ABSORBED DOSE CALCULATIONS
FOR $^{113m}$In PLACENTAL SCANNING

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Indium-$^{113m}$In-hydroxide (pH 3.4) has recently been introduced as a blood-pool scanning agent. When used to visualize the placenta, this radiopharmaceutical has distinct advantages over $^{99m}$Tc-labeled serum albumin because of its low urinary excretion and ease of preparation.

Little information is available regarding the radiation dose to the mother and fetus resulting from the use of this agent.

In the present study the biological half-life of the $^{113m}$In blood-pool scanning preparation was determined in pregnant females and the transfer across the placenta measured in the pregnant female South African baboon (Papio ursinus).

PREPARATION OF SCANNING AGENT

Indium-$^{113m}$In was eluted from a $^{118}$Sn generator with dilute HCl (pH 1.3). To 8 ml of the eluate, 1 ml 5% NaCl solution was added and the pH adjusted to 3.4. After autoclaving, doses of 1 mCi were used intravenously in all the studies.

PHYSICAL HALF-LIFE

Indium-$^{113m}$In (Fig. 1) decays by a single isomeric transition which undergoes 35.5% internal conversion. Gamma photons of 0.3917 MeV are emitted in 64.5% of the decay processes (1).

The physical half-life was determined because different values, ranging from 1.65 to 1.73 hr, have been published.

Samples of the $^{113m}$In eluant were evaporated to dryness in a counting vial and counted in an automatic gamma sample counter system. Counting was done for 2 min over a period of 360 min.

Regression analysis on deadtime-corrected counts was performed and the slope of the regression equation,

$$ Y = 1.91415 - 0.69269X, $$

with a regression coefficient of $r = 0.999937$ resulted in a physical half-life of

$$ T_{1/2} = 1.667 \text{ hr} \ (\text{Fig. 2}). $$

LOCAL ENERGY DEPOSITION PER DISINTEGRATION

The local energy deposit per disintegration, $n_eE_e$, due to internal-conversion electrons was calculated according to the method of Smith, Harris and Rohrer (2) and is given by

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TABLE 1. EQUILIBRIUM ABSORBED DOSE CONSTANTS: THE VARIOUS ENERGY COMPONENTS

<table>
<thead>
<tr>
<th>Type of radiation</th>
<th>( n_i ) (per dis)</th>
<th>( E_i ) (MeV)</th>
<th>( n_i E_i ) (MeV/dis)</th>
<th>( \Delta_i ) (gm-rad/( \mu )Ci-hr)</th>
<th>( \Gamma_i ) (cm(^3)/mCi-hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal conversion</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.13259</td>
<td>0.2825</td>
</tr>
<tr>
<td>electrons</td>
<td>γ</td>
<td>0.645</td>
<td>0.3917</td>
<td>0.25263</td>
<td>0.3384</td>
</tr>
<tr>
<td>Kα x-rays</td>
<td>0.20526</td>
<td>0.0231</td>
<td>0.00495</td>
<td>0.0105</td>
<td>0.270</td>
</tr>
<tr>
<td>Kβ x-rays</td>
<td>0.041239</td>
<td>0.0273</td>
<td>0.00113</td>
<td>0.0024</td>
<td>0.043</td>
</tr>
<tr>
<td></td>
<td>( \Gamma = 1.743 ) cm(^3)/mCi-hr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( \eta E_x = n_\gamma N_{eK} \left\{ E_\gamma - \omega_K E_X + \omega_K \right\} 

\left\{ \left( \frac{K_\alpha}{K_\alpha + K_\beta} \right) E_L^{II-III} + \left( \frac{K_\beta}{K_\alpha + K_\beta} \right) E_M^{II-III} \right\}

+ N_{et} (N_{el} + N_{em}) MeV/dis \) (1)

where \( f_i \) = fractional frequency of the disintegrations that gives rise to a photon of energy \( E = 0.3917 \) MeV

\( = 1.00, \omega_K = K\)-fluorescent yield

\( = 0.850 \) (3), \( E_K \) = bind energy of K-electrons

\( = 0.0279 \) Mev (4)

\( E_L^{II-III} \) = average binding energies of \( L_{II} \) and \( L_{III} \) electron shells, where \( E_{L_{II}} = 0.003929 \) MeV and \( E_{L_{III}} = 0.003732 \) MeV (4),

\( E_M^{II-III} \) = average binding energies of \( M_{II} \) and \( M_{III} \) electron shells where \( E_{M_{II}} = 0.000691 \) and \( E_{M_{III}} = 0.000653 \) MeV (4),

\( K_\alpha + K_\beta \) = relative abundance of the \( K_\alpha \) x-rays emitted per disintegration as the result of \( K \) internal conversion,

\( = 0.8327 \) (5),

\( K_\beta + K_\beta \) = relative abundance of the \( K_\beta \) x-rays emitted per disintegration as the result of \( K \) internal conversion,

\( = 0.1673 \) (5),

and \( N_{et} = N_{eK} + N_{et} + N_{em} \),

\( = total number of conversion electrons. \)

The value of \( N_{et} \) can be calculated from the total internal-conversion coefficient \( \alpha_t = 0.55 \) (6) and the K internal conversion coefficient \( \alpha_K = 0.45 \) (7)

where \( N_{et} = \frac{\alpha_t}{1 + \alpha_t} \).

The numbers of K electrons and of L plus M electrons which undergo internal conversion, respectively, are

\( N_{eK} = \frac{\alpha_K}{1 + \alpha_t} = 0.29 \)

and \( N_{eL} + N_{eM} = 0.064 \).

Substituting the above values into Eq. 1 gives \( n_\gamma E_x = 0.13259 \) MeV/dis.

GAMMA PHOTON YIELD

The number of unconverted photons is given by \( n_\gamma = 0.645 \) photons/dis.

CHARACTERISTIC X-RAY YIELD

The \( K_\alpha \) and \( K_\beta \) x-ray yield is

\( n_{K\alpha} = 0.20526 \) photons/dis.

\( n_{K\beta} = 0.041239 \) photons/dis.

TOTAL ENERGY LIBERATED PER DISINTEGRATION

The equilibrium absorbed dose constant, \( \Delta \), is given by

\( \Delta = \sum \Delta_i = \sum n_i E_i \) MeV/dis

\( = 2.131 \sum n_i E_i \) gm-rad/\( \mu \)Ci-hr

where \( n_i \) is the fractional frequency of its type of radiation with energy \( E_i \) MeV. The values of \( \Delta \) are listed in Table 1.

The specific gamma-ray constant, \( \Gamma \), is not used in the calculation of the absorbed dose but is useful in shielding calculations or source calibrations. The specific gamma-ray constant (Table 1) is given by (8)

\( \Gamma = 1.5 \times 10^5 \sum n_i E_i \mu_{at} \) cm\(^2\)-R/mCi-hr.

INDIUM-113m BIOLOGICAL HALF-LIFE IN THE BLOOD

The biological half-life of \( \text{In}^{113m} \) in blood for placentas scanning was determined in three pregnant women over a period of 5 hr. Blood samples were counted in a scintillation well counter and expressed as a percentage of the 5-min blood sample. The re-
results were corrected for physical decay for the time between counting the standard and the samples.

Regression analysis was performed, and a biological half-life (for blood) of $T_b = 6.74$ hr with a regression coefficient of 0.97553 was found (Fig. 3).

The value of the half-life is similar to that obtained for $^{99m}$Tc-labeled albumin and $^{131I}$-labeled albumin, but differs from the approximately 3-hr value reported for $^{113m}$In (9).

**ABSORBED DOSE**

The absorbed dose to the maternal total body and blood was calculated using an average total-body weight of 65 kg with a blood volume of 60 ml/kg. It was assumed that the activity was uniformly distributed in an ellipsoidal body (10).

**Total-body absorbed dose.** The physical decay of $^{113m}$In was used to calculate the total-body absorbed dose because the amount of $^{113m}$In found in the urine (Fig. 4) and feces over a period of 4 hr was only 0.1%.

The average total-body dose is given by (11)

$$\bar{D}_\infty (v \rightarrow v) = C_v \sum_i \Delta_i \phi_i (v \rightarrow v) \text{ rad}$$

where $C_v = 1.44 \sum_i C_i(0) T_{eff} \mu\text{Ci-hr}/\text{gm}$,

$C_i(0) =$ initial concentration,

$T_{eff} =$ effective half-life,

$\phi_i =$ absorbed fraction (10–13) of the $i$th type radiation.

The values of $\Delta_i$ and $\phi_i$ are given in Table 2 for a 65-kg ellipsoid.

The total-body dose $\bar{D}_\infty (v \rightarrow v)$ per 1 mCi $^{113m}$In administered for placental scanning and effective half-life of 1.667 hr is

$$\bar{D}_\infty (v \rightarrow v) = 0.0176 \text{ rad}.$$  

**Maternal blood absorbed dose.** For the beta-type or nonpenetrating component of the absorbed dose to the blood, it is assumed that the activity is uniformly distributed in the blood. The biological disappearance of the $^{113m}$In in the blood consists of only one component, resulting in an effective half-life of

![FIG. 3. Biological half-life of $^{113m}$In scanning agent.](image)

![FIG. 4. Normal placental scan with $^{113m}$In placental scanning agent. Activity in bladder region is insignificant.](image)

**TABLE 2. ABSORBED FRACTIONS FOR 65-KG ELLIPSOID WITH UNIFORM ACTIVITY AND CENTRAL POINT ACTIVITY DISTRIBUTED FOR VARIOUS ENERGY COMPONENTS**

<table>
<thead>
<tr>
<th>Type of radiation</th>
<th>$T_i$ (MeV)</th>
<th>$\Delta_i$ (gm-rad)</th>
<th>Uniform activity</th>
<th>Central point activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\phi_i$ $\phi_i \Delta_i$</td>
<td>$\phi_i$ $\phi_i \Delta_i$</td>
<td></td>
</tr>
<tr>
<td>Internal-conversion electrons</td>
<td>—</td>
<td>0.2825</td>
<td>1.000</td>
<td>0.2825</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.3917</td>
<td>0.5384</td>
<td>0.340 $\phi_i$ 1.0831 $\phi_i$</td>
<td>0.486 $\phi_i$ 0.2617 $\phi_i$</td>
</tr>
<tr>
<td>Ka x-rays</td>
<td>0.0241</td>
<td>0.0105</td>
<td>0.840 $\phi_i$ 0.0088 $\phi_i$</td>
<td>0.990 $\phi_i$ 0.0104 $\phi_i$</td>
</tr>
<tr>
<td>Kg x-rays</td>
<td>0.0223</td>
<td>0.0034</td>
<td>0.790 $\phi_i$ 0.0019 $\phi_i$</td>
<td>0.980 $\phi_i$ 0.0024 $\phi_i$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\sum \phi_i \Delta_i$</td>
<td>0.4763</td>
<td>0.5570</td>
</tr>
</tbody>
</table>

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TABLE 3. COMPARISON OF ABSORBED DOSE FROM \(^{99m}\text{Tc}\)-SERUM ALBUMIN FOR PLACENTAL SCANNING, \(^{131I}\)-SERUM ALBUMIN FOR PLACENTAL LOCALIZATION, \(^{113m}\text{In}\) FOR PLACENTAL SCANNING AND DIAGNOSTIC X-RAY PELVIMETRY

<table>
<thead>
<tr>
<th>Radiopharmaceutical and dose (mCi)</th>
<th>Organ</th>
<th>Absorbed dose (mrad)</th>
<th>Nonpenetrating</th>
<th>Penetrating</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{99m}\text{Tc})-albumin (14)*</td>
<td>Maternal total body</td>
<td>4</td>
<td>13</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>1 mCi</td>
<td>Maternal blood</td>
<td>34</td>
<td>13</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fetal blood</td>
<td>0.7</td>
<td>13</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>(^{131I})-albumin (14)†</td>
<td>Maternal total body</td>
<td>5</td>
<td>0.2</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>0.005 mCi</td>
<td>Maternal blood</td>
<td>83</td>
<td>4</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fetal blood</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>(^{113m}\text{In})</td>
<td>Maternal total body</td>
<td>10</td>
<td>7</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>1 mCi</td>
<td>Maternal blood</td>
<td>139</td>
<td>7</td>
<td>146</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fetal blood</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

| General diagnostic radiology (pelvimeter) (15) | Mean gonadal dose/examination | Female | 745 mR |
|                                               |                                  |        |
|                                               |                                  | Male   | 885 mR |

* Mother pretreated with potassium perchlorate.
† Mother pretreated with Lugol’s solution.

\[ T_{eff} = 1.377 \text{ hr}. \]

It is assumed that the beta-radiation component is completely absorbed in the blood to give a dose of

\[ \bar{D}_{\infty \beta} = 0.139 \text{ rad}. \]

The contribution from the gamma component is equal to the gamma component of the total-body dose to give a total absorbed dose in blood of

\[ \bar{D}_{\infty} = 0.146 \text{ rad}. \]

**Fetal blood absorbed dose.** It is assumed that the fetus is in the center of the ellipsoid and that it would receive the absorbed dose of the ellipsoid at the central axis (Table 2).

The contribution of the gamma component to the total dose absorbed by the fetus is

\[ \bar{D}_{\infty \gamma} = 0.008 \text{ rad}. \]

Two pregnant baboons were injected with 1 mCi \(^{113m}\text{In}\) placenta scanning agent to measure transfer of \(^{113m}\text{In}\) across the placenta.

A cesarean section was performed 30 min after injection of \(^{113m}\text{In}\), and blood samples were taken from the fetus and the mother. The mean percentage activity in the fetal blood was less than 0.1% of that of the mother. The contribution of the nonpenetrating component of \(^{113m}\text{In}\) in the fetus can thus be neglected to give a total fetal dose of

\[ \bar{D}_{\infty} = 0.008 \text{ rad}. \]

**SUMMARY**

By using \(^{113m}\text{In}\) as a scanning agent, the absorbed dose to the total maternal body and the maternal and fetal blood was calculated. A 65-kg maternal body weight with a blood volume of 60 ml/kg and a fetal body weight of 3.9 kg was assumed. The biological half-life of \(^{113m}\text{In}\) in the blood was found to be 6.74 hr. In the first 4 hr after administration of \(^{113m}\text{In}\) the activity in the urine was found to be less than 0.1%. Therefore the physical half-life was used in calculating the total-body absorbed dose.

The concentration of \(^{113m}\text{In}\) in the fetal blood was less than 0.1% of the concentration in the maternal blood.

The absorbed dose received from 1 mCi \(^{113m}\text{In}\) to the total maternal body is 17 mrad, maternal blood is 146 mrad (Table 3) and fetal blood is 8 mrad.

**ACKNOWLEDGMENTS**

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**REFERENCES**


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18th ANNUAL MEETING

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The Society of Nuclear Medicine has set aside time for a nuclear medicine technologists’ program at the 17th Annual Meeting in Washington, D.C., July 6–12, 1970.

The Scientific Program Committee welcomes the submission of abstracts for 12-minute papers from technologists for this meeting. Abstracts must be submitted on an abstract form similar to the form for general scientific papers. The length must not exceed 400 words and the format of the abstracts must follow the requirements set down for all abstracts for the scientific program (see “Call for Abstracts for Scientific Program” in this issue). Send the abstract form and three carbon copies to:

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