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Experiences with a Solid State Detector for Surface Counting of Phosphorus-32[1,2,3]

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The possibility of using solid state detectors in place of miniature GM tubes for monitoring ^{32}P turnover in superficial lesions of the skin and the eye has been explored. This paper describes the instrument and its characteristics and discusses the results of its application to the differentiation between malignant and benign superficial lesions.

INSTRUMENTATION

Measurements were made with a surface barrier type detector (1) with a depletion depth of 300 microns (ORTEC-SBB-7007-300). The detector was made of hyper-pure, n-type silicon, which forms a junction with a Mylar window measuring 0.65 cms in diameter and 0.5 mg/cm^2 in thickness. The device was housed in a gold plated brass can 2.24 cm long and 0.8 cm in diameter. Electrons penetrating the window deposited their charges in the detector. These charges were collected at the signal pin and converted into a pulse which was transmitted down the center conductor and through a four-foot long coaxial Micro Dot Mininoise cable into an amplifier. After amplification, the pulses were routed through the low level discriminator. Both amplifier and discriminator were housed in model ORTEC-207. The pulses which exceeded a preset discriminator level were fed into a scaler. The detector bias was set at 10 volts and the discriminator level at 75 keV.

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PROCEDURE

A total of 31 examinations were carried out: 11 on melanomas of the iris, one on a melanoma of the ciliary body and 19 on skin lesions. Of the skin lesions, one was a keloid from a thoracentesis, two were melanomas and 14 were metastases. Of the metastatic lesions, six were from carcinoma of the breast, one from carcinoma of the lung, two from carcinoma of the pharynx and five from carcinoma of the parotid gland. Four of the metastatic lesions were reexamined after radiation treatment.

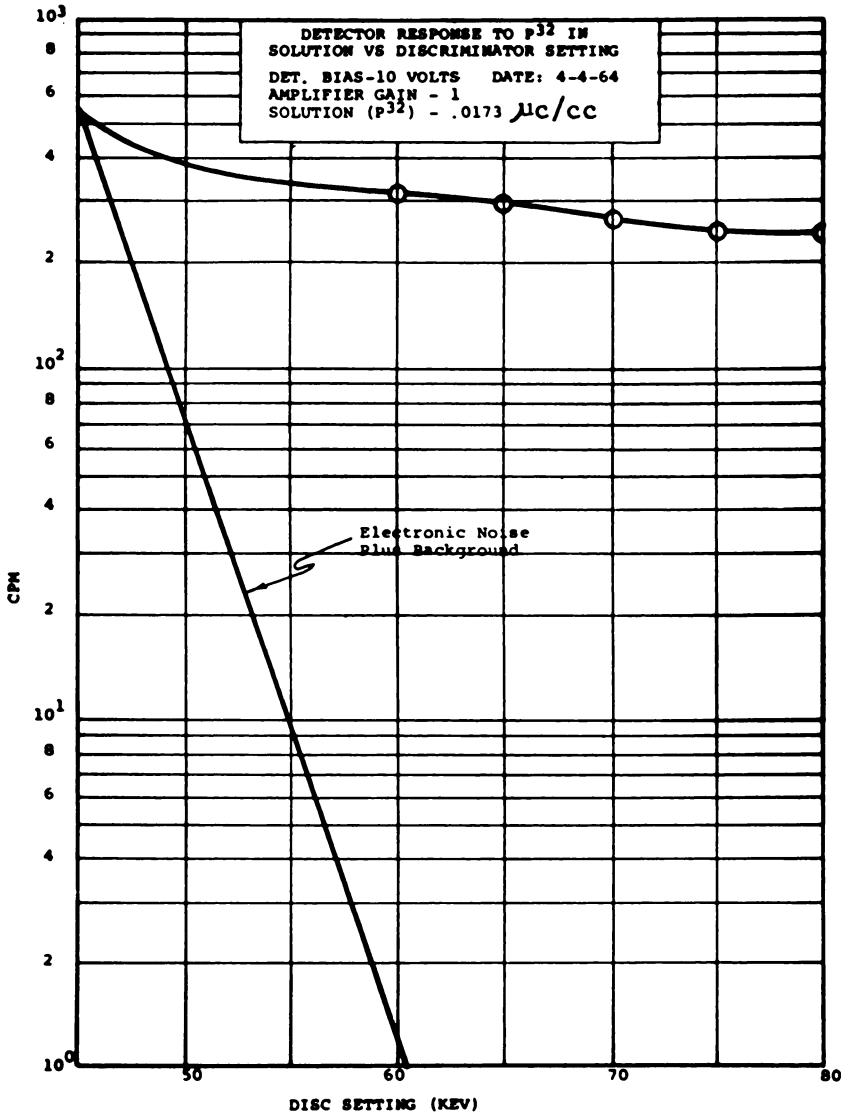

Fig. 1. Detector response to ^{32}P versus discriminator setting (see text).

All patients received sodium phosphate-^{32}P solution intravenously. The doses ranged from 20 to 100 uC per liter of calculated blood volume. The lesions were counted, when possible, at 1, 4, 24 and 48 hours after the injection of the tracer. The detector was covered with a sterile tonofilm (American Bio-Chemical Laboratory, Inc., Lot # 1108) and then carefully centered over the lesion (eye) or in contact with the lesion (skin). Counts were also obtained each time over areas situated on the opposite side of the patient at a point symmetrical to the lesion. The lesions as well as the control sites were counted for two minutes. The results were expressed as differential uptake of ^{32}P in the lesion, i.e.,

$$\frac{\text{cpm over lesion}-\text{cpm over control}}{\text{cpm over control}} \times 100$$

RESULTS

The characteristics of the surface barrier type detectors have been described by others. For the purpose of this investigation, some *in vitro* experiments were done with the surface of the tonofilm covered detector submerged into a ^{32}P solution of 10 cc total volume and a concentration of 0.0173 microcuries/cc. Figures 1 and 2 show the detector's response in counts per minute at various discriminator and voltage levels. The counting efficiency of the detector was determined in a ^{32}P solution of 10 cc total volume and a concentration of 0.538 microcuries/cc under the same geometrical conditions as before. The count rate of the solid state detector was 1.09% of the calculated disintegration rate. For the Anton probe, the count rate was 1.03%. The background counts, i.e., the counts registered per minute without any radiation source in the vicinity, were 2 cpm for the solid state detector and 15 cpm for the Anton probe.

The results of the "*in vivo*" measurements obtained with the detector are listed in Table I for the eye lesions and in Table II for the skin lesions. Table III shows the effect of radiation therapy on the differential uptake in four lesions of the skin metastatic from carcinoma of the breast.

DISCUSSION

In 1941 Erf and Lawrence reported, "Wherever there is leukemic or neoplastic infiltration there is a higher uptake of labeled phosphorus than in uninvolved tissues, and this uptake is found to be higher than that of any other soft tissue." (2). A year later, Marinelli and Goldschmidt described a method by which the concentration of ^{32}P uptake was measured in superficial tissue with a GM tube (3). Since then, the technique has been applied to differentiate between malig-

TABLE I

AVERAGE DIFFERENTIAL UPTAKE OF ^{32}P IN MELANOMAS OF THE EYE

Location of lesion	*Number of lesions*	*Differential uptake (average)*		
		4 hrs.	*24 hrs.*	*48 hrs.*
Iris	11	20 ± 7.9	32 ± 7.1	34 ± 6.2
Ciliary body	1	399	482	

nant and benign tumors of the skin (3), superficial tumors of the breast (4), and lesions of the eye (5, 6, 7); for the localization of brain tumors (8); and, in recent years, for the study of growth of tumors and their response to treatment (9, 10, 11). A great variety of GM type detectors have been designed for these various applications. Marinelli's GM tube measured 5 cm in diameter; the newest miniature probes range in size from 0.06 to 0.1" in diameter (11).

Miniature detectors are particularly well suited for "*in vivo*" measurements of uptake and turnover of radioisotopes. Because of their small size they may be used for counting radioactivity in small superficial lesions such as those of the skin and eye; they may be introduced through catheters into body cavities such

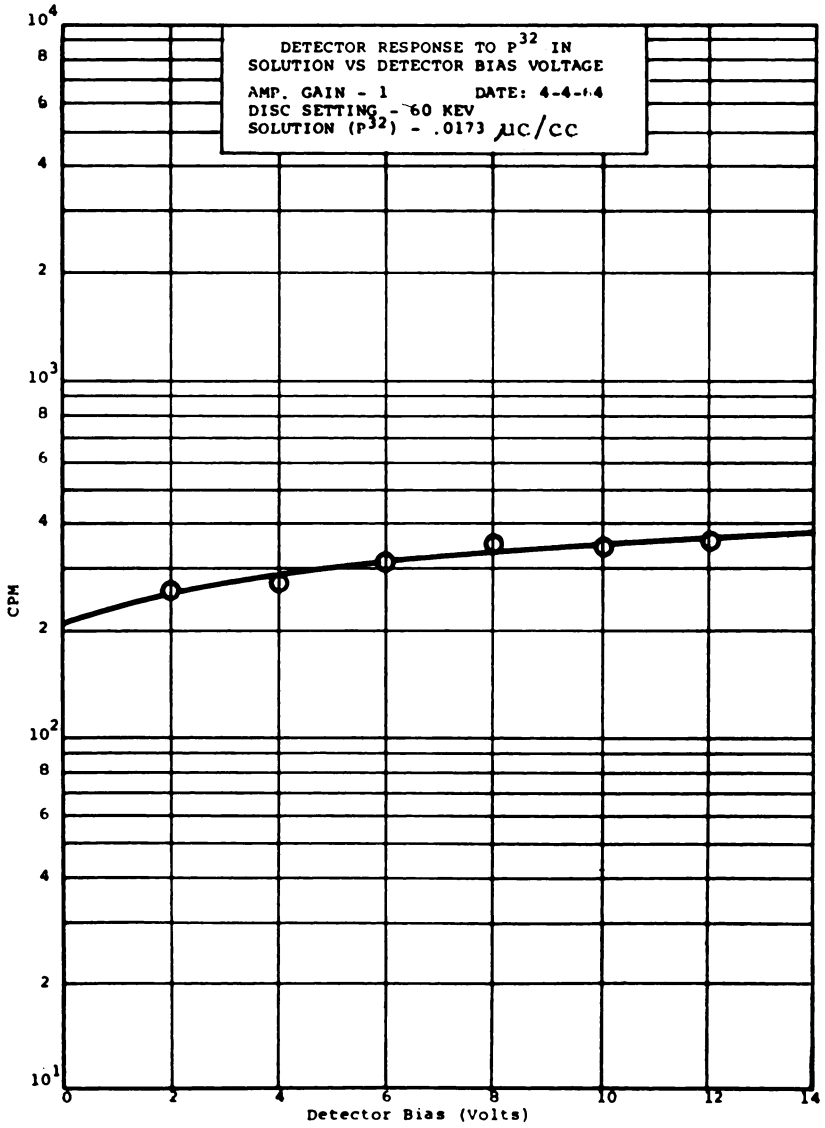

Fig. 2. Detector response to ^{32}P versus detector bias voltage (see text).

as those of the GI and GU tracts, the cardiac chambers and great vessels, or they may be implanted into tissue through trochar needles.

Solid state detectors which are essentially solid versions of gas-filled ionization chambers have several advantages over GM type detectors. According to Friedland and co-workers (1), they can be made small and in a variety of shapes. They have excellent resolution which allows reduction of the background count and makes them well suited for the assay of samples in the presence of large amounts of "contaminants." Because they can be small they may be used for "internal monitoring" and thus permit the use of relatively small doses. They are also quite inefficient in the detection of photons originating elsewhere and therefore allow a precise localization of radioactivity. Furthermore, they have a high degree of stability and operate at a low voltage.

Our clinical experience with miniature solid state detectors has so far been limited to surface counting of ^{32}P uptake in melanomas of the anterior hemisphere of the eye and in lesions of the skin. Although a rather small group of patients have so far been studied, certain characteristics of the detector have been observed so consistently that a report of the results appears justified even at this early stage of investigation. The most obvious of its favorable features is the ease with which it can be handled. It can be centered accurately over small lesions and kept in position for as long as three minutes in such delicate areas as the cornea of the eye without discomfort to the patient. The diameter of the detector rarely exceeds that of a skin lesion and only occasionally that of an iris melanoma. This fact, we believe, is of importance because normal tissue included in the lesion count would tend to "dilute" the count and thus falsely decrease the differential uptake value. This favorable relationship between detector to lesion geometry probably accounts for the relatively narrow range of differential uptake in the iris melanomas as indicated by the standard deviations in Table I and, in part, for the large difference in differential uptake between the melanomas of the iris and the melanoma of the ciliary body. This large difference is also in agreement with our clinical experience—that melanomas of the iris are relatively benign, slow-growing and rarely require intervention—and this difference also agrees with the histological findings in the melanoma of the ciliary body which was described

TABLE II

AVERAGE DIFFERENTIAL UPTAKE OF ^{32}P IN SKIN LESIONS

Nature of lesion	*Number of lesions*	*Differential uptake (average)* *24 hrs.*	*48 hrs.*
Keloid	1	144	182
Metastases from			
Ca of parotid	5	216	162
pharynx	2	304	371
lung	1	530	576
breast	6	640	493
Primary melanoma	2	1107	581

as an undifferentiated lesion. The differential uptakes of ^{32}P in the skin lesions appear to move along a sliding scale rather than through a sharp line separating benign from malignant lesions (Table II). This should not be surprising in view of the fact that mitotic and growth rate in skin lesions is known to extend over a wide range of small increments. However, further valuable clues as to the nature of the lesion may be derived from this technique by observing the turnover of ^{32}P in these lesions in addition to the differential uptake. The fact that decrease in differential uptake has been observed as early as one week after initiation of radiation therapy, (Table III), a period in which regression is rarely noticed clinically, suggests that the detector may be used to study growth of tumors and their response to therapeutic agents (9, 10, 11).

Initially, we used the doses recommended by investigators in the past (6), i.e., from 300 to 500 microcuries intravenously, or, as we prefer it, 100 microcuries per liter of calculated blood volume—the adjustment of the dose to the blood volume offers the advantage of approximation of initial concentration of ^{32}P in the blood and of comparable counts over the control sites. In the course of this study it became possible to reduce the dose as the counts over the control sites of the skin lesions were over 100 per minute and those over the control sites of the eye lesions around 100 per minute, while the background count was consistently two per minute. The dose was first reduced by a factor of 2 and finally by a factor of 3 to about 30 microcuries per liter of calculated blood volume.

TABLE III

EFFECT OF RADIATION THERAPY ON ^{32}P UPTAKE IN LESIONS OF THE SKIN, METASTATIC FROM CARCINOMA OF THE BREAST

Differential uptake at 48 hrs.		*Difference*	*Per cent decrease*
Before Rx	*After Rx*		
740	248	492	66
954	350	604	63
429	327	102	23
334	245	89	26

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CORRECTION NOTICE

Dr. Alexander P. Remenchik wishes to make a correction in the Abstract T-1, which appears on Page 328-329, May, 1967 issue of JNM: *"Precision and Accuracy of Assay in Whole-Body Counters of Radioactivity in Man."* Charles E. Miller, Wayne Kessler and Alexander P. Remenchik. The 1st, 4th, 6th and 7th lines of the second paragraph (page 329) contain the phrase "weight/height." The authors wish to delete "/height", leaving "weight" by itself.