Positron Emission Tomography and Computed Tomography Fetal Dose in Pregnant Patients

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BACKGROUND

Diagnostic imaging that uses ionizing radiation may sometimes be necessary for a pregnant patient despite the potential risk to the fetus. Typically, when such diagnostic information is needed, it is relating to the health of the mother. When a radiologist or nuclear medicine physician needs to decide if the diagnostic benefits will outweigh the risks of radiation, it is important they have a reasonable estimate of what radiation dose the fetus may receive. In cases where pregnancy is discovered during or after a diagnostic examination, the physician or the patient may request an estimate of the radiation dose received by the fetus. The risks of fetal adverse outcomes, including childhood cancer induction, are small at a dose of 100 mGy and negligible at doses of less than 50 mGy. [1,2] In the case of hybrid imaging where both modalities involve radiation, the fetal dosimetry resulting from both modalities should be considered. One example is positron emission tomography/computed tomography (PET/CT) where the CT scan provides anatomic information, and the PET scan provides information on radionuclide uptake at the tumor site. Fetal dose estimates from CT have been primarily based on Monte Carlo simulations of geometric patient models. [3-5] PET studies of pregnant patients are extremely uncommon, and even ^{18}F-FDG PET studies accidentally performed in pregnant patients are rare. [6-11] Therefore, providing fetal dose estimates from CT and ^{18}F-FDG PET images where the dose can be estimated from the image itself and from dose reports would be helpful to the medical imaging community. In this study, fetal dose estimates for PET/CT scans that are based on a series of pregnant patients in their first, second and third trimester. These images were used to calculate the size-specific dose estimate (SSDE) [12] from the CT scan portion, and the standard uptake value (SUV) and ^{18}F-FDG uptake dose from the PET scan portion using the Medical Internal Radiation Dose (MIRD) formulation. This study will provide the imaging community with dose estimates to the fetus in PET/CT based on patient data, the availability of which is quite rare.

METHODS

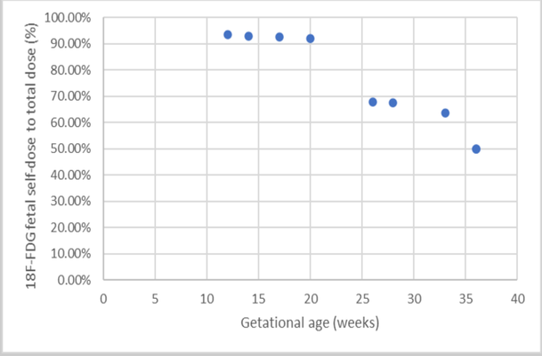
There were 9 PET-CT scans of pregnant patients obtained over an 11 year period who were 12-36 weeks pregnant (gestational age). The average size-specific dose estimates (SSDE) calculated using the water-equivalent diameter for the fetus volume. The 18F-FDG fetal self-dose and total dose from other organs from PET was calculated using a MIRD approach with specific absorption factor from Stabin et al. for 0.5 MeV with initial injection of 3.5 mCi for all patients. The maximum, 95th percentile and mean sum of uptake (SUV) for the entire fetus volume was determined using HERMES software. Fetal depth was calculated from CT images.

RESULTS

The ^{18}F-FDG PET fetal self-dose and total dose is 0.0017-2.18 mGy and 0.0034-2.35 mGy, respectively, and decreases with increasing fetal depth. The percentage of fetal dose to total dose ranges from 50-94% and decreases as gestational age increases. The maximum SUV is 0.11-0.73 MBq^{-1} kg^{-1} and decreases with gestational age. The SSDE ranges from 1.0-2.0 mGy.

Patient #	Gestational age (weeks)	SSDE (mGy)	FDG fetus self-dose (mGy)	FDG fetus total dose (mGy)	SSDE + FDG self-dose fetus (mGy)	Fetal self-dose to total fetal dose (%)
1	17	N/A	1.28	1.38	N/A	92.8
2	33	N/A	6.3×10^{-3}	9.9×10^{-3}	N/A	63.6
3	12	N/A	2.18	2.35	N/A	93.6
4	36	N/A	1.7×10^{-3}	3.4×10^{-3}	N/A	50.0
5	28	N/A	1.4×10^{-2}	2.1×10^{-2}	N/A	67.6
6	36	2.0	1.7×10^{-3}	3.4×10^{-3}	2.0	50.0
7	14	1.2	1.82	1.96	3.0	92.9
8	26	1.2	1.7×10^{-2}	2.5×10^{-2}	1.2	68.0
9	20	1.0	0.74	0.80	1.7	92.2

Table 1. The patient number (year of exam), the gestational age (weeks), the 18F-FDG uptake MIRD calculation using RADAR with interpolation for weeks between 12, 24 and 36 weeks.



. 18F-FDG fetal self-dose to fetal total dose from organs of patient.

RESULTS

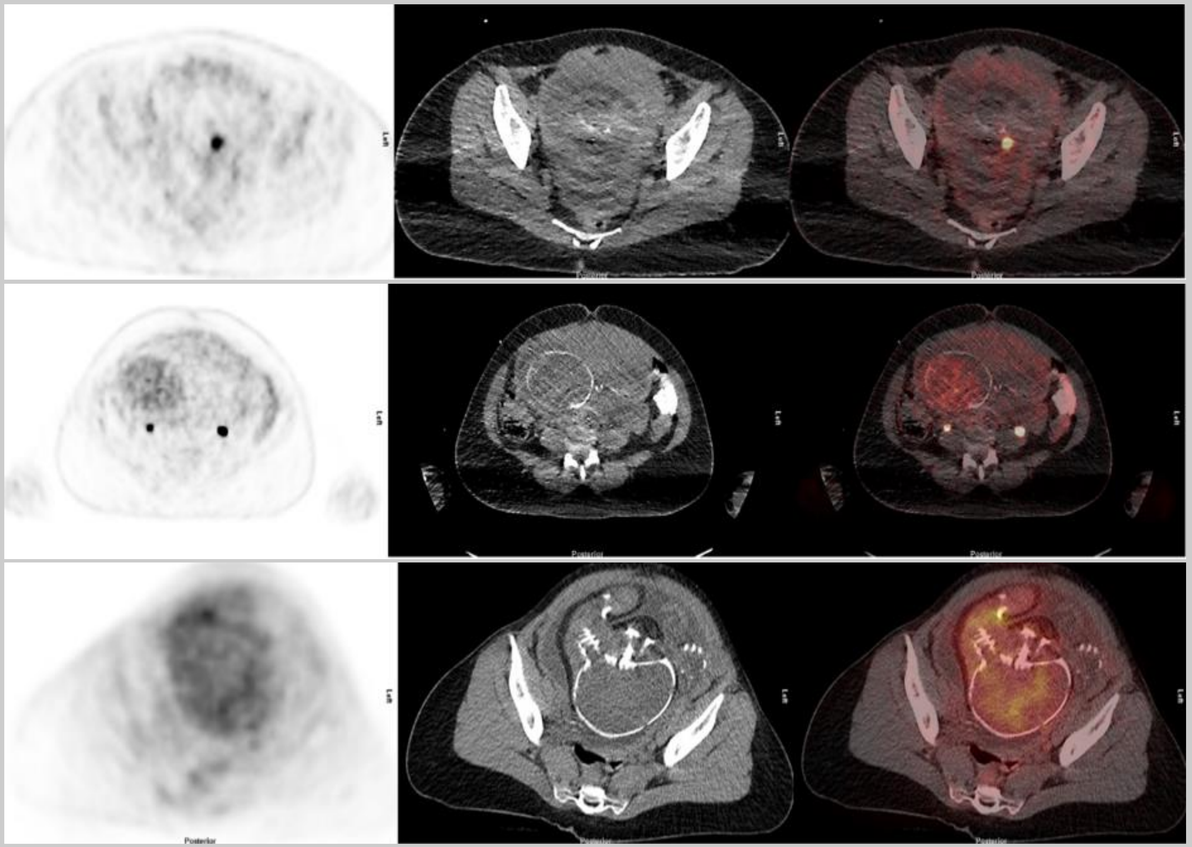


Figure 1. Examples of a single PET, CT and PET/CT fused image for 6 patients in the cohort at gestational age of a) 12 weeks b) 20 weeks, c) 36 weeks to demonstrate 1st trimester, 2nd trimester, and 3rd trimester pregnancy, respectively. The 18F-FDG uptake in the fetus is seen in the PET images.

CONCLUSIONS

This is the first study where fetal doses have been determined from CT and PET images. These types of images from pregnant patients are rare. Our data indicate that the fetal radiation exposure from ^{18}F-FDG PET and CT performed, when medically necessary, in pregnant women with cancer is low. All efforts should be made to minimize the fetal radiation exposure by modifying the protocol appropriately.