Significance of Radiocontaminants in ^{123}I for Dosimetry and Scintillation Camera Imaging

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Estimates of absorbed radiation dose and qualitative assessments of image resolution were compared for pure ^{131}I and for ^{123}I produced by the $^{122}Te(d,n)$, $^{124}Te(p,2n)$, and $^{127}I(p,5n)^{123}Xe$ reactions. A substantial reduction in radiation dose is indicated when ^{123}I replaces ^{131}I, in spite of the radiocontaminants typically present 30–35 hr after the production of ^{123}I by any of these methods. Only a marginal further reduction in radiation dose was noted with use of the most "pure" ^{123}I as opposed to the least "pure" ^{123}I. Comparable scintillation camera resolution was obtained for all ^{123}I preparations at 30–35 hr after bombardment when the medium-energy and pinhole collimators were used. However, the radiocontaminants in the ^{123}I produced from tellurium affected image resolution when the low-energy collimator was used.

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With the increasing interest in ^{123}I, high-efficiency production methods are being explored to meet potential demands. Undesirable radiocontamination may occur with some of the more efficient production methods. The present work evaluates the effects of the radioiodine contaminants associated with the various production methods on the absorbed radiation dose and image resolution with a scintillation camera.

Iodine-123 production by the $^{127}I(p,5n)^{123}Xe \rightarrow {}^{123}I$ reaction, hereafter referred to as the (p,5n) reaction, has a high yield and low radiocontaminants. However, it requires proton energies much greater than those generally available from accelerators now in use for the commercial production of radionuclides. Iodine-123 production by the $^{124}Te(p,2n)^{123}I$ reaction, hereafter referred to as the (p,2n) reaction, also gives a high yield but has substantial ^{124}I contamination. The proton energy required is well within the range of compact industrial accelerators. The $^{122}Te(d,n)^{123}I$ reaction, hereafter referred to as the (d,n) reaction, results in a much lower ^{123}I yield, but with less ^{124}I contamination. "Pure" ^{123}I could be produced by the (d,n) reaction if isotopically pure ^{122}Te were available.

MATERIALS AND METHODS

The ^{123}I produced by the (p,5n) reaction was obtained from the Crocker Nuclear Laboratory at the University of California at Davis. The ^{123}I produced by the (p,2n) and (d,n) reactions was obtained from the Medi-Physics cyclotron at Emeryville, Calif., using 22-MeV protons and 12–14-MeV deuterons. Enriched ^{124}Te (>95%) and enriched ^{122}Te (>95%) were obtained from the Oak Ridge National Laboratory, Oak Ridge, Tenn. The radionuclidic identity and purity were determined through the use of a calibrated Ge(Li) detector and 1,024-channel analyzer.

Scintillation camera studies were performed with a medium-energy collimator (1,000 holes), a low-energy collimator (4,000 holes), and a pinhole collimator. For the ^{123}I studies the scintillation camera was set at 160 keV with a window of 20%, and for the ^{131}I studies the scintillation camera was set at 360 keV with a window of 20%. A phantom was

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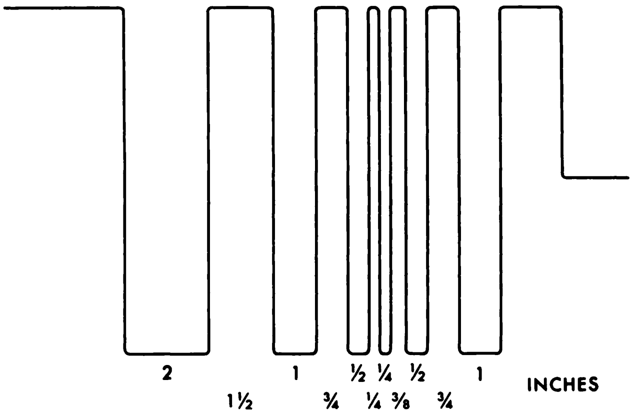


FIG. 1. Line spacing in phantom used for resolution studies.

constructed using 0.025-in.-i.d. continuous plastic tubing with line spacings varying from ¼ to 2 in. (Fig. 1). During imaging the phantom was covered with 2 in. of Plexiglas. For the medium-energy and low-energy collimators, the source was placed 3 in. from the face of the collimator. For the pinhole collimator the source was placed far enough from the collimator face (generally 7–7.5 in.) to achieve an image size comparable with those of the parallel-hole collimators.

Radiation dose calculations for the radioiodides were based on MIRD Dose Estimate Report No. 5 (*1*). Dose estimates for radioiodine administered in the form of o-iodohippurate were made from the biologic data given by Blaufox and Wedeen (*2*) and the formalism of the MIRD Committee.

RESULTS AND DISCUSSION

Table 1 presents the radiation dose (in mrads per 100 μCi for radioiodide and in mrads per mCi for o-iodohippurate) for preparations containing the radiocontaminants at various times after production by the three activation methods under study. In our experience, 30–40 hr are required between the end of the bombardment process and administration to the patient (i.e., the calibration time) to allow for processing, quality control procedures, distribution, and typical delays in the nuclear medicine laboratory. Table 1 gives the radionuclidic composition of preparations at various times after bombardment; these are needed to calculate the radiation dose that patients absorb when studied with ^{123}I produced by the various methods.

The use of Na^{123}I produced by any of the three methods decreases the radiation dose to the thyroid gland by over an order of magnitude, compared to that associated with the use of Na^{131}I. The lowest absorbed dose was noted with the ^{123}I produced by the (p,5n) method, next was that for the (d,n)

TABLE 1. ABSORBED RADIATION DOSE AFTER ADMINISTRATION OF IODIDE AND o-IODOHIPPURATE LABELED WITH RADIOIODINE PRODUCED BY VARIOUS METHODS

	^{127}I(p,5n)^{123}Xe	^{122}Te(d,n)^{123}I		^{124}Te(p,2n)^{123}I			
Time after bombardment:	38 hr	30 hr	54 hr	30 hr	55 hr	75 hr	^{131}I
Radionuclidic content (%)							
^{123}I	98	96.7	93.6	96.2	87.2	68.7	—
^{124}I	—	0.45	1.28	3.8	12.8	31.3	—
^{125}I	2	—	—	—	—	—	—
^{126}I	—	0.58	1.86	—	—	—	—
^{130}I	—	1.73	1.52	—	—	—	—
^{131}I	—	0.55	1.69	—	—	—	100
Absorbed dose (mrad/100 μCi) of radioiodine administered as the iodide							
Liver	3.18	3.88	5.09	4.40	8.20	16.0	35.0
Ovaries	3.40	4.14	4.57	4.45	6.93	12.0	14.0
Marrow	3.09	3.72	4.44	4.26	7.23	13.3	20.0
Stomach wall	23.1	28.7	33.0	30.5	48.2	84.7	160
Testes	1.22	1.63	1.92	1.83	3.35	6.45	8.50
Thyroid	1635	2078	4621	2736	7438	17104	80000
Total body	3.23	3.96	5.62	4.84	9.90	20.3	47.0
Absorbed dose (mrad/mCi) of radioiodine administered as o-iodohippurate							
Bladder wall	857	1047	1149	1062	1541	2525	4120
Kidney	24.8	30.2	32.6	30.2	42.3	67.3	110
Ovaries	29.6	35.4	36.9	35.3	47.9	73.8	69.0
Red marrow	9.25	10.7	11.0	10.6	13.3	19.0	18.0
Testes	18.7	23.9	25.3	23.6	34.5	56.9	51.0
Total body	9.9	12.0	12.5	11.9	16.3	25.3	24.0

method, and that for the (p,2n) method was highest. The variation in radiation dose to various tissues of the body is relatively independent of the production method, being approximately 1.5 times larger for the most contaminated compared to the least contaminated.

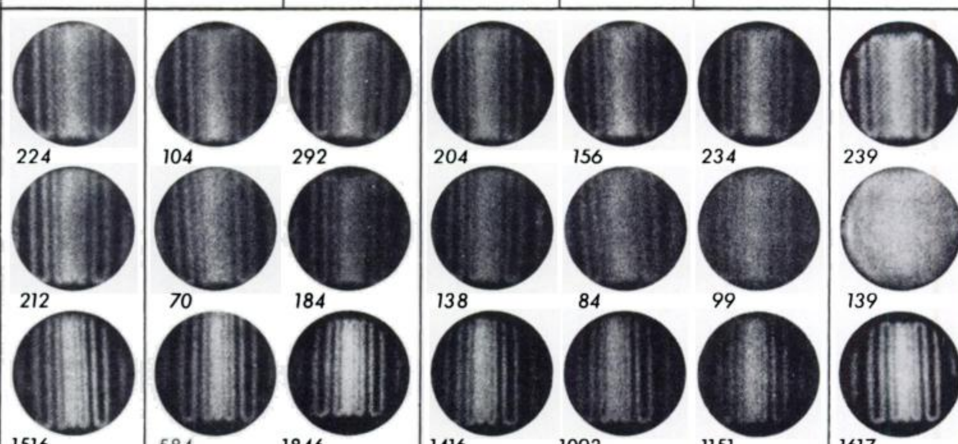
For radioiodine-labeled o-iodohippurate, the differences in the radiation dose among the various ^{123}I preparations are even less marked. However, the use of any of these o-iodohippurate preparations results in only a 2–4-fold decrease in radiation dose to various tissues in normal subjects relative to the ^{131}I-labeled material, since in normal subjects the body clearance of o-iodohippurate is much more rapid than that of iodide.

Table 2 presents scintigrams obtained from the phantom, the source plane being 3 in. from the multihole collimators or 7–7.5 in. from the face of the pinhole collimator. The phantom was covered with 2 in. of Plexiglas to simulate tissue attenuation above the image plane at which the comparable clinical study would be performed. Note that for the "purest" ^{123}I used [i.e., that produced by the (p,5n) reaction], the image resolution was only slightly better when the low-energy parallel-hole collimator was used, compared with the medium-energy parallel-hole collimator. Moreover, only a slightly longer exposure time was required to accumulate 200,000 events with the latter than with the former (224 sec vs. 212 sec). Thus, only modest gains were achieved by using the low-energy collimator instead of the medium-energy collimator in these simulated clinical studies using "pure" ^{123}I.

When ^{123}I from the (d,n) or (p,2n) reaction is studied with the medium-energy collimator 30 hr after bombardment, the resolution is comparable to that obtained with "pure" (p,5n) ^{123}I. With the low-energy collimator, the "pure" ^{123}I is only moderately better than the other two. With ^{131}I and a medium-energy collimator, the septal penetration was more marked and the image was inferior to those obtained with ^{123}I.

When the pinhole collimator was used, comparable resolution was found for all of the ^{123}I products studied 30–40 hr after bombardment, as well as with ^{131}I. With the progressive percentage increase in radiocontaminants seen with the (d,n) and (p,2n) products 54 or more hours after bombardment, image degradation becomes apparent even with the pinhole and medium-energy parallel-hole collimators.

TABLE 2. SCINTILLATION CAMERA IMAGES OF PHANTOM FOR VARIOUS RADIOIODINE PREPARATIONS USING MEDIUM-ENERGY, HIGH-ENERGY, AND PINHOLE COLLIMATORS

Production reaction	^{127}I(p,5n)^{123}Xe	^{122}Te (d,n) ^{123}I		^{124}Te (p,2n) ^{123}I			^{131}I
Time after end of bombardment	38 hours	30 hours	54 hours	30 hours	55 hours	75 hours	
Radionuclidic content Expressed as %							
I-123	98	96.7	93.6	96.2	87.2	68.7	–
I-124	–	0.45	1.28	3.8	12.8	31.3	–
I-125	2	–	–	–	–	–	–
I-126	–	0.58	1.86	–	–	–	–
I-130	–	1.73	1.52	–	–	–	–
I-131	–	0.55	1.69	–	–	–	100
Collimator employed: 							
Medium-energy collimator	224	104	292	204	156	234	239
Low-energy collimator	212	70	184	138	84	99	139
Single-pinhole collimator	1516	584	1846	1416	1093	1151	1617

Time in seconds to accumulate 200,000 counts noted below each figure.

Scintiphotos in each column were obtained serially and represent images of comparable activity in the phantom.

SUMMARY

"Low-radiocontaminant" ^{123}I produced by the (p,5n) reaction can be imaged acceptably using a low-energy collimator on the scintillation camera, whereas ^{123}I containing higher levels of radiocontaminants—as produced in the (d,n) and (p,2n) reactions—shows septal penetration and scatter. However, when a scintillation camera is used to image ^{123}I, only modest gains in resolution and efficiency are realized if the low-energy collimator replaces the medium-energy collimator. When ^{123}I contained in line phantoms is covered with 2 in. of Plexiglas and placed 3 in. from the collimator face, the effective image resolution is about the same for the low- and medium-energy collimators, and the times required to collect comparable counts from the same source differ by only 10–20%. With the use of the medium-energy collimator, the camera image resolution is comparable for ^{123}I produced by any of the three techniques, assuming the level of radiocontaminants typically present 30–40 hr after production (i.e., at their projected time of use). With the use of the pinhole collimator, comparable resolution is obtained with all the ^{123}I products and with ^{131}I.

When the material is administered to a normal subject as the radioiodide, a 30–40-fold reduction in the dose to the thyroid gland is realized with any of the ^{123}I products, compared with ^{131}I, but when o-iodohippurate is given to normal subjects, only a 2–4-fold reduction in radiation dose to various tissues is achieved if ^{123}I replaces the ^{131}I. Compared to the large dose reduction obtained when any of the three ^{123}I preparations is used instead of ^{131}I, the further dose reduction realized by minimizing the radiocontaminants in the ^{123}I preparations is only modest.

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