New Generation Fetal Dose Estimates for Radiopharmaceuticals

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Technical Note

Radiopharmaceutical dose estimates to the fetus have been based for many years on the reported placental crossover data and dose estimates of Russell et al. ([[1]](#endnote-1),[[2]](#endnote-2)), which employed pregnant female phantoms developed by Oak Ridge National Laboratory ([[3]](#endnote-3)) (Fig 1). New fetal dose estimates have now been generated using the new RADAR ICRP 89 reference female pregnant and nonpregnant models ([[4]](#endnote-4)) (Fig 2), as implemented in the OLINDA/EXM 2.0 software ([[5]](#endnote-5)). Table 1 summarized the differences in the masses of the fetus, placenta, and uterus between the two sets of models.

Most maternal and fetal time-activity integrals were taken from Russell et al. (2), to maintain consistency with the previous estimates. Although biokinetic models may have changed somewhat, the previous values were retained. One exception is that dose estimates for 18FDG were taken from Zanotti-Fregonara and Stabin ([[6]](#endnote-6)), as this provided a significant update to the older dose estimates, including placental crossover. Other radiopharmaceuticals, not considered by Russell et al., were added; references are given in Table 2. Rows with dose estimates that include consideration of placental crossover are shaded.

When there is no information provided in the literature on placental crossover, only maternal contributions to fetal dose can be considered. If there is placental crossover, this may underestimate fetal doses, but there is no reliable way to arbitrarily assign placental crossover in the absence of any scientific data. As with the adult/pediatric RADAR radiopharmaceutical dose compendium (5), this manuscript will be maintained in electronic format, allowing for revisions and additions, as needed.

Doses are provided for ‘early pregnancy’ (dose to the nongravid uterus in the RADAR reference adult female model), and to the fetus at 3, 6, and 9 months’ gestation. Uncertainties in using these estimates for a specific subject are considerable, both in the physiology of the radiopharmaceutical kinetics and the assumed geometry of the maternal and fetal organs. Dose estimates that bracket a given real life exposure (e.g. for a case at 4 months’ gestation, the 3 and 6 month values can be used) should not employ sophisticated interpolation methods. Rather, look at the dose estimate on either side, take the higher of the two, and round to one significant figure to give an estimate to a real patient.

Example: a pregnant woman at 4 months’ gestation is administered 370 MBq of 18FDG. The estimated fetal dose at 3 months from Table 2 is 7.0 mGy, and at 6 months is 5.2 mGy. An estimate of 5-7 mGy is reasonable and conservative.

Table 1. Masses of the fetus, placenta and uterus in the RADAR (4) and ORNL (3) pregnant female phantoms.

|  |  |  |
| --- | --- | --- |
| Source Organ | RADAR (g) | ORNL (g) |
|   | 3 mo | 6 mo | 9 mo | 3 mo | 6 mo | 9 mo |
| Fetus | 85 | 1115 | 3495 | 485 | 1640 | 2960 |
| Placenta | 48 | 319 | 650 | 0 | 310 | 466 |
| Uterus | 270 | 550 | 1047 | 374 | 834 | 1095 |

|  |
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| Table 2. Embryo/fetus doses for selected radiopharmaceuticals |
|  | Estimated Fetal Dose (mGy/MBq\*) |
| Radiopharmaceutical | Early Pregnancy | 3 months’ Gestation | 6 months’ Gestation | 9 months’ Gestation |
| 13N Ammonia | 2.3 x 10-3 | 1.9 x 10-3 | 2.0 x 10-3 | 1.8 x 10-3 |
| 18F FDG | 2.6 x 10-2 | 1.9 x 10-2 | 1.4 x 10-2 | 6.9 x 10-3 |
| 18F Fluoride | 3.1 x 10-2 | 2.2 x 10-2 | 8.6 x 10-3 | 6.7 x 10-3 |
| 32P Phosphate | 8.7 x 10-1 | 1.7 x 100 | 2.3 x 100 | 2.3 x 100 |
| 67Ga Citrate | 9.4 x 10-2 | 7.1 x 10-1 | 1.1 x 10-1 | 3.2 x 10-2 |
| 123I Hippuran | 4.9 x 10-2 | 3.3 x 10-2 | 9.2 x 10-3 | 6.6 x 10-3 |
| 123I IMP | 2.2 x 10-2 | 1.6 x 10-2 | 1.1 x 10-2 | 8.9 x 10-3 |
| 123I mIBG | 2.2 x 10-2 | 1.6 x 10-2 | 8.2 x 10-3 | 6.8 x 10-3 |
| 123I NaI (35% uptake) | 2.3 x 10-2 | 1.6 x 10-2 | 9.3 x 10-3 | 6.3 x 10-3 |
| 123I BMIPP | 2.0 x 10-2 | 1.5 x 10-2 | 1.1 x 10-2 | 9.6 x 10-3 |
| 125I HSA | 2.4 x 10-1 | 1.6 x 10-1 | 1.2 x 10-1 | 1.0 x 10-1 |
| 125I mIBG | 3.2 x 10-2 | 2.0 x 10-2 | 1.0 x 10-2 | 9.1 x 10-3 |
| 131I Hippuran | 9.8 x 10-2 | 6.8 x 10-2 | 2.0 x 10-2 | 1.4 x 10-2 |
| 131I mIBG | 1.2 x 10-1 | 9.6 x 10-2 | 7.3 x 10-2 | 6.6 x 10-2 |
| 131I NaI (35% uptake) | 7.6 x 10-2 | 1.6 x 10-1 | 2.9 x 10-1 | 2.2 x 10-1 |
| 111In DTPA | 9.4 x 10-2 | 6.5 x 10-2 | 2.1 x 10-2 | 1.6 x 10-2 |
| 111In Pentetreotide | 1.1 x 10-1 | 7.8 x 10-2 | 3.7 x 10-2 | 3.0 x 10-2 |
| 111In Platelets | 1.7 x 10-1 | 1.3 x 10-1 | 1.1 x 10-1 | 9.8 x 10-2 |
| 111In RBCs | 2.2 x 10-1 | 1.6 x 10-1 | 1.4 x 10-1 | 1.2 x 10-1 |
| 111In WBCs | 1.2 x 10-1 | 9.3 x 10-2 | 8.6 x 10-2 | 8.0 x 10-2 |
| 81mKr Gas | 1.2 x 10-7 | 1.4 x 10-7 | 1.9 x 10-7 | 2.0 x 10-7 |
| 177Lu DOTATATE[[7]](#endnote-7) | 1.9 x 10-2 | 1.9 x 10-2 | 2.0 x 10-2 | 1.9 x 10-2 |
| 82Rb Chloride | 9.5 x 10-4 | 3.5 x 10-4 | 6.3 x 10-4 | 6.3 x 10-4 |
| 153Sm EDTMP[[8]](#endnote-8) | 2.0 x 10-2 | 3.6 x 10-2 | 1.8 x 10-2 | 1.3 x 10-2 |
| 89Sr Chloride[[9]](#endnote-9) | 8.4 x 10-1 | 2.1 x 100 | 2.3 x 100 | 2.3 x 100 |
| 99mTc Disofenin | 1.9 x 10-2 | 1.3 x 10-2 | 7.8 x 10-3 | 6.4 x 10-3 |
| 99mTc DMSA | 5.9 x 10-3 | 8.8 x 10-3 | 3.4 x 10-3 | 2.2 x 10-3 |
| 99mTc DTPA | 1.7 x 10-2 | 1.1 x 10-2 | 3.8 x 10-3 | 3.2 x 10-3 |
| 99mTc DTPA aerosol | 7.6 x 10-3 | 5.1 x 10-2 | 1.9 x 10-3 | 2.1 x 10-3 |
| 99mTc Glucoheptonate | 1.6 x 10-2 | 1.4 x 10-2 | 4.8 x 10-3 | 3.7 x 10-3 |
| 99mTc ECD | 1.4 x 10-2 | 1.0 x 10-2 | 4.9 x 10-3 | 3.9 x 10-3 |
| 99mTc HMPAO | 1.0 x 10-2 | 7.2 x 10-3 | 4.3 x 10-3 | 3.6 x 10-3 |
| 99mTc MAA | 3.2 x 10-3 | 1.2 x 10-2 | 2.6 x 10-3 | 1.7 x 10-3 |
| 99mTc MAG3 | 2.6 x 10-2 | 1.8 x 10-2 | 5.7 x 10-3 | 4.1 x 10-3 |
| 99mTc MDP | 8.1 x 10-3 | 9.1 x 10-3 | 2.6 x 10-3 | 2.1 x 10-3 |
| 99mTc MIBI rest | 1.7 x 10-2 | 1.2 x 10-2 | 6.9 x 10-3 | 5.6 x 10-3 |
| 99mTc MIBI stress | 1.4 x 10-2 | 9.5 x 10-3 | 6.0 x 10-3 | 4.8 x 10-3 |
| 99mTc Pertechnetate | 1.4 x 10-2 | 6.2 x 10-2 | 1.1 x 10-2 | 5.8 x 10-3 |
| 99mTc Red Blood Cells(in vivo) | 7.0 x 10-3 | 5.5 x 10-3 | 2.2 x 10-3 | 8.7 x 10-4 |
| 99mTc Sulfur Colloid - normal | 1.4 x 10-3 | 2.1 x 10-3 | 1.9 x 10-3 | 1.9 x 10-3 |
| 99mTc White Blood Cells | 3.6 x 10-3 | 2.7 x 10-3 | 2.6 x 10-3 | 2.4 x 10-4 |
| 201Tl Chloride[[10]](#endnote-10) | 8.2 x 10-2 | 5.6 x 10-2 | 5.0 x 10-2 | 4.4 x 10-2 |
| 133Xe 5 min rebreathing | 3.9 x 10-4 | 3.7 x 10-4 | 3.7 x 10-4 | 3.6 x 10-4 |

\* mGy to the fetus per MBq administered to the mother. Conversion rad/mCi = mGy/MBq x 3.7.

References

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