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Radiation dose to the fetus from [¹⁸F]-FDG administration during the second trimester of pregnancy

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Abstract

We estimated the fetal radiation dose from [¹⁸F]-FDG in a rare case of a woman who underwent a PET/CT scan during the second trimester of pregnancy. The patient, a 27-year-old female with a paraganglioma, received 181.3 MBq [¹⁸F]-FDG. From the concentrations of radioactivity measured on the images, we derived the time-integrated activity coefficients of the fetus and the placenta. The time-integrated activity coefficients of the mother's organs were taken from the standard values of the ICRP publication 106. The final fetal dose was calculated using the 6 month pregnant model of the OLINDA/EXM software. The fetus showed an overall low and homogeneous [¹⁸F]-FDG uptake, with an average concentration of 2.41 kBq cm⁻³. The uptake in the placenta was generally higher (average concentration = 3.69 kBq cm⁻³). The estimated time-integrated activity coefficients were 0.0130 and 0.0058 Bq hr Bq⁻¹ for the fetus and the placenta respectively. The final average dose to the fetus was 1.97 × 10⁻² mGy MBq⁻¹ (3.6 mGy in this patient who received 181.3 MBq). Therefore, the dose to the fetus from [¹⁸F]-FDG administration during the second trimester of pregnancy is low. When medically indicated, pregnancy should not be a categorical basis for withholding [¹⁸F]-FDG PET scans.

Keywords

[¹⁸F]-FDG; dosimetry; pregnancy; PET

Introduction

In the last decade, Positron Emission Tomography (PET) with [¹⁸F]-FDG has become a mainstay in the clinical management of many types of cancer. The benefits of nuclear medicine imaging should however be weighed on an individual basis against the risks associated with ionizing radiations. This is especially true for pregnant patients, because the developing fetus may be particularly sensitive to radiations. In order to make rational choices in the management of pregnant patients with cancer, the fetal absorbed dose after

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Conflict of interest

The authors have no conflicts of interest

[¹⁸F]-FDG administration must be known. Although the photon component of the fetal dose, coming from maternal tissues, can be reliably estimated from phantom measurements, the [¹⁸F]-FDG uptake in the fetus—which is essential for deriving the self-dose from positrons and photons—is poorly known. Only very scarce data exist in the literature documenting fetal uptake in pregnant women (Zanotti-Fregonara et al. 2008, Zanotti-Fregonara et al. 2010). In the present article, we estimated the fetal absorbed dose in a very rare case of a woman who underwent a [¹⁸F]-FDG PET/CT scan during the second trimester of pregnancy.

Methods

A 27-year-old pregnant woman, weighing 53 kg, was admitted with a clinical syndrome including hypertension, headaches, palpitations and anxiety. She had elevated urinary and plasma-free normetanephrine and plasma-free metanephrine concentrations. When she was at 21-weeks of pregnancy, she underwent [¹⁸F]-FDG PET/CT scan to localize a possible pheochromocytoma. [¹⁸F]-FDG PET/CT scan demonstrated a very active ($SUV_{max} = 16$) extra-adrenal lesion, medial to the lower pole of the left kidney. The patient underwent a laparotomy with successful removal of a benign paraganglioma. A more detailed clinical history of this patient has been reported elsewhere (Koroscil et al. 2010).

The PET/CT scan was carried on a Siemens Emotion 6 hybrid scanner and started 40 minutes after injection of 181.3 MBq of [¹⁸F]-FDG. Scanner calibration is performed on a daily basis, utilizing a uniform cylindrical ⁶⁸Ge phantom with a known level of activity. Each morning, prior to any clinical scanning, a quality control scan is acquired (45 minutes duration). This quality control scan checks for scanner uniformity as well as determines the scanner calibration factor - (measured counts per mL)/(known activity per mL). An unenhanced low-dose CT scan (130 keV, 60 mAs) was used for attenuation correction. Imaging was obtained from the base of skull to mid-thigh level.

[¹⁸F]-FDG dosimetry calculations: the fetal volume and the concentration of radioactivity in fetal tissues were measured from the images by manually drawing a volume-of-interest encompassing the entire fetal volume. These measurements were used to derive the fetal uptake in terms of fraction of injected activity and the fetal time-integrated activity coefficient. Since the [¹⁸F]-FDG kinetics in fetal tissues are unknown; we assumed an effective [¹⁸F]-FDG half-life equal to the physical half-life of [¹⁸F]. The same approach was used to measure the concentration of radioactivity and the time-integrated activity coefficient of the placenta. The standard time-integrated activity coefficients of the mother's organs were taken from the ICRP publication 106 (ICRP 2008). The final fetal dose was then calculated using the 6 month pregnant female model of the OLINDA/EXM software (Stabin et al. 2005).

Results

The fetal skeleton is well visualized on the CT images in the upper portion of the uterine cavity (Figure 1), and this allowed an accurate calculation of the fetal body volume, which was estimated at 369 cm³. By contrast, the placental volume could not be reliably defined from the images, therefore we considered a volume of 110 cm³, which is the average placental volume at 21-wk of pregnancy (Zalud and Shaha 2007).

On PET images (Figure 1), the fetus shows an overall low and homogeneous [¹⁸F]-FDG uptake, except in the region of the head, where the uptake is slightly higher ($SUV_{max} = 3.9$), most likely due to [¹⁸F]-FDG uptake in the brain. No focal uptake was seen in the other fetal organs, like the heart, the liver or the bladder. The average concentration of radioactivity in

the whole fetus was 2.41 kBq cm^{-3} , which corresponded to a fraction of 0.49% of the injected activity. Therefore, the fetal time-integrated activity coefficient was $0.0130 \text{ Bq hr Bq}^{-1}$. The placenta showed a higher uptake, with a mean concentration of 3.69 kBq cm^{-3} , corresponding to 0.22% of the injected activity and a time-integrated activity coefficient of $0.0058 \text{ Bq hr Bq}^{-1}$.

In total, the average dose to the fetus was estimated at $1.97 \times 10^{-2} \text{ mGy MBq}^{-1}$. About 75% of this dose was due to photons, while only 25% was due to the positron self-dose. The placenta was responsible for only 1.8% of the final dose to the fetus.

Discussion

The present study shows that the dose received by a 21-wk fetus is about $1.97 \times 10^{-2} \text{ mGy}$ per MBq of [^{18}F]-FDG injected to the mother. This figure is in close agreement to the current standard values for the second trimester of pregnancy ($1.7 \times 10^{-2} \text{ mGy MBq}^{-1}$) (Stabin 2004), which were extrapolated from a monkey model (Benveniste et al. 2003). Since this patient was injected with 181.3 MBq, the final dose to the fetus was of 3.6 mGy. Even when adding the dose of the transmission scan used for attenuation correction, which in this case was estimated at about 5 mGy (Elojeimy et al. 2010), the fetal absorbed dose from [^{18}F]-FDG PET/CT scans remains well within the “safe” levels. At this stage of pregnancy, the threshold dose is 650 mGy for mental retardation and 500 mGy for small head size and growth retardation (Steenvoorde et al. 1998). Therefore, when medically indicated, [^{18}F]-FDG PET scanning should not be withheld in pregnant patients for fear of excessive radiation exposure to the fetus. Procedures to minimize the fetal radiation exposure should however be taken, such as decreasing the injected [^{18}F]-FDG activity, using an appropriate low-dose CT protocol (the mAs was reduced to 60 in the present case) and providing adequate hydration to enhance urinary elimination of the tracer.

Our two previous case-reports (Zanotti-Fregonara et al. 2008, Zanotti-Fregonara et al. 2010) showed a much higher [^{18}F]-FDG uptake in fetal tissues and, by consequence, a higher absorbed dose (3.3 and 4.0 mGy MBq $^{-1}$, respectively). Indeed, the fetal absorbed dose in these two previous cases was mostly due to the positron self-dose, whereas in the present study the positrons account for only 25% of the final dose. The most likely explanation is the different stage of pregnancy, as the two previous cases were in early pregnancy (8 and 10-wk). Early pregnancy is characterized by a rapid cell proliferation, which is generally associated with high glucose consumption.

Finally, this study is a further proof that [^{18}F]-FDG crosses the human placenta and accumulates in the fetus. The human placenta expresses at least two different types of glucose transporters: GLUT1 (Fukumoto et al. 1988) and GLUT3 (Korgun et al. 2005). In the present study, we found that about 0.22% of the injected activity is localized in the placenta 40 minutes after [^{18}F]-FDG injection. This finding is consistent with our previous report, which estimated the placental uptake at 8-wk pregnancy as 0.19% of the injected activity (Zanotti-Fregonara et al. 2009). Also in agreement with the previous report, the placental contribution to the final dose to the fetus is small: it was about 1.2% in the previous case (Zanotti-Fregonara et al. 2009) and it is about 1.8% in this one, the increase being likely due to the bigger volume of the placenta in the present case.

At 39-weeks gestation, the patient was induced and she delivered a healthy female, weighing 3030 grams.

Conclusion

Fetal radiation dose from [^{18}F]-FDG administration during the second trimester of pregnancy is low. When medically indicated in pregnant patients, [^{18}F]-FDG PET scanning should not be withheld for fear of excessive radiation exposure to the fetus.

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Figure 1.

Transaxial (A, B) and coronal (C) fused [^{18}F]-FDG PET and CT slices through uterus. The fetal skeleton is well visible on the CT images. The PET images show that the fetus corresponds to a photopenic area in the upper part of the uterine cavity. The fetus is surrounded by a hotter placenta (white arrows), whose insertion is on the anterior wall of the uterus. The two symmetrical hot spots visible on the transaxial images near the vertebral column correspond to the urinary activity contained in the ureters.