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PRELIMINARY NOTE

Tumor Scanning With Radioactive ^{131}Cesium

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During the course of an investigation of radioactive ^{131}cesium as an agent for heart scanning (1), we noticed that the isotope was deposited in the pulmonary infiltrate of a patient with disseminated Hodgkin's disease. This was not entirely unexpected, inasmuch as cesium is metabolized by man similarly to its alkali metal congeners, potassium and rubidium (2), both of which are present within some neoplastic tissues in concentrations greater than normal (3-6).

Subsequently, patients were selected for ^{131}Cs heart scanning who were known to have advanced malignant diseases in order to determine whether the isotope localized to a sufficient degree in the tumors to be visualized. Twenty patients with a variety of neoplastic diseases were studied, employing doses of ^{131}Cs acetate of 0.134 to 2.2 mc, given intravenously.

The kinetics of ^{131}Cs distribution were evaluated by means of ratemeters and scalers fed by scintillation detectors placed close to the tumor and to normal tissues (heart, liver, thyroid and bone). Previous studies in our laboratory had demonstrated ^{131}Cs uptake by these tissues. Biopsies of tumors from six patients were taken from 1½ hours to 9 days after injection, and tumor uptake of ^{131}Cs was confirmed in five. One patient had two primary carcinomas, excised two and nine days postinjection. Tumor concentration was compared with ^{131}Cs concentration in normal tissues and in blood.

SCANNING

Scans of the heart and tumor were carried out in 14 of the patients ten minutes to three hours after injection, and were repeated in 24 to 48 hours in four. In seven patients the isotope was readily identified in the tumor, often strikingly so (Fig. 1). Normal cesium distribution in the heart, liver, thyroid, salivary glands, kidneys and gut was also noted. In the four patients scanned

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24 hours after injection less isotope concentration was noted in the tumor than shortly postinjection. This was confirmed by counting dots on the dotscan and by external counting with the detecting probe. Counting rates over normal tissues also fell at 24 hours, and the scans were less satisfactory than those done 10 minutes to 3 hours after injection. Scintigrams at 48 hours were unsatisfactory in two of two cases.

Scans of the abdomen done in five patients 10 minutes to 24 hours following injection failed to reveal tumor known to be present by other methods. Renal carcinoma, retroperitoneal tumors, para-aortic lymph node metastases and intra-abdominal metastases were all missed. On anterior scans considerable gut deposition was seen, and obscured tumor uptake. On the posterior scans only the kidneys and liver were well visualized. The renal carcinoma which was missed was scanned in 24 hours; neither were the kidneys visualized, however.

EXTERNAL COUNTING

Immediately following injection, the count rate rose over the tumors and continued to rise for a variable period of time. In one patient (M.S. in Fig. 1), the count rate rose as rapidly over the tumor as over the liver and heart. In two patients with mammary cancer, counts over the tumor were 160 and 220 per cent that over the normal breast 3 and 50 minutes following injection. (For these studies a specially constructed brass probe was employed, utilizing a recessed 1.5 inch × 2 mm sodium iodide crystal with a .001 inch Al. entrance window.) Nineteen to 24 hours later the counts fell over tumors by approximately 30-70 per cent and to a similar extent over liver and bone.

By using a high resolution 253-hole focusing collimator with the thin-crystal brass probe, it was possible to demonstrate a more marked difference in ^{131}Cs concentration between pathologic and normal tissues than when the open probe was used.

TISSUE COUNTS

Tissues were available in six patients for well scintillation counting. One patient had a simple mastectomy 48 hours postdose and the entire breast was available for analysis (Table). ^{131} Cs content of tumor was 1.36 × that of normal breast tissue, and 1.1 × plasma. However, individual tumor specimens varied in ^{131}Cs concentration almost twofold. This patient also had a second primary malignancy, an adenocarcinoma of the colon, which was removed nine days following ^{131}Cs injection. Isotope concentration in the tumor was greater than in normal bowel (Table), and even more than in the mammary carcinoma. Both tumors concentrated radiocesium more than the other normal tissues studied, except red cells. However, tumor ^{131}Cs levels were less than whole blood concentration.

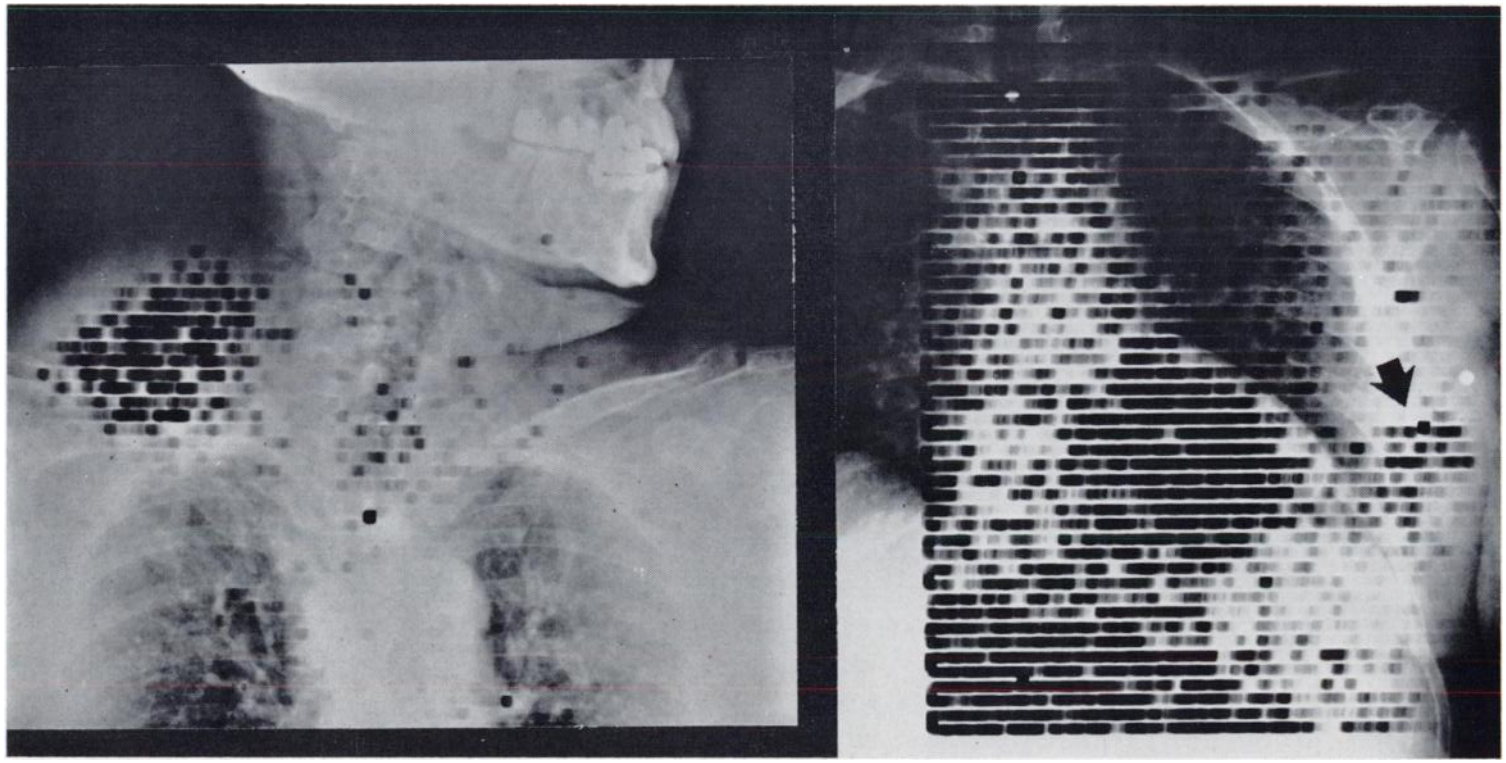
In a patient with epidermoid carcinoma of the vulva, tumor tissue obtained 24 hours postdose contained 5.1 × as much ^{131}Cs as plasma. A carcinoma of the stomach concentrated almost 50 per cent more radiocesium 2 hours post-injection than normal stomach (a simultaneous blood level was not obtained). A renal adenocarcinoma removed 48 hours following ^{131}Cs injection had six

TABLE

SCINTILLATION COUNTING OF TUMOR AND NORMAL TISSUES OF A PATIENT WITH CARCINOMA OF BREAST AND COLON GIVEN 2.0 MC ^{131}Cs

A. External Counting (cpm)				*B. Well Counting of Biopsy Specimens (unfixed)*		
Time after injection	*Over breast tumor*	*Over knee*	*Over liver*	*Tissue*	*Wet Weight (gm)*	*% Admin dose per gm × 10^{-3}*
2 min	15,500	13,200	63,000	Breast carcinoma*	6.84	0.46
5	14,500	13,500	64,000	(range of 5 specs)		(0.37–0.65)
15	12,000	16,000	68,000	Normal breast tissue*	4.53	0.34
30	11,500	15,600	75,000	Fat*	5.44	0.03
55	9,000	14,000	82,000	Skin*	3.92	0.29
24 hours	5,100	13,800	100,000	Plasma*	1.0 ml	0.39
				Rbc*	1.0 ml	2.02
				Whole blood*	1.0 ml	0.95
				Colon carcinoma**	0.91	0.83
				Muscularis**	1.16	0.40
				Fat**	2.25	0.12
				Mucosa**	0.78	0.66
				Plasma**	1.0 ml	0.32
				Rbc**	1.0 ml	1.83
				Whole blood**	1.0 ml	0.85

*From breast—removed 2 days after ^{131}Cs injection
**From colon—removed 9 days after injection



(Left): M.S., with multiple myeloma, was injected with 1.3 mc ^{131}Cs ten minutes prior to scan. Note marked isotope deposition in supraclavicular plasmacytoma and normal uptake in thyroid, salivary gland, and hilar structures.

(Right): R.H., mammary carcinoma, scanned ten minutes following administration of 2.0 mc ^{131}Cs. Note normal distribution in heart, liver, thyroid, hilar structures, and in breast tumor *(arrow)*. Scan lesion measures 5 × 4 cm; mastectomy specimen measured 4.0 × 3.5 × 2.5 cm.

times as much radiocesium as whole blood, but 10 per cent less than normal kidney.

In two cases, tissues fixed in formalin contained no detectable ^{131}Cs. It was found that the isotope had been leached from the tissues by the fixative.

DISCUSSION

^{131}Cs has been shown to localize in some malignant tumors to a sufficient degree to be visualized by scanning. Scintigrams performed within four hours of injection demonstrated the tumors better than scans done at 24 to 48 hours, due to a fall in the count rate with time.

All positive scans, however, were in relatively superficial lesions such as lymph nodes and breast tumors. An esophageal carcinoma (upper third) was also well seen. Deeply placed masses in the abdomen were missed. This was due to (A) marked attenuation of the soft ^{131}Xe x-ray by overlying tissues; (B) the confusing pattern of gut deposition; and (C) incorrect scanning times.

It is likely that the rapid initial uptake of ^{131}Cs by malignant tumors is related to their vascularity and not to their stable cesium concentration, since it is known that the initial distribution of the alkali metal congeners (potassium and rubidium) is closely proportional to fractional organ blood flow (7). In some organs, such as the kidney, exchange of K and Rb takes place so rapidly that maximum uptake occurs within seconds after injection. A redistribution begins immediately though, as plasma levels decline, so that in time the organ concentration of these radioisotopes is proportional to the concentration of the stable (natural) nuclide (8,9).

Since the bulk of the body's alkali metals is in muscle, external counts over tumor and viscera diminish in the first 24 hours, while muscle counts increase. Urinary loss of radiocesium plays no role in the changing organ concentration, since less than 2 per cent of the dose was excreted in the first two hours and less than 4 per cent in 24 hours in the patients studied. Similar findings have been reported by others (10).

These inferences are supported by scan data showing marked ^{131}Cs deposition shortly after injection in the kidneys and gut, organs which receive about 10 and 15 per cent of the cardiac output, respectively. It can be reasoned that renal diseases which impair blood flow would therefore decrease ^{131}Cs deposition in the affected portion of the kidney, and such was found to be the case in one patient with stenosis of a renal artery. Renal cysts might be differentiated from renal tumors on this basis also, and in one patient no ^{131}Cs was seen in such a cyst on scan. The patient with renal carcinoma was not scanned until 24 hours following injection, but the isotope concentration in the tumor was almost that in the normal kidney on biopsy.

It must be emphasized, however, that simultaneous blood and tissue specimens were not obtained from organs operated upon within two hours of injection, and therefore the possibility cannot be ruled out that the high counts in organs such as kidney and gut were due to isotope contained in the blood itself and not as exchanged radiocesium.

Tissue counts of five cancers in four patients demonstrated an increase in

cesium concentration as compared with normal tissues in four of the five, which correlates well with previous knowledge of increased potassium and rubidium content of some malignant tumors (3-6). Since cesium is taken up by normal skeletal muscle in preference to potassium and rubidium (11), it is not surprising that it also concentrates in tumors as do the congeners.

Two modes of uptake are therefore postulated: (A) an early uptake of ^{131}Cs due to tumor vascularity, probably resulting in exchange with stable cesium, and (B) a later uptake following isotope redistribution based upon greater alkali metal content of tumors than of normal tissues.

^{131}Cs decays by electron capture to stable ^{131}Xenon, with emission of the characteristic K_α x-ray of Xenon of 29.8 Kev. Its half-life is 9.6 days. The soft radiation is easily collimated by thin-septae lead focusing collimators so that high resolution scans can be readily obtained, as with ^{125}I (12). A major drawback to external detection with ^{131}Cs is the low penetrability of the x-ray in tissues (half value layer about 2.5 cm) and its marked attenuation by bone (12).

The whole body radiation dose from 1 mc of ^{131}Cs is approximately 0.38 rads, assuming uniform distribution and excretion of 10 per cent of the dose with a biologic half-life of two days. The remainder of the dose is considered to be excreted with a biologic half-life of 100 days (10).

SUMMARY

Fourteen patients with cancer were scanned 10 minutes to 48 hours after injection of radioactive ^{131}Cs, and satisfactory scans of the tumors were obtained in seven. Positive scans were obtained in large, superficial tumors, in a pulmonary lymphoma, and in a carcinoma of the upper third of the esophagus. The negative scans were all in abdominal tumors. Correlations were made with data obtained from external counting and by well scintillation counting of biopsy specimens. Two modes of uptake are suggested: (A) early uptake due to vascularity and probably not proportional to stable cesium content; and (B) a later uptake based upon greater alkali metal content of tumors than of normal tissue.

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