with the intraseptal injection. When 2% lidocaine without epinephrine was used in the intraseptal injection, pulpal blood flow increased significantly.

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Introduction.

The addition of a vasoconstrictor to a local anesthetic potentiates and prolongs the anesthetic effect. Vasoconstrictor-containing local anesthetics such as 2% lidocaine with epinephrine 1:100,000 are employed in dentistry to induce profound anesthesia. However, it is possible that these agents are capable of altering pulpal blood flow. Olgart and Gazelius (1977) reported that supraperiosteal injection of lidocaine containing epinephrine in the apical area of the tooth caused almost complete cessation of blood flow in the pulp. Hellner (1927) has suggested that a marked reduction in pulpal blood flow resulting from dental anesthesia could result in tissue injury. In spite of the importance of local anesthesia in dental practice, little is known about the effect of local anesthetic agents on the hemodynamics of the dental pulp. Therefore, employing the 15 μm radioisotope-labeled microsphere injection method, the present study was designed to determine to what extent the administration of a commonly used anesthetic agent, 2% lidocaine with epinephrine 1:100,000, alters pulpal blood flow.

Materials and methods.

Ten mongrel dogs of both sexes, weighing 10-15 kg each, were anesthetized with an intravenous injection of sodium pentobarbital (30 mg/kg initial dose, with supplements of 2 mg/kg as needed). Following tracheal intubation, pancuronium bromide (0.08 mg/kg) was given intravenously, and the dog was ventilated with a Harvard respirator†, to maintain the PCO_2 level between 35-42 mmHg. A cardiac catheter was introduced into the left ventricle *via* the left femoral artery. A femoral vein was cannulated with a polyethylene catheter for blood transfusion. The right femoral artery was also cannulated, and a polyethylene catheter (PE 320) was inserted into the abdominal aorta to collect the reference blood flow sample. The dog was heparinized intravenously with an initial dose of 1 mg/kg, followed by hourly supplemental doses of 0.5 mg/kg throughout the duration of the experiment.

The local anesthetic used in this investigation was lidocaine hydrochloride 2% with epinephrine 1:100,000.‡ In each of the dogs, infiltration anesthesia was performed on the maxillary canines, while block anesthesia was administered in the mandible. The local anesthetic was given on one side only (either the left side or the right), while saline injections were administered on the contralateral side as a control. Intraseptal injections were performed as follows: The crest of the alveolar process on the mesial and distal sides of a mandibular molar was punctured with a #30 gauge needle attached to an aspirating syringe. Under pressure, a few drops of the anesthetic solution were deposited into the septal bone. If anesthetic solution leaked from the injection site, the needle was pushed deeper into the bone. Blanching of the gingiva overlying the bone was taken as an indication that the solution had been properly deposited. The contralateral side of the mandible was subjected to a similar injection with physiological saline and served as the control.

In order to determine the extent to which the anesthetic solution spread from the site of injection, a small amount of dye (crystalline blue) was introduced into the anesthetic solution prior to injection. After death of the animal, the jaws were dissected to assess the dispersion of the dye within the tissues.

Measurement of pulpal blood flow with microspheres. – Five types of radioisotope-labeled microspheres were employed. Each type was labeled with one of the following: ^{57}Co, ^{113}Sn, ^{103}Ru, ^{95}Nb, or ^{46}Sc. All microspheres had a diameter of 15.0 ± 1.0 μm (mean ± SD) and were purchased from the New England Nuclear Corp.§ as suspensions in 10% dextran solution (molecular weight = 78,000). In preparation for the microsphere injections, the vials were shaken vigorously with a Vortex mixer‖ for at least five min, then sonicated in an ultrasonic sonicator for two min. Subsequently, a 0.5-1.0-ml quantity of the microsphere suspension (containing approximately 6×10^6 spheres) was diluted to 7 ml with 0.05% Tween 80 in isotonic saline in a 10-ml syringe. Microscopic examination was performed on an aliquot of the solution to assure the complete dispersion of microspheres and to determine their concentration. A minimum of 6×10^6 microspheres per 10 kg body weight was injected in order to ensure the trapping of more than 384 microspheres in the pulp of each tooth in order to attain statistical reliability (Buckberg *et al.*, 1971). One of the five types of labeled microspheres was injected prior to administration of the local anesthetic, in order to establish the control pulpal blood flow. The others were injected at various intervals following administration of the anesthetic solution. Immediately following thorough dispersion, the microspheres were injected steadily over a period of 30 sec, *via* the cardiac catheter, into the left ventricle. An arterial reference blood sample was drawn at a constant rate (Q_{ar} = 15.5 ml/min) from the abdominal aorta by using an in-

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†Harvard Apparatus Co., South Natick, MA

‡Astra Pharmaceutical Products, Inc., Worchester, MA

§New England Nuclear Corp., Boston, MA

‖Scientific Industries, Inc., Queensville, NY

fusion-withdrawal pump†, while cross-matched whole blood was simultaneously infused into the femoral vein at the same rate to maintain constant blood volume. The withdrawal and tranfusion of blood preceded the injection of microspheres by ten sec and were continued for a period of two min.

In all experiments, the arterial blood pressure was monitored during and after microsphere and saline injections. No detectable changes were observed. The reference blood flow samples were divided into aliquots and counted in a well-type scintillation counter connected to a gamma ray spectrometer∞. The total activity of each reference flow (A_{ar}) was obtained by summing the activities of the aliquots.

At the termination of the experiment, the dog was killed by an overdose of sodium pentobarbital administered intravenously, following which the teeth were extracted and the pulp tissues were removed and accurately weighed. The tissue specimens were then placed into the counting vials and their radioactivities determined in the gamma counter. The weight and radioactivity of each tissue sample were entered into a PDP 11/10 minicomputer•. A computer program was used to resolve the radioactivity of each isotope and to calculate the radioactivity per 100 g of tissue sample (C_t). The flow rate per 100 g of tissue sample determined by microsphere (Q_t) was calculated as:

$$Q_t = C_t / (A_{ar}/Q_{ar})$$

A_{ar} and Q_{ar} represent the total activity of reference flow in cpm and a reference withdrawal rate in ml/min, respectively.

Results.

Pulpal blood flow of the teeth measured five to six min after local anesthetic injections (2% lidocaine with 1:100,000 epinephrine) is shown in Table 1. There were no significant changes in pulpal blood flow in the control teeth throughout the experiments. The Fig. depicts the effect of infiltration anesthesia on the maxillary canine teeth. One min following injection of the anesthetic solution, the pulpal blood flow had decreased to 60.6% of the control value, and after six min was only 28.5% of control. Between 15 and 75 min were required for pulpal blood flow to return to near-normal.

∞Packard Instrument Co., Downers Grove, IL
•Digital Equipment Corp., Marlboro, MA

The mandibular block anesthesia caused a decrease in pulpal blood flow for both the molar and canine teeth (Table 1). Within six min following injection, blood flow had decreased to 47.2% of control in molars and 33.2% in canine teeth.

Of the injection methods tested, the intraseptal injection caused the most severe reduction in pulpal blood flow of the molar teeth. Five min following injection of the anesthetic solution, the blood flow had fallen to 9.6% of that in the control teeth in molars and 30.2% in canines (Table 1). Even 65 min after injection, blood flow had only returned to 65.3% and 84.2% in molar and canine teeth, respectively. Spread of the anesthetic solution from the site of injection was confirmed by assessing the dispersion of dye within the tissues. The area of the apex of the tooth was stained as well as was the mandibular nerve bundle along the mandibular canal adjacent to the tooth. In contrast to the flow reduction seen with the intraseptal injection with 2% lidocaine with 1:100,000 epinephrine, pulpal blood flow of the molar teeth increased about 55% above that of the control when the intraseptal injection was made with 2% lidocaine alone (Table 2).

Discussion.

Results of the present study show that local anesthetic injections of 2% lidocaine with epinephrine 1:100,000 are capable of reducing pulpal blood flow significantly in teeth in the area of, or distal to, the injection site. It would appear that, of the three injection methods evaluated in this study, the intraseptal method produces the greatest decrease in blood flow. This effect can probably be attributed to the epinephrine in the anesthetic solution, since the use of 2% lidocaine without epinephrine in the intraseptal caused an increase in pulpal blood flow of the molar teeth.

The circulatory effects of epinephrine 1:80,000 injected supraperiosteally in the area of the canine teeth of cats have been previously reported by Olgart and Gazelius (1977). To monitor pulpal blood flow, these investigators employed the tracer disappearance method which measures the washout rate of radioactive iodide ^{131}I placed in a deep cavity prepared in the crown of the tooth. They reported almost complete cessation of pulpal blood flow within a few min following the anesthetic procedure. During the following two hours, a complete standstill of the tracer washout was observed.

In comparison with the ^{131}I washout method used by Olgart and Gazelius, the radioisotope-labeled microsphere injection method used in the present study offers two

TABLE 1
COMPARISON OF CONTROL AND EXPERIMENTAL PULPAL BLOOD FLOWS (ML/MIN/100 G) BETWEEN FIVE AND SIX MIN FOLLOWING INJECTION OF 2% LIDOCAINE WITH 1:100,000 EPINEPHRINE

	Canine Teeth			Molar Teeth		
	Control (C)	Exp. (E)	E/C	Control (C)	Exp. (E)	E/C
Infiltration	33.32 ± 6.40	7.72 ± 1.5	0.28 ± 0.08	–	–	–
Mandibular Block	28.08 ± 5.39	9.88 ± 3.65	0.33 ± 0.09	26.30 ± 5.16	12.02 ± 2.21	0.47 ± 0.04
Intraseptal	27.36 ± 4.78	8.16 ± 1.45	0.30 ± 0.03	20.04 ± 3.81	1.76 ± 0.37	0.09 ± 0.01

Values are means ± SEM.
Number of experiments is five.
E/C represents the averaging results of the ratio between experimental and control pulpal blood flow of each animal.

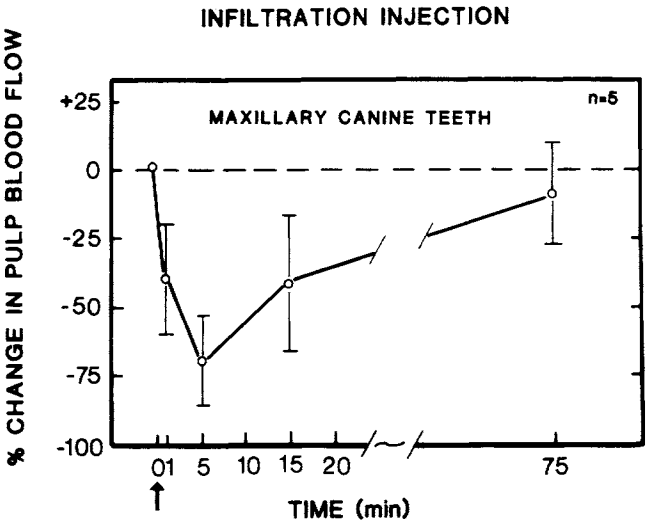

Fig. – Effects of infiltration anesthesia (2% lidocaine with 1:100,000 epinephrine) on pulpal blood flow in the maxillary canine teeth of dogs. The arrow indicates the time of injection. The bar depicts S.D.

TABLE 2
PULPAL BLOOD FLOWS (ML/MIN/100 G) OF MOLAR TEETH BETWEEN FIVE AND SIX MIN FOLLOWING THE INTRASEPTAL INJECTION WITH 2% LIDOCAINE ALONE

Tooth #	Control (C)	Exp. (E)	E/C
1.	25.6	36.8	1.44
2.	18.7	33.3	1.78
3.	20.1	38.9	1.94
4.	34.2	44.6	1.30
5.	22.8	29.8	1.31
Mean	24.28	36.68	1.55
± SEM	2.75	2.51	0.13

distinct advantages: First, it provides a quantitative estimation of pulpal blood flow (Meyer, 1970; Kim *et al.*, 1980). Second, the microsphere method gives the total blood flow of the pulp. The ^{131}I washout method only yields a qualitative blood flow analysis in the subodontoblastic capillary plexus immediately subjacent to the cavity preparation in which the ^{131}I is deposited. Although our results are in general agreement with those of Olgart and Gazelius, discrepancies that do exist can probably be ascribed to differences in methodology.

The magnitude of the effect of mandibular block anesthesia on pulpal blood flow in our experiment was unexpected. The mechanism by which the block anesthesia produces such a marked decrease in blood flow might be explained by the following hypothesis: Since the volumetric flow has a fourth-power relationship with the diameter of the vessel, according to the Poiseuille-Hagen Law, a small change in vessel diameter produced by epinephrine near the inferior alveolar foramen would markedly affect the volumetric flow.

In both the intraseptal and intraosseous injection techniques, the needle of the syringe must puncture the cortical plate of bone in order to deposit the anesthetic solution in the bone marrow space. Introduced under pressure, the anesthetic solution flows radially down the established hydrostatic pressure gradient along the path of least resistance until it reaches the arterioles which supply the pulp. Pashley *et al.* (1981) have shown that pressures ranging from 1448 to 2431 mm Hg can be produced by the intraseptal injection technique in dogs. Since control intraseptal injections of isotonic saline solution did not produce any detectable changes in pulpal blood flow, the possibility that the pressure of the anesthetic solution in the marrow space could have interfered with circulation to the pulp seems unlikely. Our clinical experience also indicates that intraseptal injection of isotonic saline does not have the anesthetic action attained by intrapulpal injection of saline (Birchfield and Rosenburg, 1975). However, the use of 2% lidocaine without epinephrine actually caused a substantial increase, rather than a decrease, in pulpal blood flow (Table 2). Therefore, the decrease in pulpal blood flow in the present study is indeed attributable to epinephrine. It is possible that this vasoconstrictive action of epinephrine is synergistic with lidocaine in achieving maximum anesthesia.

Since dental procedures are usually performed following the use of a local anesthetic, it would appear that blood flow in the pulp may be compromised at the time of operation. Pashley (1979) has shown that the pulpal concentration of substances diffusing across the dentin depends in part on the rate of removal *via* the pulpal circulation. Thus, a significant reduction of blood flow resulting from preoperative administration of a local anesthetic could lead to a high concentration of irritants permeating the dentin from a cavity or crown preparation. These considerations indicate that attempts should be made to maintain an optimal pulpal blood flow during dental restorative procedures.

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