Dose estimation of the radiation workers in the Cyclotron and PET/CT center

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Abstract

Objective: To measure and evaluate the radiation dose of medical staff who worked in the Cyclotron and PET/CT Center for clinical radiation protection.

Methods: Monitored the radiation dose level in the workplace and used radiation dose meter to measure dose rate in 10 medical staff members during each procedure in Cyclotron Center and PET/CT Department. In this study each radiation worker was observed. The estimated annual dose of each member at different working sites was calculated by the dose rate, working hours, and workload.

Results: The estimated annual dose per working procedure per person was: hands 35.0 mSv and whole body 0.07 mSv for distribution; hands 35.0mSv and whole body 0. 07 mSv for carrying the compound; hands 2.0 mSv and whole body 5.0 mSv for injection, and whole body 3.0 mSv to get the patients ready for imaging operation.

Conclusions: Under the normal operational conditions, the dose received by staff members did not exceed the national radiation safety standards (GBSS) for occupational and public personal annual dose limits.

Key words: cyclotron; PET; radiation protection; dose estimation

1. Introduction

Positron emission tomography scanner is an advanced nuclear medical imaging equipment. Positron emission tomography accompanied with computed tomography (PET/CT) is considered one of the most reliable diagnostic imaging techniques having the peculiar characteristic to provide both functional and morphological information of the organ of interest. [1] Because the PET's radiopharmaceuticals half-life is short, a hospital is usually equipped with Mini cyclotron and radiochemistry Laboratory for production of radioisotopes.

In recent years, with the wide use of this kind of equipment, much attention is paid to the radiation dose of the radiopharmaceuticals. The most commonly used positron drug is 18F-FDG, which is emitted with characteristic 511 keV annihilation photons detected simultaneously by coincidence systems of the PET tomograph. This high radiation brings radiation safety problems in a nuclear medicine department. Special attention is required when dealing with radioprotection aspects in a PET/CT facility in order to optimize the absorbed dose for workers.

At present, most workers wear personal dosimeter TLD badges for monitoring cumulative dose during work time. Due to many factors that may influence the TLD system, we prefer X-ray gamma ray survey meter which is most effective in monitoring the dose of the medical staff during single operation procedure. Therefore, we used the X-ray gamma ray survey meter to monitor the radiation dose rate of the medical staff who worked in PET/CT Center of Shenli Hospital, Shandong Province in China. The purpose of this study was to evaluate the radioprotection and calculate the dosage of the medical staff work there.

2. Method

2.1. Facilities and Instruments

The PET-CT Center at Shenli Hospital was equipped with a GE Minitrace Cyclotron and a PET/CT facility. In this Center only 18F-FDG radiopharmaceuticals were produced. 18F-FDG was more than 37 GBq under the work of the Cyclotron in 60 min.

The monitoring instrument was 451P X-ray gamma ray survey meter, which was in the period of legal metrological verification. The measuring range was 0-50 mSv/h and the measurement accuracy was within 10%.

2.2. Measurement and Calculation

We monitored the dose rate of chest and hand in 8 medical staff who were responsible for production, quality control, distribution, administration, injection, and getting the patients ready for scanning in the PET-CT Center during every step. The annual accumulated dose was multiplied by the dose rate, working time and workload.

3. Results

The workload was as follows: two times a week, 3 to 5 patients in need of PET-CT diagnosis each time. Each year the largest diagnostic workload was 400 cases. The number of using the cyclotron throughout the year was up to 80 times. There were 8 staff members in charge of the steps for production, distribution, quality control, injection of the radiopharmaceuticals, and get the patients ready in the hospital.

Cyclotron was an automatic processor which could produce the radiopharmaceuticals under control. The radiation level in the control room was 0.13~0.21 μSv/h. Therefore, no medical staff members received additional radiation.

Other process annual doses were calculated and the results were shown below:

A) Quality Control: Appearance, pH, radiochemical purity, chemical purity, XID or XIE were checked before distribution and injection. The dose rate was 4.08 μSv/h in the condition of extracting liquid 0.0073 GBq (0.2mCi). Each time the human-source distance was 0.5 m, and it was accomplished within 20 min. Quality control was performed 80 times a year and the cumulative dose was 0.11 mSv.

B) Distribution and Transmission: In the pharmaceutical room, workers put vial containing liquid into a lead tank， and then distributed with a sterile catheter.

According to the number and dose of the patients, radioactive drug was pumped into the injection needle first and then sent to the injection room under shielding condition. The typical dose was 0.74 GBq (20mCi) 18F-FDG. Distribution was 30 s, and transmission took 5 minutes each time. The dose rate of hand and chest in medical staff were 40.8 mSv/h and 2.65 μSv/h, respectively.

For the condition of 400 distributions a year, 1.7 h, the annual dose per worker for distribution was: hands 69.4 mSv and chest 4.5 μSv. The dose rate of waist was 0.6 μSv/h, when the car transported radioactive sources. For the condition of 80 transportations a year, 6.7 h, the annual dose per worker for transportation was 4.0 μSv. If all the working procedure was conducted by one person, the annual dose of hands and chest was 69.7 mSv and 0.14 mSv, respectively. In fact, the work borne by two workers, the annual dose of hands and chest was 35 mSv and 0.07 mSv per person, respectively.

C) Injection: Nurses injected drugs according to the patient's dosage. In this study we considered 0.55 GBq 18F-FDG as the typical dose and nurses gave drugs to the patients in shield within 25 s. The dose rates of head and chest were 150 μSv/h and 400 μSv/h, respectively, for the condition of 400 injection a year, 2.8 h, the annual doses of head and chest were 0.42 mSv and 1.12 mSv.

D) Positioning: Nurse guided patients to the PET-CT scan room. Each patient required positioning 3 to 6 times, about 2.5 min. For the condition of 400 times a year, about 16.7 h, the dose rate was 30 μSv/h, the annual dose of per worker for positioning was 0.50 mSv. The annual dose for injection and positioning was

1.62 mSv. The total dose was basically shared by four nurses, with 0.4 mSv for each.

4. Conclusions

Outside of the subminiature cyclotron, the actual measurement data of ray and neutron doses were provided by the manufacturer and dose contour value was at the range of 1/5～1/10. It is suggested that the protection of the accelerator shielding system was good. The ability of shielding showed to be good because the compound drug shield box in the laboratory had a lead shield with 70 mm.

Packaging of drugs was the major operation of receiving maximum dose. When packaging drugs with protection screen, medical staff hands were exposed to a heavy dose. It is recommended providing a packaging manipulator for protection.

The protection for injection, waiting, and PET-CT diagnosis was found to be good. However, the site was not originally constructed for PET-CT Center. So the site had somewhat an inappropriate layout. For instance, there was no special restroom for patients and the shared restroom is far from the diagnostic place. The PET-CT diagnosis facility was connected to the X-ray diagnosis facility.

When detecting, a staff member holding a lead can (with 9.43 GBq drugs), jogging from the pharmaceutical facility to the PET diagnosis facility, and transferring the radiopharmaceuticals took 145 s. In such practices, hand dose rates were 20 μSv/h and waist was 13～15 μSv/h. It was unnecessary to increase staff dose and physical exertion. Following this practice, the hospital took measures to improve the situation in a short time. A shielded trolley for transporting was provided. The dose rate of handlebars at the hands was 0.7 μSv/h and waist was 0.6 μSv/h. As compared with the portable transfer, the dose rate decreased by more than 96%.

This study indicated that radiation staff operated in normal and reasonable protection conditions. The annual cumulative dose was lower than the national standard for occupation personnel who required annual dose limits.

The environmental radiation level of pharmaceutical and diagnostic facility was very low and would not cause harm to the public and non-radiation workers at adjacent workplaces.