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Effects of Morphine and Nalorphine upon Tooth Pulp Thresholds of Dogs in the Alert and Drowsy State*

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It is well known that morphine elevates the threshold for repetitive stimulation of the tooth pulp in dogs with chronically implanted electrodes (KOLL and REFFERT 1938; GOETZL et al. 1943; WIKLER 1950; BOREUS and SANDBERG 1955). However, opiates induce sleep which in itself may raise the "pain" threshold by 50 per cent (WOLFF et al., 1940). Therefore, it was important to determine if the elevation in tooth pulp threshold caused by morphine was secondary to the drowsiness it produced. This report offers some experimental evidence in the elucidation of this problem.

Chronic bipolar electrodes were implanted in the upper canine teeth of six mongrel dogs (7 to 10 kg) under pentobarbital anesthesia. By aseptic techniques Formex coated stainless steel wires were placed into two small cavities in the upper canines. The holes were sufficiently deep so that the pulp could be visualized through a thin layer of dentine. A small loop was made at the bared peripheral end of the wire and placed into the cavity which was then firmly packed with silver-mercury amalgam. Dental acrylic was placed over the cavity to insulate the tooth and to help prevent the wires from pulling out. The appropriately identified wires were led below the skin through the vestibule to the top of the scalp for ease of electrical stimulation. To prevent infection, each dog received 100,000 units of penicillin intramuscularly for 3 days after surgery. In order to maintain a constant environment all tooth pulp thresholds were taken in a relatively quiet room each morning, beginning 3 to 10 days postoperatively. To restrict extraneous movements the dog was placed in a stockade. Before the actual experiment the animal was throughly familiarized with the apparatus and environment. Each of the upper canines was stimulated separately to determine which tooth gave the most reproducible response. Subsequently, that tooth was used for the remainder of the study. Repetitive shocks were applied to the tooth via the bipolar electrodes. A Hunter interval timer triggered a Grass Model S4B stimulator and isolation unit. Square wave pulses of 1 millisecond duration usually at 100 cycles per second

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for 1 second were repeated every 3 to 5 minutes in order to determine the threshold intensity to produce the characteristic response. For purposes of comparison a frequency of 30 cycles per second was used in one dog. In some experiments both voltage and current were monitored. Inasmuch as the current thresholds paralleled the voltage thresholds the data were expressed in volts for reasons of convenience.

The responses produced by stimulation of the tooth pulp varied between dogs but were consistent in each individual animal. A sufficient period of training was needed for the observer to differentiate spontaneous movements from those caused by stimulation. The intensity of repetitive electrical stimulation of the tooth pulp required to elicit a characteristic reaction response varied with the state of the animal. If the dog was wide awake the threshold of stimulation was lower than when the animal was drowsy or lethargic. The criterion for a response was a definite motor movement such as opening the mouth, chewing, or licking. After a period of training when the thresholds were stabilized, control thresholds were obtained in both the alert and drowsy states on the day that morphine and nalorphine were administered. The alert state was considered that in which the eyes were open and the dog was aware of minor changes in the environment, vocalized, or made some motor movement indicating an aroused or awake condition. The drowsy state was defined as that in which the eyes were closed and the animal was quiet and unaware of minor stimuli in the environment. After relatively constant thresholds were obtained a dose of 2 mg/kg of morphine was given intravenously and antagonized with 1 mg/kg of nalorphine given intravenously. The effects of morphine on the tooth pulp thresholds were determined periodically every 5 to 10 minutes. At the time of maximal elevation of the tooth pulp threshold following morphine (usually within 30 to 60 minutes) nalorphine was administered. The peak effect of nalorphine was usually 6 to 15 minutes after injection. The data obtained at maximal effect are listed in table 1. The tooth pulp thresholds after morphine were obtained immediately after the animal was awakened from deep morphine narcosis by gentle tapping on the table. Thus, the animal under morphine was aroused and aware of his surroundings at the time that the tooth pulp was stimulated. Inspection of table 1 shows a consistent trend in the effects of various treatments in each dog. In each animal both the drowsy state alone and morphine produced an increase in the threshold voltage greater than that seen during the awake state. Nalorphine reduced the elevated threshold after morphine toward the control level. Individual differences in dogs are indicated since each animal responded at considerably different threshold voltages. In a 2 way classification analysis of variance this individual difference in dogs was significant at the 5 per cent probability level. A Student "t" paired comparison test was used on the different

combination of treatments summarized in table 1. The voltage required of elicit a response during the alert state was found to be significantly different ($P < .005$) from that in the drowsy state. When the threshold during the alert state was compared to that after morphine, a 2.5 per cent level of significance was obtained. The data also show that the elevation in tooth pulp theshold produced by morphine is greater than that of the drowsy state alone ($P < .05$). Threshold voltages after morphine were also significantly different from those after nalorphine antagonism.

Table 1. *Effects of morphine and nalorphine on the threshold voltages required to elicit a response to repetitive stimulation of the tooth pulp in chronic dogs*

Dog	Threshold in Volts ± S.D.[1]			
	Control State		Morphine (M) 2 mg/kg IV	Narlorphine (N) 1 mg/kg
	Alert (A)	Drowsy (D)		
I	3.0 ± 0	4.0 ± 0	7.0 ± 0	5.0 ± 0
VI	1.5 ± 0	3.8 ± .3	5.3 ± .6	3.0 ± 0
VII	2.0 ± 0	6.0 ± .8	6.0 ± 0	3.3 ± .4
VIII	3.8 ± .3	8.3 ± .6	14.7 ± .6	7.3 ± .6
X	10.3 ± .5	12.0 ± 1	18.0 ± 2	10.5 ± 3.5
XII	9.5 ± .7	14.3 ± .4	26.0 ± 0	9.7 ± .6

[1] The voltage for each observation was measured to the nearest 0.5 V, but the threshold listed is the mean of 2 to 4 observations. The standard deviations are given only as an index of the reproducibility of the observations but were not included in the student „t" paired comparison test. The pairs compared with their P values are as follows: A—D, <.005; A—M, <.025; D—M, <.05; M—N, <.05.

Similar results were obtained when an analysis of variance of the subdivisions of treatment was performed except that the analysis of variance differed from that of the Student "t" test in that the thresholds during the alert state were significantly different from that of the drowsy state only at the 7 per cent probability level. The discrepancy between these two tests is probably due to an overestimate of the true error in the analysis of variance since the residual term included both interaction and sampling error. The results indicate that the effect of morphine in elevating the threshold for repetitive stimulation of the tooth pulp in chronic dogs is greater than that due to drowsiness alone. After morphine, nalorphine is effective in lowering the tooth pulp threshold toward the control alert state.

Summary

The alteration of tooth pulp thresholds of dogs with chronically implanted electrodes was determined in the awake and drowsy states after morphine and nalorphine. The elevation in tooth pulp threshold was significantly greater after morphine than during the alert or drowsy state of the animal. Nalorphine antagonized this effect of morphine.

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