

**DETECTION OF SMALL BONE ABSCESSES WITH A HIGH-RESOLUTION CADMIUM TELLURIDE PROBE**

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*A cadmium telluride (CdTe) semiconductor probe was tested under clinical conditions as an external detector of medium-energy gamma rays and its performance was compared with that of the detector system of a rectilinear scanner. The two systems were used to detect acute infectious abscesses in dogs following the administration of <sup>99m</sup>Tc-polyphosphate (Tc-PP). The counting efficiency of the CdTe probe when held in contact with the jaw was 50 to 75% of that obtained with a 5-in. NaI(Tl) crystal detector at a 3-in. focal plane distance from its medium-energy, fine-focus collimator (168 hole). The reproducibility of the CdTe probe measurements of normal teeth fell within a range of ±13%. Diagnostically significant increases in Tc-PP uptake were detected in abscessed teeth with both detector systems within 1 to 2 weeks after infection as compared with intraoral radiography, which required 4 weeks for positive detection. In terms of spatial resolution, the CdTe probe proved to be superior in that it could readily distinguish contiguous normal and infected root tips less than 1 cm apart. In contrast, the NaI detector system was unable to distinguish the normal root tips of an uninfected tooth interposed between those of two adjacent infected teeth.*

Semiconductor detectors that can be operated at room temperature have become available recently and their clinical use with beta- and gamma-emitting radiopharmaceuticals has been reported (1). Two major advantages of this class of detector over sodium iodide systems are superior-energy resolution and the variety of miniaturized designs which are possible. Semiconductor probes containing silicon are used primarily for beta- and low-energy gamma radiation whereas cadmium telluride (CdTe), with a

higher atomic number ( $Z = 50$ ), is the preferred material for medium-energy gamma radiations including <sup>99m</sup>Tc. Recent improvements in design have resulted in CdTe detectors with gamma-ray counting efficiencies comparable to those of NaI(Tl) systems of equivalent dimensions.

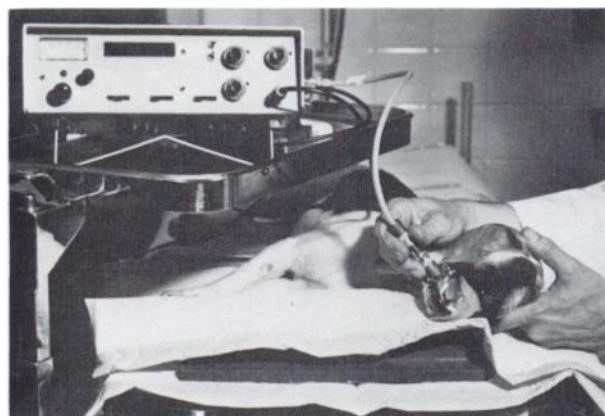
This communication reports the detection of tooth abscesses in dogs made possible with the use of a CdTe probe by the external counting of previously administered <sup>99m</sup>Tc-PP. The diagnostic usefulness, stability of performance, and the reproducibility of measurements of the probe were investigated under clinical conditions.

**METHODS**

The detector was constructed from a 1-cm diam by 2-mm thick slice of chlorine-doped CdTe crystal grown by the traveling heater method (2). The crystal is contacted on its large faces with 7-mm-diam

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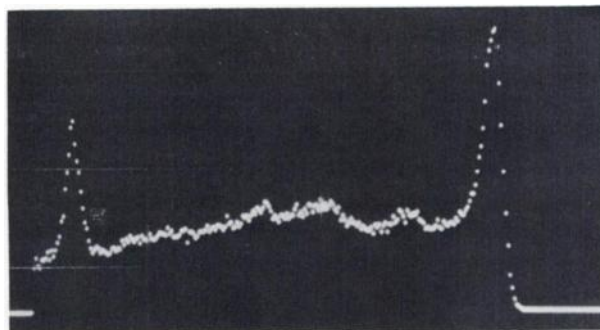
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**FIG. 1.** Positioning of CdTe probe for <sup>99m</sup>Tc-PP uptake measurements in posterior teeth.

platinum contacts. Contacting is achieved by substitution of platinum for cadmium on the surface of crystals immersed in a platinum chloride solution (3). Undesirable polarization effects are eliminated by this procedure, and finished detectors are obtained with very high stability at operating voltages of only 50 volts. The detector is encased in a thin aluminum package which was collimated with a 4-mm diam by 1-cm long lead aperture. The associated electronics included a commercial timer, scaler, discriminator unit with the bias supply, preamplifier, and amplifier modified for use with the CdTe detector. The entire assembly, shown in Fig. 1, weighs less than 8 lb and is easily portable. A  $^{99m}\text{Tc}$  pulse-height spectrum measured with the detector is shown in Fig. 2. Animal bone-uptake measurements were made with a discriminator setting to exclude photons less than 115 keV.

Acute infectious abscesses were induced in three right molar teeth in each of four beagles by sealing fresh dog fecal material in the vital, mechanically exposed pulp chambers. The animals were probed and intraoral radiographs made under nembutal anesthesia at weekly intervals thereafter. Probing was done 3 to 4 hr after intravenous administration of  $^{99m}\text{Tc}$ -Sn-polyphosphate at 1.5 to 2 mCi/kg of body weight. Counting rates were accumulated with the probe tip hand-held against the buccal gingiva overlying the molar root apices. Three 30-sec counts were made for each of the two roots per molar and the final data were expressed as the ratio of the average counting rate of an infected right tooth to that of the same tooth in the left untreated jaw. Each dog was probed at least three times prior to infection and ratios of right-to-left molars were calculated from these data and pooled. Postinfection ratios were compared with the mean of the pooled pretreat-



**FIG. 2.** Pulse-height spectrum of  $^{99m}\text{Tc}$  as measured with a collimated CdTe detector. Peaks at 20 keV and 140 keV have FWHM of 4.5 keV and 6.6 keV, respectively.

ment data to determine changes in Tc-PP uptake resulting from infection.

Right and left lateral head bone images were made with a standard Ohio-Nuclear rectilinear scanner containing a 3- × 5-in. NaI(Tl) crystal and a 168-hole fine-focus collimator. Imaging was performed immediately after CdTe probe measurements of the jaws.

#### RESULTS AND DISCUSSION

The counting rates of normal teeth obtained with the probe ranged from 2 to 6 × 10<sup>3</sup> cpm/mCi of injected dose/kg of body weight, 3 hr after injection. These rates were, on the average, 50 to 75% of comparable measurements obtained with the collimated rectilinear scan detector at its 3-in. focal plane distance. Daily measurements of a standard  $^{57}\text{Co}$  source made at room temperature and with a fixed geometry revealed counting rate variations of ±6% over a 6-month period. The variability of in vivo measurements is shown by the data of Table 1. Counting rates for a normal tooth over a 6-week

**TABLE 1. REPRODUCIBILITY OF REPEATED MEASUREMENTS WITH A CdTe PROBE OF Tc-PP UPTAKE IN A NORMAL LOWER LEFT THIRD PREMOLAR**

Dog	Weeks					
	1	2	3	4	5	6
<b>No. 1</b>						
Counting rate (cpm/mCi/kg)*	2919	2894	3219	3655	3660	3374
Mean counting rate	3287	—	—	—	—	—
% deviation from mean	-11.2	-12.0	-2.1	+11.2	+11.3	+2.6
<b>No. 2</b>						
Counting rate (cpm/mCi/kg)	2412	2162	2184	1986	2402	2538
Mean counting rate	2280	—	—	—	—	—
% deviation from mean	+5.8	-5.2	-4.3	-12.9	+5.4	+11.3

\* cpm/mCi of injected dose/kg of body weight. Raw data were adjusted for variations in daily instrumental performance (±6%) by means of measurements with a fixed geometry of a standard  $^{57}\text{Co}$  source. The adjusted data were corrected for  $^{99m}\text{Tc}$  decay to 3 hr after injection.

period in each of two dogs are shown. The data were adjusted for <sup>57</sup>Co counting rate differences and corrected for <sup>99m</sup>Tc decay beyond 3 hr after injection. Mean counting rates were determined and the deviations of weekly counting rates from their respective means were calculated for these representative data. The deviations ranged from -12.9% to +11.3%, with average deviations of 8.4 and 7.5% for Dogs 1 and 2, respectively. This net variability of repeated in vivo measurements, over and above that of instrumental performance, was assumed to reflect differences in the biologic uptake of Tc-PP as well as variations in the repositioning of the probe over a particular area.

A total of 60 right-to-left tooth counting rate ratios were obtained from preinfection probe measurements. The mean and standard deviation of the pooled data were 1.01 ± 0.08 (range 0.85-1.16). From these results, it was determined that ratios obtained after infection which were either greater than 1.21 or less

than 0.81 (±2.5 s.d.) could be considered statistically significant. Table 2 contains the ratios obtained over a 6-week period after infection. Technetium-99m counting rates of all infected teeth were higher than their normal counterparts throughout the study. Ratios for 10 of 12 infected teeth were greater than 1.21 by the first week while the remaining two teeth (Dog 3, lower third premolar and first molar) exceeded this level by the second week after infection. Essentially the same results were obtained by rectilinear scanning. Although subtle changes in the radiographic density of the lamina dura surrounding infected tooth apices were apparent by the second and third weeks, the earliest unequivocal evidence of a periapical radiolucency was obtained by the fourth week after infection. In all instances, therefore, the earliest diagnostic evidence of periapical pathology was provided by bone scanning.

One upper and two lower teeth were infected in each dog. The lower teeth, the third premolar and

**TABLE 2. RATIOS OF Tc-PP COUNTING RATES OF RIGHT (INFECTED) TO LEFT (NORMAL) POSTERIOR TEETH FOLLOWING INFECTION**

Dog	Weeks after infection					
	1	2	3	4	5	6
	Upper fourth premolar					
1	1.26	1.39	1.84	1.74	1.72	1.83
2	1.22	1.29	1.37	1.31	1.23	1.33
3	1.24	1.41	1.56	1.88	2.06	2.04
4	1.23	1.32	1.89	2.10		
	Lower third premolar					
1	1.26	1.58	1.47	1.40	1.39	1.38
2	1.35	1.50	1.41	1.40	1.38	1.43
3	1.19	1.34	1.42	1.61	1.60	1.53
4	1.31	1.50	1.51	1.50		
	Lower first molar					
1	1.33	1.50	1.64	1.73	1.61	1.70
2	1.32	1.26	1.29	1.25	1.34	1.35
3	1.08	1.33	1.35	1.40	1.35	1.42
4	1.23	1.27	1.32	1.52		

**TABLE 3. RATIOS OF Tc-PP COUNTING RATES OF RIGHT TO LEFT LOWER TOOTH ROOTS FOLLOWING INFECTION**

Tooth	Root	Separation (mm)	Weeks after infection*					
			1	2	3	4	5	6
Third premolar	Distal	7	1.37	1.50	1.37	1.47	1.44	1.43
Fourth premolar	Mesial	6	1.02	0.98	1.16	1.19	1.23	1.21
Fourth premolar	Distal	6	0.93	1.16	1.21	1.29	1.40	1.40
First molar	Mesial	9	1.30	1.58	1.76	1.59	1.63	1.77

\* The lower right third premolar and first molar were infected whereas the lower right fourth premolar and the same three teeth of the left jaw were normal.

first molar, were separated by a distance of approximately 2 cm. This space was occupied by the fourth premolar, which was normal or untreated in both jaws. Rectilinear scans of these teeth 1 and 2 weeks after infection showed areas of increased Tc-PP uptake as two distinct "hot spots" with diffuse borders which merged in the intervening region occupied by the normal fourth premolar. Superimposition of the scans on lateral head radiographs showed that each hot spot covered both roots of an infected tooth as well as one root of each of its mesial and distal neighbors. Consequently, it was not possible to rule out the presence of pathology in the root tips of the uninfected lower fourth premolar. The superiority of the CdTe detector in this respect is demonstrated by the data of Table 3. The data are ratios of contiguous individual root tips of the three lower teeth in question. The distances separating the root apices were estimated from intraoral radiographs. During the first 3 weeks after infection, ratios for the root apices of the untreated fourth premolar remained within the normal range whereas those of the infected teeth exceeded the level of significance. These data allowed the unequivocal differentiation of normal

from diseased root tips. From 4 to 6 weeks after infection, data obtained with both detector systems indicated a significantly higher uptake of Tc-PP in the root tips of the normal fourth premolar. However, no radiographic evidence of periapical bone destruction was seen during this or later times.

The results of this study illustrate the spatial resolution of the CdTe probe that made possible the detection of closely spaced lesions. The superior resolution of the CdTe detector, together with the stability of performance and a counting efficiency comparable with that of a rectilinear scanner, suggest its potential usefulness in the detection of small superficial lesions.

#### REFERENCES

1. MARTINI M: Semiconductor radiation probes for nuclear medicine and radiobiology: The state of the art. *IEEE Trans Nucl Sci* NS-20: No 1, 294-309, 1973
2. BELL RO, WALD FV: Recent advances in the preparation of CdTe for nuclear detectors. *IEEE Trans Nucl Sci* NS-19: No 3, 334-345, 1972
3. SERREZE HB, ENTINE G, BELL RO, et al: Advances in CdTe gamma-ray detectors. *IEEE Trans Nucl Sci* NS-21: No 1, 404-407, 1974

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