External dose assessment from the patients treated by $^{177}$Lu-DOTATATE

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**INTRODUCTION**

One of the most important radionuclides in the field of therapy with nuclear medicine is Lu-177, which is a new and promising tool for control of non-operable metastatic neuroendocrine tumor when it is combined with somatostatin analogues ($^{1}$-$^{3}$). Currently most centers offering $^{177}$Lu-DOTA-tyr$_3$-octreotate treatment perform it only in hospitals; because isolation and hospital admission are among controversial subjects. Conversely, in some countries, patients are discharged within a few hours after treatment when a determined outpatient’s release criterion is achieved according to local regulations (for example 30 $\mu$Sv/h in Turkey and 25 $\mu$Sv/h in Australia) ($^{4}$-$^{5}$). Since, treatment with $^{177}$Lu-DOTA-tyr$_3$-octreotate is costly, additional costs of hospitalization are incurred by many patients. Long-term isolation in the hospital may also cause emotional disturbances to the patient. The use of different types of shield is questionable due to production of specific X-rays of lead following collision of high-energy gamma rays ($^{6}$). However, various reports on methods of reducing the dose received by staff have been published by some national and international organizations ($^{7}$). Therefore, the present study is designed to firstly focus on quantification of the caregiver’s mean dose, and secondly establishment of release criterion for patients treated with $^{177}$Lu-DOTATATE.

**MATERIALS AND METHODS**

The current study was approved by the Ethics Committee of the University (IR.SBMU.MSP.REC.1400.292), and an informed written consent was obtained from all the patients then, it was carried out according to provisions of the Declaration of Helsinki. Inclusion criteria were having over 35 years of age, being diagnosed with metastatic neuroendocrine tumor, and being candidate to be treated with $^{177}$Lu-DOTA-tyr$_3$-octreotate. Mean age of patients was equal to 52.6 years (in a range of: 38-60 years) old. A total of 30 patients undergoing treatment with $^{177}$Lu-DOTA-tyr$_3$-octreotate, were enrolled in the current study from March to August 2019. Patients were admitted in Department of Nuclear Medicine, Shohada-e Tajrish Hospital, Tehran Province, Iran. Infusion of 1,500-2,000 mL of normal...
saline and amino acids, mixture of 5% lysine HCl (50 mg) and 10% L-arginine HCl (50 mg) was carried out for 4 h to reduce radiation exposure of kidneys and subsequent adverse effects. The procedure was started 30 min after administration of 5.5 ± 1.1 GBq (in a range of: 3.7-7.4 GBq) of $^{177}$Lu-DOTA-TATE. All the administered patients were positioned in an isolated room with an area about 30 m². The room included 4 beds located in 4 corners of the room, with about 2 m of distance from each other.

### Dose rate measurement

The dose limit recommended by European guidelines for discharge of patients after iodine-131 therapy was set as the basis for discharge (20 µSv/h at 1 meter) (8-9). Using equation (1), cumulative dose can be estimated, $E$, to a caregiver standing from the patient for an unlimited time, assuming that only physical decay occurs. It was assumed that rate of initial dose is $D_0 = 20$ µSv/h at 1 m of distance, with half-life of $^{177}$Lu, 6.7 days, which is represented by $t_{1/2}$. Following calculation it was found that $E = 4.6$ mSv (10).

$$E = \int_{0}^{\infty} D_0 e^{-\ln(2) \cdot \frac{t}{t_{1/2}}} dt \tag{1}$$

This study was carried out using an ionization chamber (Thermo, FH 40G-L10, made in Germany) calibrated by the secondary standard dosimetry laboratory (SSDL). Energy response of the dosimeter is equal to 30 keV-4.4 MeV and it has the capability to measure dose rate in the range of 10 nSv/h to 100 mSv/h.

Dose rate was measured on chest position at 1 meter.

### Statistical analysis

Data processing and fitting were performed using Microsoft Excel (Microsoft office professional plus, 2013) and SPSS (ver. 16.0, IBM Corp.) softwares were used for statistical analysis. For this purpose, the K-S (Kolmogorov-Smirnov) test was used to investigate normal distribution of data. A value of $p$-value of $\leq0.05$ was assumed as statistically significance. Data were presented as mean and standard deviation unless stated otherwise.

### RESULTS

Mean dose rate at a distance of 1 m from the patients treated with $^{177}$Lu-DOTA-tyr³-octreotate in different times after administration was measured and results are presented in figure 1. As shown in figure 1, dose rate was gradually decreased due to excretion of activity from the body. According to figure 1 for $^{177}$Lu-DOTA-tyr³-octreotate therapy, equation (2) was obtained from the curve, which was fitted to the data.

$$y = 28.442 e^{-0.067x} \tag{2}$$

The $x$ and $y$ indicates the time (h) and dose rate ($\mu$Sv/h), respectively. Mean dose rate at a distance of 1m from the patient, approximately 5 h after the injection was measured as the discharge criterion.

According to the results of current study, mean
dose rate (µSv/GBq.h) at a close distance to a patient was obtained equal to 13.6 (SD=1.2) at 0 m, 8.9 (SD=1.2) at 0.25 m, 4.1(SD=0.6) at 0.5 m, 1.3 (SD=0.2) at 1 m, and 0.6 (SD=0.2) at 2 m.

**Table 3. Mean, minimum and maximum dose (µSv per patient) of the staff during PRRT with 177Lu-DOTATATE, without and with the use of lead shield.**

| Staff                     | Without lead shield | With lead shield |
|---------------------------|---------------------|------------------|
|                           | Min dose per Patient (µSv) | Max dose per patient (µSv) | Mean± SD | Min dose per Patient (µSv) | Max dose per patient (µSv) | Mean± SD |
| Staff in charge of radiopharmaceutical injection | 6.1 | 8.0 | 6.5±0.5 | 5.0 | 6.5 | 5.7±0.8 |
| Staff in charge of imaging | 3.0 | 4.0 | 3.3±0.5 | 2.0 | 3.1 | 2.5±0.4 |
| Physician                 | 2.0 | 3.2 | 2.5±0.4 | 1.8 | 2.5 | 2.1±0.2 |
| Physician                 | 2.2 | 3.0 | 2.7±0.2 | 2.0 | 2.5 | 2.2±0.2 |
| Nurse                     | 6.5 | 8.5 | 7.5±0.5 | 6.8 | 5.0 | 6.3±0.4 |

**Table 4. Estimated annual mean dose to staff in treatment by 177Lu-DOTATATE.**

| Staff                     | Mean annual dose using lead shield (mSv) | Mean annual dose without lead shield (mSv) |
|---------------------------|------------------------------------------|-------------------------------------------|
| Staff in charge of radiopharmaceutical injection | 1.3 | 1.7 |
| Staff in charge of imaging | 0.6 | 0.8 |
| Physician                 | 0.5 | 0.6 |
| Physician                 | 0.5 | 0.6 |
| Nurse                     | 1.4 | 1.8 |

**Dose to caregivers**

Mean dose to 30 caregivers was found to be within a range of 36-390 µSv in 177Lu-DOTA-tyr³-octreotate therapy after infusion of 5.5±1.1 (in a range of: 3.7-7.4) GBq. Mean dose of the first caregiver group was estimated to be 47.3 ± 8.4 µSv (in a range of: 36-60 µSv). Mean dose of the second group was equal to 184 ± 29 µSv (in a range of: 150-220 µSv). The third group had the highest mean dose, by 340.5±29 µSv (in a range of: 300-390 µSv).

**DISCUSSION**

Two important features of clinical treatment are cost-effectiveness and availability of treatment. Many nuclear medicine centers are not able to offer this treatment because of lack of facilities for hospitalization, increasing waiting time for patients to receive 177Lu-DOTA-tyr³-octreotate treatment. Based on results of the current study presented in figure 1, mean dose rate at a distance of 1m from the patient, approximately 5 h after the injection was considered to be lower than the discharge limit. According to figure 1, equation (2) would also be used to achieve release criterion which was defined less than 20 µSv/h at a distance of 1m, and can be considered as a dose limit for discharge from the patients treated with 177Lu-DOTA-tyr³-octreotate. In a similar study on iodine therapy, Ahmadi...
Jeshvaghane et al., (9) showed that the maximum and minimum doses after release were equal to 21 (SD-18) and 11 (SD-4.0) μSv/h at a distance of 1 m from the patients, respectively.

Mean dose for caregiver in three groups was measured below the level recommended by the International Commission on Radiological Protection (ICRP) for each patient [5 mSv] in each treatment period (10). The amount of activity received by the patients and duration of the caregiver’s presence at close distances to the patient are important parameters regarding the caregiver’s mean dose. Abuqbeitah et al., (8) in a study reported the limit of 20 μSv/h for hospital discharge. They estimated a dose rate of 100-200 μSv for caregiver of the patients receiving 177Lu-DOTA-tyr3-octreotate treatment (8). Calais et al., (5) estimated the mean total dose to 25 caring sessions during day of therapy and they reported a dose rate of 10-470 μSv for surrounding people while taking the patient to home within a period up to 5 days after treatment. However, some nuclear medicine clinics prefer to admit patients in hospital to monitor the probable side effects. In a study by Kurt et al., (12), patients were admitted in two centers to be hospitalized for 48 and 72h. The maximum dose to individual members in the public per treatment cycle was ~ 250 ± 55 and ~ 190 ± 36 μSv when the patients were discharged after 48 and 72 h, respectively. But our findings, showed no need for intensive radiation monitoring of caregivers who had a distance more than 1 m from the treated patients. Abuqbeitah et al., (8) showed that the maximum mean dose received by radiopharmaceutical injection was equal to 4 ± 1.9 μSv per patient. Calais et al., (5) reported the mean maximum staff dose (of 33 μSv) for the nurse. Results of the current study showed the maximum mean dose of 7.5 μSv per patient for nurse. Table 5 presents comparison of the results for staff. The nurse’s high mean dose is due to the fact that the nurse has the most contact with the patient during treatment. The difference between results of studies may be due to experience, skills, and promptness of the staff. No measured dose to hospital staff or family members exceeded the limits.

Table 5. Comparison of the results of current study with international results.

|                      | Abuqbeitah et al. (8) μSv Per therapy treatment day with one patient | Calais et al. (5) μSv Per therapy treatment day with four patients | Current study μSv Per therapy treatment day with one patient |
|----------------------|--------------------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------------------------|
| Staff in charge of patient imaging | 3.0 ± 0.5                                                          | 7.0                                                             | 3.4±0.5                                                  |
| radiopharmaceutical  | 4.0 ± 1.9                                                           | 17.0                                                            | 6.5±0.5                                                  |
| physician            | 2.0 ± 0.6                                                           | 9.0                                                             | 2.7±0.2                                                  |
| Physician            | 2.0 ± 0.5                                                           | 8.0                                                             | 2.5±0.4                                                  |
| Nurse                | 5.0 ± 1.1                                                           | 33.0                                                            | 7.5±0.5                                                  |

LIMITATION

The limitation of this study was low number of patients included in the study. Also there were no lead and syringe shields of varying thicknesses for general assessing the effect of protective equipment on the received dose.

CONCLUSION

Results of the present study showed that the dose rate from the injected patients was decreased to lower than the specified threshold of 20 μSv/h at a distance of 1 m after approximately 5 h, which was considered as release criterion for patients treated with 177Lu-DOTA-tyr3-octreotate. Due to the effect of lead shield on reducing staffs mean dose, it is recommended that protective device should be used in all treatment stages. In summary, no measured mean dose to hospital personnel, caregivers, family or member of the public exceeded the annual related dose limits.

Ethical consideration: Provide The current study was approved by the Ethics Committee of the University (IR.SBMUMSP.REC.1400.292).

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