# Pediatric Renal Iodine-123 Orthoiodohippurate Dosimetry

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**Radiation exposure to the kidney from iodine-123 orthoiodohippurate ([$^{123}$I]OIH) and any associated [$^{124}$I]OIH contamination may vary by a factor of several hundred depending upon the health of the kidney. Calculations of kidney dose were made for patients with the following renal states: normal, acute tubular necrosis (ATN), obstruction, and renal transplant. The dosimetry was based on a minimum practical administered activity (MPAA) of 200 μCi for pediatric patients and 500 μCi for adults. High-grade obstruction of recent onset and severe ATN are the only disease processes which could result in high exposures, and this is due primarily to the contribution of $^{124}$I. For selected cases, OIH labeled with pure $^{123}$I should be very seriously considered.**

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The increasing availability of iodine-123 orthoiodohippurate ([$^{123}$I]OIH) as a replacement for iodine-131 ($^{131}$I)OIH is most welcome. Due to the fact that the radiation exposure from this new radiopharmaceutical is highly dependent on renal pathophysiology and $^{123}$I purity (*1*), potential users should be aware of the radiation exposure commitments from its use in a variety of disease states. This is especially important in infants and small children, for whom the minimum practical administered activity (MPAA) is several times greater than that for adults after correction for weight.

At the present time, the commercial production of [$^{123}$I]OIH is based on $^{123}$I obtained by the following reaction: $^{124}$Te (p, 2n) $^{123}$I. This reaction contains iodine-124 ($^{124}$I) as a contaminant. Iodine-124 has a half-life of 4.2 days, and decays by electron capture (75%) and positron emission (25%). If 1 μCi $^{124}$I stays in the kidney until total decay, the kidney absorbs about 50 times as much radiation as it would from 1 μCi of $^{123}$I that remains until total decay.*

## MATERIALS AND METHODS

The [$^{123}$I]OIH† prepared in our laboratory is made with $^{123}$I obtained by the reaction $^{127}$I (p, 5n) xenon-123 ($^{123}$Xe) (which decays with a 2-hr half-life to $^{123}$I). It does not contain contaminant $^{124}$I.

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From July 25, 1984 through June 11, 1985 we administered [$^{123}$I]OIH to 126 patients, nine of whom were children aged 1.5 mo to 4 yr weighing 3.2–18 kg. The administered activity to these children ranged from 100–600 μCi. Administered activity to the adults ranged from 500 μCi—5 mCi.

Images were acquired on a scintillation camera and processed by minicomputer to yield flow images at 10-sec intervals for the first 60-sec postintravenous bolus injection, 20 consecutive 60-sec images thereafter including renogram curves, and a static image of kidneys, ureters, and bladder at the termination of the study. Approximately one-half of the adult studies were transplant cases. None of the pediatric cases involved transplants.

Dosimetry was performed using MIRD methodology and published biodistribution data (*1–5*). Calculations were made for the following age groups: newborn, 1 yr, 5 yr, 10 yr, 15 yr, and 18 yr. Pediatric kidney weights and fractions for pediatric administered activity based on the two-thirds power of body weight were taken from NCRP data (*4*). The renal states chosen for the calculations were: normal kidneys and transplant, moderate and severe acute tubular necrosis (ATN), and acute and chronic obstruction. Dosimetry was calculated using a pediatric MPAA of 200 μCi and an adult MPAA of 500 μCi. Calculations were made for [$^{123}$I]OIH without $^{124}$I contamination and with 10% $^{124}$I contamination at time of administration.

### Biodistribution assumptions and calculations

For normal pediatric kidneys, the NCRP (*4*) dosimetry values for pure [$^{123}$I]OIH were used directly. Doses are in mrad/μCi [$^{123}$I]OIH administered: newborn, 0.69; 1 yr, 0.23; 5 yr, 0.18; 10 yr, 0.13; 15 yr, 0.10; 18 yr (adult), 0.07. If only one kidney is present, and it has normal function, the absorbed dose is doubled. No such tabulations are available for [$^{124}$I]OIH. However, one may calculate these values using the following assumptions:

1. $T_B$ for [$^{124}$I]OIH = $T_B$ for [$^{123}$I]OIH. Using data from Kaul et al. (*6*) tabulated in NCRP 70 (3), $T_B$ = 0.265 hr.
2. Fractional uptake by normal kidneys is 0.5 (*6*).
3. $T_{eff}$ for [$^{124}$I]OIH = 0.264 hr. ($T_{eff} = T_P T_B / T_P + T_B$).
4. Administered activities as listed in Table 1. We have found these activities to be clinically appropriate.
5. 10% contamination of $^{123}$I by $^{124}$I at time of administration. The package insert of commercial [$^{123}$I]OIH states that $^{124}$I contamination at time of calibration is no more than 4.8% of $^{123}$I activity. At time of expiration, 24 hr later, $^{124}$I contamination would therefore be up to 14.7% of $^{123}$I activity. We chose 10% contamination as a reasonably conservative typical level.

The following calculation is for dosimetry of contaminant [$^{124}$I]OIH in normal newborn kidneys:

$$\bar{D}_{kidneys} = 1.44 \begin{pmatrix}\mu\text{Ci admin.}\\ \text{activity}\end{pmatrix} \begin{pmatrix}\text{fractional up-}\\ \text{take, kidneys}\end{pmatrix} \begin{pmatrix}T_{eff,}\\ \text{hr}\end{pmatrix}$$
$$\text{(S, kidney to kidney)}$$
$$= 1.44\,(20)(0.5)(0.264)(2.18 \times 10^{-2})$$
$$= 0.083 \text{ rad.}$$

The absorbed dose to the kidneys from 200 $\mu$Ci [$^{123}$I]OIH + 10% [$^{124}$I]OIH is the sum of two doses:

$\bar{D}_{kidneys}$ from 200 $\mu$Ci [$^{123}$I]OIH = 0.69 (200/1000) = 0.138 rad

$\bar{D}_{kidneys}$ from 20 $\mu$Ci [$^{124}$I]OIH = 0.083 rad

$\bar{D}_{kidneys}$ (total) = 0.138 + 0.083 = 0.22 rad.

Similar calculations were performed for the other age groups using the following "S" values for $^{124}$I: 1 yr, 8.42 $\times 10^{-3}$; 5 yr, 4.77 $\times 10^{-3}$; 10 yr, 3.27 $\times 10^{-3}$; 15 yr, 2.33 $\times 10^{-3}$; 18 yr (adult), 2.1 $\times 10^{-3}$.

For cases of moderate ATN, we used the model of Elliott and Britton (*1*) who assumed a transit time of iodinated hippuran through the kidneys of 4 hr; $T_B$ = 4/1.44 = 2.78 hr; $T_{eff}$ for [$^{123}$I]OIH = 2.29 hr; $T_{eff}$ for [$^{124}$I]OIH = 2.70 hr. Fractional uptake by kidneys = 1. "S" values for $^{123}$I are: newborn, 4.17 $\times 10^{-3}$; 1 yr, 1.28 $\times 10^{-3}$; 5 yr, 7.83 $\times 10^{-4}$; 10 yr, 5.59 $\times 10^{-4}$; 15 yr, 4.04 $\times 10^{-4}$; 18 yr (adult), 3.4 $\times 10^{-4}$. "S" values for $^{124}$I are listed in the previous calculation.

For cases of acute, near-total bilateral obstruction, we assumed $T_B = \infty$, $T_{eff} = T_P$, and uptake of each kidney = 0.5. Fractional uptake of kidneys thus = 1. "S" values are as for previous calculations.

For cases of chronic, near total bilateral obstruction, we assumed $T_B = \infty$, $T_{eff} = T_P$, and uptake of each kidney = 0.05. Fractional uptake of kidneys thus equals 0.1. Exposure doses are 0.1 times that for the acute case with 50% uptake by each kidney.

For single kidneys (e.g., transplants) exposures are double that for two kidneys with similar pathology.

For the sake of comparison, calculations were also made for [$^{131}$I]OIH in the 1 yr group using the same model assumptions as described above. The administered activity chosen was 50 $\mu$Ci, a typical minimum pediatric activity. The "S" value (kidney to kidney) is 6.5 $\times 10^{-3}$.

For the sake of completeness, we have also included calculations for the dose contribution of contaminant $^{125}$I (found at

**TABLE 1**
**Pediatric Dosimetry for [$^{123}$I]OIH**

| Item | Newborn | 1 yr | 5 yr | 10 yr | 15 yr | 18 yr (adult) |
|---|---|---|---|---|---|---|
| Body weight, kg | 4.0 | 10.4 | 20.0 | 32.0 | 57.0 | 70.0 |
| Mass of kidneys, g | 19 | 68 | 116 | 179 | 230 | 284 |
| Activity administered, $\mu$Ci | 200 | 200 | 215 | 300 | 435 | 500 |
| | | | Dose (rad procedure) to kidneys; Pure $^{123}$I/$^{123}$I + 10% $^{124}$I | | | |
| Normal kidneys | 0.14/0.22 | 0.046/0.078 | 0.039/0.059 | 0.039/0.058 | 0.044/0.063 | 0.035/0.055 |
| Moderate ATN | 2.8/4.4 | 0.84/1.5 | 0.56/0.96 | 0.56/0.94 | 0.82/1.2 | 0.56/0.97 |
| Acute, near total obstruction with 50% uptake in obstructed kidney | 16/79 | 4.8/29 | 3.2/18 | 3.2/17 | 3.4/18 | 3.2/18 |
| Chronic, near total obstruction with 5% uptake in obstructed kidney | 1.6/7.9 | 0.48/2.9 | 0.32/1.8 | 0.32/1.7 | 0.34/1.8 | 0.32/1.8 |
| Renal transplant, normal | 0.28/0.44 | 0.092/0.16 | 0.078/0.12 | 0.078/0.12 | 0.088/0.13 | 0.070/0.11 |
| Renal transplant, moderate ATN | 5.5/8.9 | 1.7/3.0 | 1.1/1.9 | 1.1/1.9 | 1.6/2.4 | 1.1/1.9 |
| Renal Transplant, Severe ATN | 31/160 | 9.6/58 | 6.3/36 | 6.4/35 | 6.8/36 | 6.4/37 |

**TABLE 2**
Comparative Dosimetry of Orthoiodohippurate-Labeled with $^{123}$I and $^{131}$I in 1-yr-old Children*

| Renal state | Kidney absorbed dose (rad/procedure): 200 $\mu$Ci pure [$^{123}$I]OIH | 200 $\mu$Ci [$^{123}$I]OIH + 10% [$^{124}$I]OIH | 50 $\mu$Ci [$^{131}$I]OIH |
|---|---|---|---|
| Normal kidneys | 0.046 | 0.078 | 0.22 |
| Moderate ATN | 0.84 | 1.5 | 1.3 |
| Acute, near-total obstruction with 50% uptake in obstructed kidney | 4.8 | 29 | 90 |
| Chronic, near-total obstruction with 5% uptake in obstructed kidney | 0.48 | 2.9 | 9 |
| Single kidney, severe ATN | 9.6 | 58 | 180 |

* Administered dose of [$^{123}$I]OIH is 200 $\mu$Ci; that of [$^{131}$I]OIH is 50 $\mu$Ci.

**TABLE 3**
Comparison of Absorbed Dose from [$^{125}$I]OIH to that of [$^{123}$]OIH in 18 yr-olds*

| Renal state | % Contribution from [$^{125}$I]OIH | $^{123}$I | Absorbed dose, rad: $^{123}$I + $^{125}$I | $^{123}$I + $^{124}$I |
|---|---|---|---|---|
| Normal kidneys | 0.95 | 0.035 | 0.035 | 0.055 |
| Moderate ATN | 1.2 | 0.56 | 0.57 | 0.97 |
| Near-total obstruction with 50% uptake in obstructed kidney; no resolution | 115 | 3.2 | 6.8 | 18 |
| Near-total obstruction with 50% uptake in obstructed kidney; resolution in 1 wk | 8.6 | 3.2 | 3.5 | 9.8 |
| Near-total obstruction with 5% uptake in obstructed kidney; no resolution | 115 | 0.32 | 0.68 | 1.8 |
| Near-total obstruction with 5% uptake in obstructed kidney; resolution in 1 wk | 8.6 | 0.32 | 0.35 | 0.98 |
| Transplant with severe ATN, no recovery | 115 | 6.4 | 14 | 37 |
| Transplant with severe ATN, recovery in 3 wk | 22 | 6.4 | 7.8 | 30 |

* Administered activity of [$^{123}$I]OIH is 500 $\mu$Ci. Iodine-125 OIH contamination is 1.4%. Iodine-124 OIH contamination is 10%. Exposures are in rad/procedure.

present in the Crocker Laboratory, University of California at Davis). The maximum contamination level at time of expiration is 1.4%, and we used this value for our dosimetry. Due to the long half-life of $^{125}$I (60 days) we have calculated exposure doses to obstructed kidneys with no resolution of obstruction and with resolution at 1 wk (e.g., by passing a stone, surgical intervention, or percutaneous nephrostomy). We have also calculated exposure to a transplant with severe ATN and no recovery and with recovery of function in 3 wk. Calculations were performed for the 18 yr-group; percentage exposure contributions would be similar for all age groups. The "S" value for $^{125}$I (kidney to kidney) is $2.5 \times 10^{-4}$.

## RESULTS AND DISCUSSION

Acceptable quality flow studies were not obtainable in the infants because of the low activity administered. The MPAA was found to be ~200 $\mu$Ci for images and renogram. If it is known beforehand that only one functioning kidney is present, the MPAA would be 100 $\mu$Ci.

Acceptable quality flow studies were obtained in adults who received activities of about 3 mCi or higher. By "acceptable" we mean the ability to differentiate approximately normal flow from very poor flow. This differentiation is critical within the first 24 hr of renal transplantation, when most transplants show moderate to severe ATN and vascular compromise needs to be ruled out as a reason for poor function. If flow studies are not required, the MPAA for images and renogram is about 500 $\mu$Ci.

Radiation absorbed doses are seen in Table 1. If the administered doses are increased beyond the MPAA (e.g., for a flow study), the exposures are proportionately larger. Note that in cases of high obstruction and severe ATN the absorbed doses are high, especially for infants. The contribution of contaminant $^{124}$I is very high, increasing the total dose by a factor of ~5. Performing a 3 mCi flow study using [$^{123}$I]OIH with $^{124}$I contamination in an 18 yr-old renal transplant recipient with severe ATN would result in a kidney dose of about 220 rad, an extremely high value. In such cases, studies would best be performed using OIH labeled with pure $^{123}$I for imaging and renogram, and 15 mCi technetium-99m diethylenetriaminepentaacetic acid ([$^{99m}$Tc]DTPA) for renal flow. In severe ATN, the exposure dose from [$^{99m}$Tc]DTPA is low relative to [$^{123}$I]OIH. If we assume uniform total body distribution and $T_{eff} = T_P$, the adult whole-body (or kidney) exposure from 15 mCi [$^{99m}$Tc]DTPA is 0.26 rad:

$$\tilde{A} = 1.44(6 \text{ hr})(15{,}000\ \mu\text{Ci}) = 129{,}600\ \mu\text{Ci-hr}$$

$$\bar{D}_{TB} = \tilde{A}_{TB}\, S(\text{TB to TB})$$

$$= 129{,}600\ (2 \times 10^{-6})$$

$$= 0.26 \text{ rad.}$$

Because of high absorbed doses from [$^{123}$I]OIH in severe ATN, we have abandoned it for flow studies and use [$^{99m}$Tc]DTPA for all cases at present.

In Table 2 we see comparative dosimetry of [$^{123}$I]OIH and [$^{131}$I]OIH in the 1-yr-old group. The [$^{131}$I]OIH gives higher doses in all cases except moderate ATN, when it is about the same as [$^{123}$I]OIH with 10% [$^{124}$I]OIH contamination. (One must bear in mind, of course, that the [$^{123}$I]OIH administered activity is four times higher and the image quality is far better.) In high grade obstruction with high uptake, and in severe ATN, it would not be advisable to use either [$^{131}$I]OIH or [$^{123}$I]OIH with [$^{124}$I]OIH contamination. With normal kidneys and obstruction with poor uptake, using [$^{123}$I]OIH with [$^{124}$I]OIH contamination instead of [$^{131}$I]OIH will lower kidney doses by about a factor of 3 and improve image quality.

In Table 3 we see the contribution of absorbed dose from contaminant [$^{125}$I]OIH in preparations of [$^{123}$I]OIH free from [$^{124}$I]OIH. These values are compared with doses from [$^{123}$I]OIH containing [$^{124}$I]OIH. In normal kidneys and in moderate ATN, [$^{125}$I]OIH contributes only about 1% extra dose. In obstructed kidneys with resolution at 1 wk, the contribution is under 10%. In a transplant with severe ATN and recovery of function in 3 wk, the contribution is about 20%. In obstructed kidneys without resolution and severe ATN without recovery, the contaminant [$^{125}$I]OIH approximately doubles the absorbed dose.

## SUMMARY AND CONCLUSION

The pediatric dosimetry for [$^{123}$I]OIH is presented for various pathophysiologic states. The contribution of contaminant $^{124}$I to renal exposure is tabulated, and is very significant in cases of acute obstruction with high uptake and severe ATN, especially in infants. In such cases, care should be taken before administering activity greater than the MPAA, and OIH labeled with pure $^{123}$I is the preferred OIH product.

## FOOTNOTES

* Kidney to kidney "S"values (adult) for $^{124}\text{I}/^{123}\text{I} = 2.1 \times 10^{-3} / 3.4 \times 10^{-4} = 6.18$; half-life ratio for $^{124}\text{I}/^{123}\text{I} = 4.2(24)/13 = 7.75$; $(6.18)(7.75) = 47.9$.

† Purchased from Crocker Laboratories, University of California at Davis.

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