Review Article, Radiation Protection.

Public Exposure to External Radiation Emanating from ^{18}F-FDG PET/CT Patients.

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ABSTRACT:

18F-fluorodeoxyglucose (18F-FDG) is the most commonly used radiopharmaceutical agent in imaging using PET/CT. F-18 is a cyclotron produced radioisotope, it has a half-life of~110 minutes which makes it an ideal isotope for use in nuclear medicine, however it has much higher photon energy than other radioisotopes used regularly in nuclear medicine practice. Current medical practice, hybrid imaging of FDG PET/CT is widely used in clinical practice for diverse diseases with cancer as main application. The increase of FDG PET/CT examinations, a concern has been raised with regard to the radiation exposure by PET/CT. The Nuclear Regulatory Commission has well-established guidelines for the release of patients undergoing therapeutic procedures. The maximum accepted exposure of the public from a material source— 20 mSv/h (2 mR/h) is used as benchmark to reduce exposure to as low as reasonably achievable. However, guidelines addressing the release of a patient undergoing diagnostic nuclear medicine using PET/CT examinations are not as clear. Nevertheless, medical facilities are under increased scrutiny to reduce the radiation exposure of both patients and the public.

Key Words: External Radiation Emanating, ^{18}F-FDG, PET/CT.

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INTRODUCTION:

Positron Emission Tomography/Computed Tomography (PET/CT) is a non-invasive nuclear medicine imaging technique which combines functional imaging obtained by PET with the superior anatomical information obtained by CT. It has been used for decades for different oncological purposes such as: staging malignant tumors, assessment of therapy, detection of recurrence, planning of radiotherapy treatment and detection of metastasis of unknown origin [1].

The increased use of diagnostic imaging throughout the world has caused a drastic increase in the radiation exposure of the population and has raised concerns about potential cancer risks associated with this trend, as well as unfavorable media coverage PET/CT has emerged as the gold standard to stage and restage various types of malignancies, while also seeing a steady incline in the number of studies performed [3,4]. Although the half-life of 18F-FDG is relatively short (110 min). It is therefore important to consider the time frame immediately after a scan. An attempt for reducing the radiation dose to patients and imaging staff has become a major focus, so some studies were done to explore the effectiveness of reducing the radiation exposure of the public from a patient who received a standard-of-care 18F-FDG PET/CT examination [5,6]. FDG PET/CT has been rapidly expanded with the increase of FDG PET/CT examinations; a concern has been raised with regard to the radiation exposure by PET/CT, because it causes both internal and external radiation from radiopharmaceutical administration and CT acquisition. The radiation dose of FDG PET/CT depends on both injected activity of FDG and CT protocol.

Radiopharmaceutical:

Radiopharmaceuticals are a combination of a radionuclide and a biologically active molecule or drug that acts as a carrier and determines localization and bio distribution. The biologically radioactive molecules can be efficiently labeled to a variety of substrates of pharmaceutical relevance that can allow the study of numerous in vivo physiological processes at the molecular level. Having short half-lives and requiring on spot cyclotrons significantly limits the use of many positron emitters such as C-11 (half-life 20 minutes), N-13 (half-life 10 minutes) and O-15 (half-life 2 minutes) and makes 18F with relatively longer half-life (110 min), the building block used in the PET/CT studies.

^{18}F- Fluoro-Geoxy-Glucose:

18F FDG is a radiopharmaceutical, specifically a radiotracer, used in the medical imaging modality with positron emission tomography (PET). Chemically, it is 2-deoxy-2-18F Fluoro-D-glucose, a glucose analog, with the positron-emitting radionuclide fluorine-18 substituted for the normal hydroxyl group at the C-2 position in the glucose molecule. The fluorine in 18F FDG decays radioactively via beta-decay to 18O−,After picking up a proton H+ from a hydronium ion in its aqueous environment, the molecule becomes glucose-6-phosphate labeled with harmless nonradioactive "heavy oxygen" in the hydroxyl at the C-2 position. The new presence of a 2-hydroxyl now allows it to be metabolized normally in the same way as ordinary glucose, producing non-radioactive end-products [7]. Although in theory all 18F FDG is metabolized as above with radioactivity elimination half-life of 110 minutes (the same as that of fluorine-18), clinical studies have shown that the radioactivity of 18F FDG partitions into two major fractions. Another fraction of 18FFDG, representing about 20% of the total fluorine-18 activity of an injection, is excreted through the kidney by two hours after a dose of 18F FDG, with a rapid half-life of about 16 minutes (this portion makes the renal-collecting system and bladder prominent in a normal PET scan). This short biological half-life indicates that this 20% portion of the total fluorine-18 tracer activity is eliminated through the kidney much more quickly than the isotope itself can decay. Unlike normal glucose, FDG is not fully reabsorbed by the kidney Because of this rapidly excreted urine 18F, the urine of a patient undergoing a PET scan may therefore be especially radioactive for several hours after administration of the isotope [8]. All radioactivity of [18 F] FDG, both the 20% which is rapidly excreted in the first several hours of urine which is made after the exam, and the 80% which remains in the patient. Thus, within 24 hours (13 half-lives after the injection), the radioactivity in the patient and in any initially voided urine which may have contaminated bedding or objects after the PET exam will have decayed to 2−13 = 1⁄8192 of the initial radioactivity of the dose. In practice, patients who have been injected with [18F] FDG are told to avoid the close vicinity of especially radiation-sensitive persons, such as infants, children and pregnant women, for at least 12 hours (7 half-lives, or decay to 1⁄128 the initial radioactive dose [9].

Radiation protection measures:

FDG PET/CT has been rapidly expanded with the increase of FDG PET/CT examinations; a concern has been raised with regard to the radiation exposure by PET/CT, because it causes both internal and external radiation from radiopharmaceutical administration and CT acquisition. The radiation dose of FDG PET/CT depends on both injected activity of FDG and CT protocol.

Radiation Protection Program:

Developing and implementing a radiation protection program is a best practice for protecting workers from ionizing radiation. A radiation protection program is usually managed by a qualified expert (e.g., health physicist), who is often called a radiation safety officer (RSO). Another best practice is designating a radiation safety committee, which includes the RSO, a management representative, and workers who work with radiation-producing equipment, radiation sources, or radioactive materials. A radiation protection program should include, at a minimum of Qualified staff (e.g., RSO, health physicist) to provide oversight and responsibility for radiation protection policies and procedures. ALARA stands for As Low As Reasonably Achievable (ALARA): The ALARA concept is an integral part of all activities that involve the use of radiation or radioactive materials and can help prevent unnecessary exposure as well as overexposure. The three major principles to assist with maintaining doses ―As Low as Reasonably Achievable‖ are time, distance and shielding.

A dosimetry program:

Personal exposure monitoring is conducted, as required by federal or state regulations, for external dose and, as needed, for internal dose. Surveys and area monitoring to document radiation levels, contamination with radioactive materials, and potential worker exposures. Radiological controls, including entry and exit controls, receiving, inventory control, storage, and disposal. Worker training on radiation protection, including health effects associated with ionizing radiation dose, and radiation protection procedures and controls to minimize dose and prevent contamination. Emergency procedures to identify and respond to radiological emergency

situations. Record keeping and reporting programs to maintain all records and provide dosimetry reports and notifications, as required by federal or state regulations. Internal audit procedures to annually audit all aspects of the radiation protection program [10].

Portal Monitors for area survey:

Geiger counter, is a useful instrument used to quickly detect and measure radiation. A Geiger counter exploits the natural process of ionization to detect and measure radiation. The device houses a stable gas within its chamber. When exposed to radioactive particles, this gas ionizes. This generates an electrical current that the counter records over a period of 60 seconds [11]. When ionization occurs and the current is produced often in milli-Sievert (mSv). There are several different types of radioactive particles that cause ionization, known as alpha, beta or gamma radiation. However, Geiger counters cannot differentiate between the different types of radiation [12].

Clinical Studies for radiation protection following ^{18}FDG Injection:

Berberogula et al reported in a study of 100 patients (57 females, 43 males, mean age 51.8 ± 14.5 years), who were diagnosed with a malignant disease and underwent ^{18}F-FDG PET/CT examination. Following imaging, external radiation exposure rate was measured at one meter distance, shortly after the completion of imaging procedure before and after urination to measure the rate of radiation emitted from patients that underwent ^{18}FDG PET/CT. Factors effecting resulting exposure from patients were examined. The mean post-urination activity ranged between 0.2 and 6.3 mSv/h. Older age, greater BMI and higher administered dose were associated with higher post-urination activity. Patients were discharging 2 hours after injection and instructing them to urinate before leaving the nuclear medicine department would be a safe practice and activity would not pose radiation health risk forrelatives or other hospital staff [13].

Also, **Razi Muza et al** enrolled 100 patients, divided into 2 groups with measuring radiation dose rate immediately after the scan. For group 1, thepatients voided and their dose rate was measured again. For group 2, the patients waited 30 min before voiding, and radiation dose measured before (group 2A) and after (group 2B) they voided. 74 of the 100 patients exceeded the 20 μSv/h (2 mR/h) threshold immediately after the scan. In group 1, the mean dose rate decreased by 20.0% from the post scan measurement, with 12 of 36 remaining at or above 20 μSv/h. In group 2A, the mean dose rate decreased by 23% from the post scan measurement, with 9 of 38 remaining at or above 20 μSv/h. In group 2B, the mean dose rate decreased by 35% from the post scan measurement, with 1 of 38 remaining at 20 μSv/h,75%. of patients undergoing an ^{18}F- FDG PET/CT scan exceed 20 μSv/h when leaving the imaging facility. They concluded that the most effective method to reduce radiation exposure was to have the patient void 30 min after the examination [(14)].

Furthermore, **Kim and Han et al** in their study derived measures to reduceexposure doses by identifying factors which affect the external radiation dose rate of patients treated with radiopharmaceuticals for PET-CT scan. The external radiation dose rates were measured in 60 patients on three parts of head, thorax and abdomen at a distance of 50cm from the surface of 60 patients. The external radiation dose rate were measured in four points at a distance of 10 cm, 50 cm, 100 cm, 200 cm from the surface of the patients' bodies. The measured values at the point of 50 cm were analyzed and the average values of the external radiation dose rate of each head, chest and abdomen were used. The measurement time of the external radiation dose rate was divided into three parts: after the injection of radiopharmaceuticals, after urination which is preparation step for PET-CT and after the PET-CT scan. The minimum dose of ^{18}F-FDG was 8 mCi, the average was 11.89 mCi, and the maximum was 15 mCi according to the patients. The factors affecting the external radiation dose rate are derived by classifying the personal variables which patients have essentially, which includes: gender, age, height, weight, body mass index, diabetes, and adjustable variables, which include: fasting time, the amount of water intake before and

after the injection of radiopharmaceuticals, urination frequency after the injection of radiopharmaceuticals, and the use of contrast medium. For gender the external radiation dose rate is higher in men than women at the point immediately after PET-CT. In this regard, variables for strategic intervention are not possible because they are personal aspects which do not allow for intervention. The external radiation dose rate was lower in the patients withmore water intake than those with less water intake before the injection of radiopharmaceuticals at all three points: right after the injection of radiopharmaceuticals (average 4.17 min.), after the pre-PEET-CT urination step (average 77.47 min.), and after the PET-CT scan (average 114.15 min.). Urination frequency was the most significantfactor to affect the external radiation dose rates at the point after the PET-CT test and the point after the pre-PET-CT urination step. There is a need to realize the strategy to increase the urination frequency of patients to maintain the external radiation dose rate low (average 77.47 min.) before and after the injection of radiopharmaceuticals. They concluded that urination frequency, the amount of water intake, fasting time and are important factors in external radiation dose exposure [15].

CONCLUSION:

It's important of reduced radiation exposure dose in relation to time following imaging using F-FDG PET/CT. The addition of hydration is necessary to reduce external radiation dose of patients to public.

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