Proposed Addendum to Previously Published Fetal Dose Estimate Tables for ^{18}F-FDG

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Placental transfer and fetal dose estimates have been published for women in early pregnancy and at the end of each trimester for a large number of radiopharmaceuticals. For the case of ^{18}F-FDG, a dose was given with no information about placental transfer of the radiopharmaceutical. Recent publications have reported quantitative values for maternal and fetal uptake of ^{18}F-FDG in primates and new values for ^{18}F-FDG kinetics. In this article, these data are applied to give radiation dose estimates for the fetus at all stages of pregnancy for ^{18}F-FDG. The recommended values are 2.2×10^{-2} mGy/MBq in early pregnancy, 2.2×10^{-2} mGy/MBq at 3-mo gestation, 1.7×10^{-2} mGy/MBq at 6-mo gestation, and 1.7×10^{-2} mGy/MBq at 9-mo gestation.

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Russell et al. have described placental transfer (*1*) and fetal dose (*2*) in early pregnancy and at the end of each trimester for a large number of radiopharmaceuticals, based on available information in the literature. For cases in which no information about placental transfer of a radiopharmaceutical was available, they provided dose estimates for fetal dose only from activity in maternal organs; such was the case for ^{18}F-FDG. A recent publication (*3*) reported quantitative values for maternal and fetal uptake of ^{18}F-FDG in primates and reported estimated values of uptake in fetal brain and heart. In addition, new values for ^{18}F-FDG kinetics have been published by the MIRD Committee (*4*). Here, an addendum is suggested for the tables of Russell et al. to update the dose values to reflect the new MIRD Committee recommendations and include transfer of ^{18}F-FDG to the fetus.

MATERIALS AND METHODS

The values of Benveniste et al. (*3*) suggest similar uptake values for fetal and maternal brain and heart activity (note that they calculated fetal standardized uptake values based on maternal activity and body weight, not fetal body weight). Thus, a reasonable approximation for an average fetal dose could be based on the assumption that the average concentration in maternal and fetal tissues is approximately equal.

RESULTS

The sum of the maternal residence times given in the MIRD Dose Estimate Report (DER) for ^{18}F-FDG in normal adults is 2.38 h (*4*). If we assume that the average concentrations in maternal and fetal tissues are similar, the following fetal residence times are calculated, based on the fetal and maternal body masses in the standard anthropomorphic models (*5*):

$$3 \text{ mo: } (458/58{,}000) \times 2.38 \text{ h} = 0.019 \text{ h},$$

$$6 \text{ mo: } (1{,}640/61{,}500) \times 2.38 \text{ h} = 0.064 \text{ h},$$

$$9 \text{ mo: } (2{,}960/63{,}700) \times 2.38 \text{ h} = 0.11 \text{ h}.$$

Using the MIRD Committee residence times for ^{18}F-FDG in most maternal tissues in the MIRDOSE3.1 software (*6*), one would obtain the dose estimates shown in Table 1, with and without assignment of these fetal residence times. The MIRD DER assumed a maternal urinary bladder voiding interval of 2 h; additional doses are shown here for a 4-h voiding interval.

DISCUSSION

Russell et al. (*1*,*2*) used residence times as suggested in NUREG/CR-6345 (*7*); the use of MIRD DER residence times with the 4-h bladder voiding interval give dose estimates very similar to those of Russell et al. However, the inclusion of placental transfer and of a 4-h bladder voiding interval both increase the dose estimates noticeably. The most conservative values in the table—specifically, 2.2×10^{-2} mGy/MBq in early pregnancy, 2.2×10^{-2} mGy/MBq at 3-mo gestation, 1.7×10^{-2} mGy/MBq at 6-mo gestation, and 1.7×10^{-2} mGy/MBq at 9-mo gestation—are recommended. These values represent average dose to the fetus per unit activity administered to the mother.

Benveniste et al. (*3*) note that the use of an anesthetic on the primates may have influenced the metabolism and placental transfer of the FDG, specifically that "... greater

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TABLE 1
Fetal Dose in Early Pregnancy and at End of Each Trimester of Pregnancy

Radiopharmaceutical: ^{18}F-FDG	Early pregnancy (mGy/MBq)	Gestation		
		3 mo (mGy/MBq)	6 mo (mGy/MBq)	9 mo (mGy/MBq)
Russell et al. (*1*)	2.7×10^{-2}	1.7×10^{-2}	9.4×10^{-3}	8.1×10^{-3}
MIRD DER (no crossover, 2-h void)	1.8×10^{-2}	9.6×10^{-3}	6.5×10^{-3}	5.5×10^{-3}
MIRD DER (no crossover, 4-h void)	2.2×10^{-2}	1.3×10^{-2}	7.9×10^{-3}	6.8×10^{-3}
MIRD DER (crossover, 2-h void)	1.8×10^{-2}	1.8×10^{-2}	1.6×10^{-2}	1.5×10^{-2}
MIRD DER (crossover, 4-h void)	2.2×10^{-2}	2.2×10^{-2}	1.7×10^{-2}	1.7×10^{-2}

Values suggested by Russell et al. (*1*) are compared with new values including placental transfer of activity (*3*) and updated maternal organ activity values (*4*).

variability in maternal brain-to-fetal brain ^{18}F activity ratios might be apparent only in the awake state." Further findings may reveal a need to revisit these dose calculations in the future. Average fetal doses are often used for planning and radiation protection purposes. Investigators may also wish to evaluate the dose to individual fetal organs, even though a standard model for such calculations is not currently available. The similar values of uptake per gram in brain and heart noted by Benveniste et al. suggest that fetal heart and brain doses may be similar to those calculated for maternal heart and brain (*8*), with some possible additional photon dose from nearby maternal organs, such as the urinary bladder.

CONCLUSION

The recent publication by Benveniste et al. (*3*) has provided the opportunity to update currently recommended fetal dose estimates for ^{18}F-FDG. Using placental crossover values suggested by this work, and the more up-to-date general biokinetics from the recent MIRD DER (*4*), new fetal doses are recommended: 2.2×10^{-2} mGy/MBq in early pregnancy, 2.2×10^{-2} mGy/MBq at 3-mo gestation, 1.7×10^{-2} mGy/MBq at 6-mo gestation, and 1.7×10^{-2} mGy/MBq at 9-mo gestation.

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