PET-CT in the Pregnant Patient

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Why Consider PET-CT in the Pregnant Patient?

Based on potential risks of fetal loss, teratogenicity, fetal growth retardation and carcinogenesis, positron emission tomography/computed tomography (PET-CT) with an 18F-2-fluoro-2-deoxy-D-glucose injection (FDG) is generally contraindicated in the pregnant patient. Rarely, PET-CT may be selectively performed as a problem-solver in specific pregnant patients. PET-CT is more likely to be performed inadvertently in patients with unsuspected pregnancy. This would most often occur in very early pregnancy, perhaps after only a few weeks gestation, especially at a time that routine urine pregnancy exams are less reliable. Occasionally, human error or miscommunication may be responsible for such events. Medical physicists, radiologists and nuclear medicine physicians may be consulted to evaluate a case and consult with a pregnant patient before or after a planned or unplanned PET-CT examination.[1,2,3,4]

Fetal Radiation Associated With the CT Component of PET-CT

For head, neck or chest CT examinations where the fetus is not directly irradiated, maternal Compton scatter radiation doses to the fetus are on the order of 0.2 mGy or less[5,6], depending on fetal size and proximity to the primary x-ray beam. With typical abdominal-pelvic CT, the fetus is directly exposed to the scanning beam, with estimated doses of 10- 25 mGy[5,6] expected. When a risk-benefit analysis in a given clinical situation favors imaging using CT, the goal is to produce diagnostic-quality images with the minimum fetal radiation exposure. For abdominal-pelvic CT in a pregnant patient, depending on patient size, 120 kVp or less and a pitch of greater than 1 may be prescribed.[5,6] Tube current modulation may be used with care to avoid low noise level settings that could result in a higher fetal dose. Where available, iterative reconstruction methods should be used to improve image reconstruction quality. Multiphase imaging should be avoided.

Normalized fetal CT Monte Carlo dose estimates range from 7.3 to 14.3 mGy/100 mAs[7]. Lazarus et. al.[8] reported a mean dose of 17.1 mGy (range 8–44 mGy). In a recent series of 54 patients, investigators estimated mean fetal dose to be 24.8 mGy (range, 6.7–56 mGy).[5]

Doses to the fetus from a single-acquisition abdominal-pelvic CT examination have ranged between 10 and 50 mGy in phantom and clinical studies. The most important stochastic risk in this dose range is a potential 1.5- to 2.0-fold increased risk of childhood leukemia. This translates into a relative leukemia risk of 3 in 1000 at background radiation levels to 4 in 1000 at 10 mGy and 6 in 1000 at 50 mGy.[6]

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.[6,7,8]

Use of Iodinated Contrast Agent During Pregnancy

Iodinated contrast agents are known to cross the human placenta and enter the fetus.[11]

While iodinated contrast agents have not been associated with teratogenic effects, and there are no reports of clinical sequelae induced by iodinated contrast agents administered IV[12], iodinated contrast agents can cause neonatal hypothyroidism if directly instilled into the amniotic fluid. A recent study of the effect of in utero exposure to a single high dose of iodinated contrast material on neonatal thyroid function identified no significant risks.[13] The ACR Manual on Contrast Media recommends that iodinated contrast agents should be used only as needed in pregnant patients.[14]

Fetal Radiation Associated With the ^{18}F-FDG Component of PET-CT

Radiopharmaceuticals deliver fetal radiation by two mechanisms (Figure 1 and Table 1):

- Irradiation from radioactivity in maternal organs including bladder, placenta and bowel
- Internal irradiation (beta+ and gamma) from trans-placental radiopharmaceuticals

Typically, smaller moieties of 500 Daltons or less readily traverse the placental barrier. As PET tracers typically represent small molecules, the available PET radiopharmaceuticals ^{18}F-FDG, Na^{18}F, ^{82}Rb and ^{18}F- Florbetapir would be expected to cross the placenta and directly irradiate the fetus.[15,16,17,18]

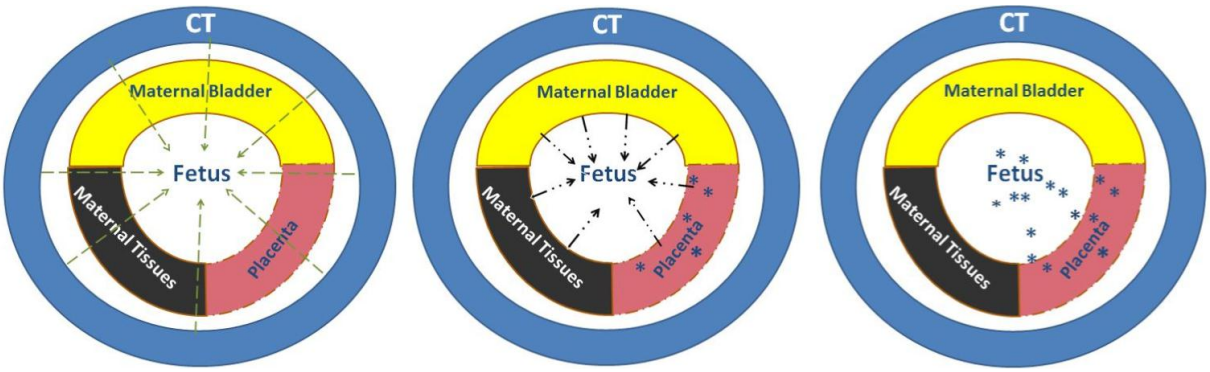
Table 1 - Fetal dose estimated from maternal ^{18}F-FDG, including placental crossover[16]

	Early	3-Month	6-Month	9-Month
Dose from ^{18}F-FDG (mGy/ mCi)	0.81	0.81	0.63	0.63

PET-CT in the Pregnant Patient: Fetal Dosimetry

Total fetal estimate radiation dose from PET-CT is the sum of CT exposure + maternal gamma irradiation + fetal beta+ + fetal gamma irradiation (Figure 1). Dosimetry estimates from clinical cases are presented in Table 2. Depending on the PET and attenuation correction technique applied, fetal age, and maternal body habitus, fetal estimated doses of between 1.1 and 21.9 mGy have been reported.

Figure 1 - Fetal radiation estimated exposure from ^{18}F-FDG PET-CT



CT Exposure
4-50 mGy

Maternal Tissue Irradiation
9-15 mGy

Trans-Placental Radiation
4-10 mGy

Table 2 - Fetal estimated irradiation from 18F-FDG PET-CT case reports

	Maternal	Placental crossover	CT	Total
Zanotti-Fregonara et al 2010[17]	3.0 mGy	8.9 mGy	10 mGy	21.9 mGy
Takalkar et al 2011[18]	1.1-9.4 mGy (reported combined maternal plus placental crossover)		Negligible (^{68}Ge rod)[19]	1.1-9.4 mGy
Hsieh et al 2012[20]	6.3 mGy (reported combined maternal plus placental crossover)		3.6 mGy	9.9 mGy

PET-CT in the Pregnant Patient: Recommendations

- Establish presence and gestational age of pregnancy
- Establish the indication for medical imaging
- Consider non-ionizing radiation alternative imaging modalities, specifically ultrasound and MRI
- Consider feasibility of obstetrical interventions, including termination or early delivery
- If ^{18}F-FDG PET is indicated during pregnancy, consider where appropriate:
    - ^{18}F-FDG dose reduction to 5 mCi
    - Apply PET imaging techniques such as 3D when possible to support reduced ^{18}F-FDG dosing.
    - Increased oral hydration or intravenous saline
    - Furosemide 20 mg IV, 15 min after ^{18}F-FDG administration
    - Encourage frequent voiding.
    - Selective urinary bladder catheterization
    - Attenuation correction with a ^{68}Ge rod source is most radiation efficient

- CT attenuation with 120 kVp and a pitch greater than 1
- Apply tube current modulation with care to exclude low noise settings
- Apply iterative CT reconstruction wherever possible

- Estimate total fetal dose: proposed interpretation
  - Recommendations: < 1 mGy (total gestation)
  - NRC worker limit: < 5 mGy (0.50 mGy/month)
  - Fetal doses of < 50 mGy, no evidence for fetal injury
  - Fetal doses of < 100 mGy, termination not justified
  - At fetal doses between 100 and 150* mGy, consider individual circumstances
  - Fetal doses > 150* mGy, possible fetal damage, termination should be seriously considered [*equivalent exposure >3 pelvic CT exams
  - Fetal doses > 500 mGy, fetal risk sufficient to recommend termination

Additional information is available in the ACR Practice Guideline for Imaging Pregnant Adolescents and Women with Ionizing Radiation.

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