Blood Flow in the Dental Pulp of the Dog.* (29443)

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Various methods have been used to examine the pulpal circulation in experimental animals. Liebman and Cosenza(1) have attempted to correlate electrical impedance with pulpal blood flow in the canine teeth of dogs. Pohto and Scheinin(2) utilized microscopic techniques to visualize pulpal vessels in the rat incisor. To our knowledge actual values for blood flow per gram of pulp tissue have not been determined, although Steiner and Mueller(3) calculated flow per gram of tooth for the rat incisor using a method similar to that employed in this study. The purpose of our investigation was to determine normal pulpal blood flow in dogs and the effect of apical infiltration of 2% xylocaine and 2% xylocaine with epinephrine on the flow. The isotope fractionation technique described by Sapirstein(4) was used to measure the flow.

Methods. Sapirstein(4) suggested that a single intravenous injection of K^{42} will be distributed initially to organs or regions in proportion to their blood flow. During the time period in which the amount in the venous drainage and recirculation is negligible, the fractional distribution of K^{42} to the organs or regions will correspond to the fractional distribution of the cardiac output to the organs or regions. Thus, the flow to any organ or region (x) is the product of the cardiac output (CO) and the fraction of total injected isotope going to the organ or region (f_x):

$$\text{Pulpal blood flow} = (CO) \cdot (f_p) \qquad 1.$$

The fraction of the cardiac output to the pulp (f_p) will simply be the ratio of K^{42} found in the pulp (CPM_p) to the total injected K^{42} (CPM_T).

$$f_p = (CPM_p) / (CPM_T) \qquad 2.$$

The isotope dilution technique as previously employed by others(5,6) was used to determine the cardiac output. With a sudden injection, the cardiac output is equal to CPM_T divided by the area under the isotope arterial dilution curve formed by a plot of the radioactivity, A in CPM per cc of blood appearing at the outflow of the left heart as a function of time.

$$CO = (CPM_T)/(\int_0^\infty A(t)\,dt) \qquad 3.$$

By combining equations 1, 2, and 3, then:

$$PBF = (CPM_P)/(\int_0^\infty A(t)\,dt) \qquad 4.$$

Since maximum amount of pulpal tissue was desired and since the amount of pulpal tissue is decreased with age, young dogs ranging in age from 5 to 7 months were used. The animals (N = 13) were anesthetized with 30 mg/kg of sodium pentobarbital. Ten to fifteen minutes prior to injection of a known volume of the indicator (K^{42}), xylocaine alone was infiltrated at the apex of a canine tooth. Then xylocaine with varying amounts of epinephrine (5 to 20 μg) was infiltrated at the apex of a canine tooth in the opposing arch. The other 2 canines served as controls.

Isotopic injections were made into the vena cava. The isotope dilution curve used to calculate cardiac output was obtained by continuous sampling from a catheter placed in the descending aorta via a femoral artery. The arterial blood was drawn through a cuvette placed in the window of a Geiger Mueller tube connected to a ratemeter. The dilution curve was recorded on a strip chart recorder. Approximately 40 seconds after administration of K^{42}, the animals were sacrificed by a rapid intravenous administration of a saturated solution of concentrated KCl. The canine teeth were extracted, all periodontal tissue removed and the tooth wiped with a saline sponge. The teeth were then separated into pulpal and hard structure, weighed,

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TABLE I. Blood Flow* in the Dental Pulp of the Dog.

Dog #	Control	Xylocaine	% difference	Control	μg of epinephrine	Epi + Xylo	% difference
1	.89	.96	+ 7.9	.97	5	.99	+ 2.1
2	.83	.82	- 1.2	.92	5	.80	- 8.7
3	.84	.87	+ 3.5	.98	5	.94	- 4.1
4	—	—	—	.84	10	.85	+ 1.2
5	.66	.60	-11.0	.70	10	.31	-55.7
6	1.43	1.36	- 4.9	1.67	10	1.21	-27.5
7	.66	.66	.0	.86	13	.19	-77.8
8	.91	.92	+ 1.1	.89	13	.89	.0
9	.90	.82	- 8.9	.87	13	.84	- 3.4
10	—	—	—	1.02	20	.32	-68.5
11	—	—	—	1.89	20	1.05	-44.4
12	1.01	1.06	+ 5.0	.87	20	.53	-39.1
13	.94	.94	.0	.91	20	.58	-36.2
Avg	.91	.90	- .8	1.03	—	.73	-27.9
S.E.	±.06	±.08	± 1.6	±.09		±.09	± 7.1

* Flows are given in cc/min-g of pulp. Experimental flows (xylocaine and epinephrine + xylocaine) are compared to control flows in the corresponding tooth in the same arch. Applying the t-test the P-value (Xylo) $>.5$, and P-value (Epi + Xylo) $<.01$.

dissolved in concentrated nitric acid and the activity counted in a scintillation well counter. All counts occurring in the hard structure were assumed to be derived from the pulpal blood supply and not from the periodontium. The total CPM injected was determined from analysis of aliquot of the injection solution. Pulpal blood flow (PBF) was then calculated using equation 4 and converted to perfusion rates (cc/min-g) by dividing by the pulp weight.

Results. The pulpal blood flows in the various canine teeth for each dog are presented in Table I. The percentage difference between the control flows and the flows in the teeth which had xylocaine alone or xylocaine with varying amounts of epinephrine is included. The average pulpal blood flow for all control teeth was 0.98 ± 0.07 (S.E.) cc/min-g. Flow in teeth which had xylocaine alone infiltrated at the apex was not significantly different from that in the controls; that is, the percentage change was not significantly different from zero. However, flow in those canine teeth that had 5 to 20 μg of epinephrine infiltrated with the xylocaine decreased on the average of 27.9% (S.E. = + 7.1%). The correlation coefficient between dose of epinephrine and percentage change in blood flow was 0.57 as calculated by the least squares method. Analysis of the variance showed that the correlation coefficient was significant at the 5% level. The ratio of activity found in the pulpal tissue to total activity found in the tooth (hard plus soft structure), averaged 0.66 ± 0.01 (S.E.) for controls, 0.66 ± 0.03 for xylocaine teeth and 0.65 ± 0.04 for teeth which had xylocaine with epinephrine infiltrated at the apex. Thus, about one-third of the K^{42} brought to the tooth via the pulpal circulation was found in the hard tissue.

Discussion. The only known values of pulpal blood flow to which these results can be compared are those of Steiner and Mueller(3). They reported a value of 0.2 cc/min-g, presumably for the whole rat incisor. The average flow, when calculated for the entire canine tooth of the data presented here, is 0.33 cc/min-g. Such a difference may be due to differences in the relative amounts of pulpal and hard tissue.

The validity of the calculation of blood flow from tissue K^{42} content is dependent upon the assumption that venous loss of the isotope in the 40 second interval after injection is small. For at least one canine organ, the brain, venous loss is large and cerebral blood flow is considerably underestimated by the K^{42} fractionation technique. It seems unlikely that this would be the case with the dental pulp; however, the possibility that the values given here are underestimated cannot be excluded. Only by means of the extremely difficult procedure of collecting venous blood derived solely from the dental pulp

could a definitive answer be obtained.

It is considered(7) that xylocaine, like procaine, does not have vaso-constrictor properties. However, Pohto and Scheinin(8) using microscopic observations felt that a mandibular injection of xylocaine in the rat retarded the flow in the pulp of the incisor tooth. They also felt that a mandibular injection of an anesthetic with epinephrine (2% Carbocaine plus a 1:200,000 concentration epinephrine) retarded blood flow in the pulp to a greater extent than an injection of 1:20,000 epinephrine alone. Scheinin (9) attempted to evaluate changes in pulpal flow in the rat incisor from red cell velocity by matching it with the moving spot on a slow sweep cathode-ray tube. He noted a widening of the vessels and that the velocity in these vessels decreased by more than 50% following the mandibular injection of 2% xylocaine. He did point out that a change in diameter of the vessel affects flow, but did not indicate if the decrease in velocity could be accounted for by the increase in diameter observed. In addition, in his study a solution such as physiological Ringer's was not used as a control injection.

Whether xylocaine or xylocaine with epinephrine has a similar effect in the human as seen in this study or that in the work of Pohto and Scheinin(8,9) can only be speculated. Clinically, it can be noted that the topical application of 2% xylocaine with epinephrine (1:50,000) on the pulpal tissue of an accidental or carious exposure in a vital human pulp or on the pulpal stumps following a pulpotomy will reduce hemorrhage more readily than 2% xylocaine alone. In experimental animals it may be possible to use the present technique to study the effects of topical application of a vasoconstrictor on the pulpal blood flow.

From the present data, no effect is seen at 10 to 15 minutes in those teeth in which 2% xylocaine was infiltrated at the apex. This indicated that if xylocaine exerts a vasodilation or vaso-constriction effect it is of short duration. The 10-15 minute delay was selected arbitrarily as an adequate period for transporting quantities of the injection to the pulpal circulation. An epinephrine effect is present after such a delay; however, some oxidation may have occurred. The decrease in flow is dependent upon the amount of epinephrine injected. This is substantiated, even with a limited number of animals, by the significant correlation between the decrease in pulpal flow and the amount injected.

Summary. Pulpal blood flow to the canine teeth of young dogs was studied using the isotope fractionation technique, which involves determining the fractional distribution of the cardiac output to the teeth. Cardiac outputs were determined from isotope dilution curves. Xylocaine and xylocaine with varying amounts of epinephrine (5-20 μg) were infiltrated separately at the apex of a canine tooth. The contralateral tooth in the same arch served as the control. The average flow in the control teeth was 0.98 cc/min-g of pulp tissue. Flow in teeth which had xylocaine alone infiltrated at the apex showed no significant difference from the controls. However, flow in those canine teeth which had 5-20 μg of epinephrine infiltrated decreased an average of about 30%. This change in flow was significantly correlated to the dose of epinephrine injected.

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