Evaluation of customize syringe carriers box for transferring radionuclide iodine-131 in nuclear medicine

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Abstract. Iodine-131 transfer from radiopharmacy facility to nuclear medicine radioablation isolation room must be carried out by fulfilling the safety and radiation protection rules. One effort is to use a syringe carrier. The purpose of this study was to evaluate the use of a customize carrier syringe for the transfer of Iodine-131 in nuclear medicine. Descriptive study with cross sectional approach on the radiation level of a custom carrier box syringe both surface and 1 m distance. Radioactivity of Iodine-131 used is a multiple of 35 mCi (1,295 GBq) to the maximum radiation level limit. Radiation level measurements were performed on 6 carrier boxes. Radiation level of the ALT 01-03 boxes ≤105 mCi, with Hmax = 0.002176 mSv/transfer, the maximum transfer frequency is 5 times/week, and the maximum capacity is 15 syringes/week. Whereas box AG 01-03 ≤175 mCi with Hmax = 0.02397 mSv/transfer, the maximum transfer frequency is 4 times/week, and the maximum capacity is 20 syringes/week. The customize carrier were evaluated in good condition and can be used to transfer Iodine-131 by considering the maximum capacity of each box. Keywords: syringe carrier, radiopharmacy, radiation level, radiation protection

1. Introduction
Thyroid cancer is the most common endocrine malignancy, with an incidence that has been increasing in United States and many other countries for several decades. Although the death rate from thyroid cancer has risen, most patients with thyroid cancer have lower stages of the disease [1]. The most common form of thyroid cancer is differentiated thyroid cancer, the recurrence rate of which is estimated to be 30% [2]. A rapid expansion in knowledge about the molecular underpinnings of thyroid cancer has led to new diagnostic test and imaging approaches, important clinical trials, and therapeutic advances [3]. Iodine-131 (I-131) therapy is one of the conventional therapeutic approaches in the treatment of patients with differentiated thyroid cancer. I-131 eliminates the residual tumour cells after surgery and prevents cancer from returning [4].

Radioiodine agent is commonly administered by the oral route and excreted by the renal system [5]. After administration of radioiodine, initially I-131 was accumulated in the stomach. Then it was absorbed by the body fluids and reached to the thyroid tissue [6]. The amount of functional cell damage is proportional to the radiation dose absorbed. Only the tissue cells well differentiated thyroid cancer (papillary, follicular, and papillary mixed-follicular) to concentrate Iodine-131 significantly, whereas anaplastic thyroid cancer cannot do the uptake of Iodine-131 [7].
In patients with low risk required a therapeutic dose (radioactivity) I-131 at 1.10 to 3.7 GBq (30-100 mCi) to achieve therapeutic success, whereas in patients with residual tumor tissue which is quite a lot, an aggressive tumor histology, and/or metastases/cancer spread wide, the necessary dose of I-131 larger, ie 3.7 to 7.5 GBq (100-200 mCi)[8, 5].

Thyroid cancer patients who received thyroid ablation therapy with radioactive iodine (I-131) with doses higher than 1.10 GBq should be hospitalized in an isolation room, with the aim to protect the environment from exposure to the radiation coming from the patient's body. Patients were allowed to go home when the maximum activity levels of I-131 in the patient's body is below 1.10 GBq, so the potential acquisition of an effective dose of radiation received by the public and the environment does not exceed 1 mSv/year[3].

The transfer of radioiodine into the isolation room facilities have to do with safety and meet the radiation protection rules. Radiation protection officer must be able to guarantee the safety of radiation, that the distribution channels through which is secure and will not provide exposure to radiation and the acquisition of an effective dose of radiation excess in society (patients, visitors, and workers). One of the efforts to ensure the safety of radiation on the transfer of Iodine-131 is to use a syringe carrier [9].

There are various types and forms of syringe carrier used in the transfer of radionuclide in nuclear medicine, ranging from the production plant to the prepared conventionally (customize). Use of the syringe carrier refers to the provisions of the package used by shippers and producers of radioactive substances.

Radionuclide Iodine-131 is a radioactive substance that kind of low activity in the transport included in category II-yellow piping, with radiation levels on the surface \((\bar{H})\) is greater than 0.005 mSv/h but less than or equal to 0.5 mSv/h \((0.005 \text{ mSv/hr} < \bar{H} \leq 0.5 \text{ mSv/h})\). While the index of transports (IA) is greater than 0 but less than equal to 1 \((0 < \text{IA} \leq 1)\), which means that the measurement of the radiation level \((\bar{H})\) with a distance of 1 meter from the outer surface of the syringe carrier maximum of 0.1 mSv/h \((100 \mu\text{Sv/h})\)[10].

Radiation safety requirements that must be met at the time of the transfer process radionuclide Iodine-131 is the acquisition value of the effective dose of radiation per year may not exceed the dose limiting value defined for the society, which is 0.5 mSv/year. This is because the transfer traversed a community mobility lines/non-radiation workers[11].

The purpose of this study was to evaluate the use of the customize syringe carrier box to transfer radionuclide Iodine-131 in nuclear medicine department of Dr. Kariadi General Hospital Semarang. It is necessary to know and make sure that the syringe carrier box that is used is in conformity with the provisions and to ensure the safety and radiation protection, both for patients, workers, the community and the environment.

2. Method

This study is a descriptive study using measurement data of carrier box radiation levels through cross sectional method. Used 6 pieces of customize syringe carrier box, which consists of a box ALT-01, ALT-02 ALT-03, AG-01, AG-02, and AG-03 (Figure 1 and Figure 2). Box evaluated in daily used to transfer Iodine-131 syringe for each patient with 35 mCi of radioactivity per patient in a 3 ml syringe. Each box is done weighing and measuring the thickness of the layer, then the measured surface radiation level on each side, followed by measurement of radiation levels at a distance of 1 meter.

Syringe containing Iodine-131 radioactivity 35 mCi inserted into the carrier box, then measuring the radiation levels gradually. Addition of Iodine-131 syringe done to limit the radiation level measurements and the acquisition of a maximum radiation dose that can be achieved.
Levels of radiation (\( \bar{H} \) in mSv/h) on the surface of the syringe carrier specified custom box 0.005 < \( \bar{H} \) ≤ 0.5. While the measurement distance of 1 meter maximum of 0.1 mSv/h (100 μSv/h). While limiting the maximum prescribed dose of 0.01 mSv/week.

3. Result

Wall box evaluated composed of a layer of lead which is covered with a layer of cast iron forgings. The wall thickness is measured in total at all levels. Generally, box AG (01-03) is thicker on the side of the 3.2%, 2.3% on the upper side, and 3% on the basic side, compared with the ALT box (01-03). The results of the weight measurements performed boxes, Boxes AG (01-03) has a weight 25% greater than the code ALT (01-03). (Table 1)

### Table 1. Measurement of weights and thickness of Carrier Box

| Box  | Total Weight (Kg) | Layer Thickness (cm) |  |
|------|------------------|----------------------|---|
|      |                  | the side  | Upper side | Basic side |
| ALT-01 | 22.50          | 2.15      | 2.11      | 2.48      |
| ALT-02 | 22.55          | 2.18      | 2.16      | 2.43      |
| ALT-03 | 22.65          | 2.22      | 2.21      | 2.44      |
| AG-01  | 27.65          | 2.24      | 2.18      | 2.52      |
| AG-02  | 27.70          | 2.27      | 2.22      | 2.54      |
| AG-03  | 27.60          | 2.25      | 2.23      | 2.51      |

The maximum radiation level at box surface area measured on the lateral side, the upper side, and on the connection. Box ALT (01-03) generally has a value of maximum radiation level greater than box AG (01-03).

As shown in Table 2, measurement of the radioactivity 35 mCi, the maximum radiation level value box ALT (01-03) 31.08% ± 13.48% larger than the box AG (01-03). The level of radiation in the joint areas having the greatest value when compared with other sides. The radiation level of the largest joint areas, namely the Box ALT-03 with a value of 0.085 mSv/h The radiation level within 1 meter of the greatest in the box ALT-01 were measured 0.0054 mSv/h, while the smallest in the box AG-01 and AG-03 amounted to 0.0031 mSv/h.

Defined duration of carrier box transfer from radiopharmacy to isolation room up to a maximum of 10 minutes (0.17 hours), so it can be calculated radiation dose received at a distance of 1 meter during the transfer.
| Radio activity of I-131 | Box     | Maximum radiation level (mSv/hour) | A distance of 1 meter | Max Radiation Dose (mSv) | Frequency Transfer Per Week |
|-----------------------|---------|-----------------------------------|-----------------------|--------------------------|-----------------------------|
|                       |         | Surface Area                      |                       |                          |                             |
|                       |         | Side | On  | Connection |                       |                           |                             |
| 35 mCi (1295 MBq)     | ALT-01  | 0.045 | 0.065 | 0.078      | 0.0054                  | 0.000918                  | 11                          |
|                       | ALT-02  | 0.048 | 0.062 | 0.081      | 0.0052                  | 0.000884                  | 11                          |
|                       | ALT-03  | 0.051 | 0.058 | 0.085      | 0.0048                  | 0.000816                  | 12                          |
|                       | AG-01   | 0.044 | 0.042 | 0.058      | 0.0031                  | 0.000527                  | 19                          |
|                       | AG-02   | 0.038 | 0.048 | 0.061      | 0.0032                  | 0.000544                  | 18                          |
|                       | AG-03   | 0.042 | 0.04  | 0.062      | 0.0031                  | 0.000527                  | 19                          |
| 70 mCi (2590 MBq)     | ALT-01  | 0.078 | 0.096 | 0.098      | 0.0083                  | 0.001411                  | 7                           |
|                       | ALT-02  | 0.085 | 0.093 | 0.096      | 0.0086                  | 0.001462                  | 7                           |
|                       | ALT-03  | 0.089 | 0.1   | 0.136      | 0.0082                  | 0.001394                  | 7                           |
|                       | AG-01   | 0.068 | 0.087 | 0.092      | 0.0064                  | 0.001088                  | 9                           |
|                       | AG-02   | 0.073 | 0.078 | 0.081      | 0.0062                  | 0.001054                  | 9                           |
|                       | AG-03   | 0.075 | 0.069 | 0.083      | 0.0064                  | 0.001088                  | 9                           |
| 105 mCi (3885 MBq)    | ALT-01  | 0.185 | 0.28  | 0.285      | 0.0125                  | 0.002125                  | 5                           |
|                       | ALT-02  | 0.223 | 0.315 | 0.335      | 0.0128                  | 0.002176                  | 5                           |
|                       | ALT-03  | 0.248 | 0.32  | 0.355      | 0.0121                  | 0.002057                  | 5                           |
|                       | AG-01   | 0.098 | 0.136 | 0.145      | 0.0085                  | 0.001445                  | 7                           |
|                       | AG-02   | 0.084 | 0.142 | 0.158      | 0.0078                  | 0.001326                  | 8                           |
|                       | AG-03   | 0.112 | 0.152 | 0.172      | 0.0085                  | 0.001445                  | 7                           |
| 140 mCi (5180 MBq)    | ALT-01  | 0.3412 | 0.3742 | 0.3881     | 0.0235                  | 0.003995                  | 3                           |
|                       | ALT-02  | 0.4122 | 0.4571 | 0.4616     | 0.0227                  | 0.003859                  | 3                           |
|                       | ALT-03  | 0.4231 | 0.4145 | 0.4749     | 0.0218                  | 0.003706                  | 3                           |
|                       | AG-01   | 0.2177 | 0.2427 | 0.2754     | 0.0115                  | 0.001955                  | 5                           |
|                       | AG-02   | 0.2221 | 0.2754 | 0.2826     | 0.0121                  | 0.002057                  | 5                           |
|                       | AG-03   | 0.2272 | 0.2582 | 0.2789     | 0.0118                  | 0.002006                  | 5                           |
| 175 mCi (6475 MBq)    | ALT-01  | 0.4726 | 0.4872 | 0.4975     | 0.0375                  | 0.006375                  | 2                           |
|                       | ALT-02  | 0.4518 | 0.4884 | 0.4917     | 0.0387                  | 0.006579                  | 2                           |
|                       | ALT-03  | 0.4624 | 0.4761 | 0.4996     | 0.035                   | 0.00595                   | 2                           |
|                       | AG-01   | 0.3418 | 0.2894 | 0.3152     | 0.0134                  | 0.002278                  | 4                           |
|                       | AG-02   | 0.3451 | 0.3421 | 0.3527     | 0.0141                  | 0.002397                  | 4                           |
|                       | AG-03   | 0.3342 | 0.3462 | 0.3521     | 0.0138                  | 0.002346                  | 4                           |
| 210 mCi (7770 MBq)    | ALT-01  | 0.5771 | 0.5875 | 0.5953     | 0.0457                  | 0.007769                  | 1                           |
|                       | ALT-02  | 0.5758 | 0.5875 | 0.5951     | 0.0471                  | 0.008007                  | 1                           |
|                       | ALT-03  | 0.5674 | 0.5912 | 0.5931     | 0.0465                  | 0.007905                  | 1                           |
|                       | AG-01   | 0.3768 | 0.4218 | 0.4841     | 0.0215                  | 0.003655                  | 3                           |
|                       | AG-02   | 0.3788 | 0.4415 | 0.4875     | 0.0227                  | 0.003859                  | 3                           |
|                       | AG-03   | 0.3784 | 0.4127 | 0.4984     | 0.0232                  | 0.003944                  | 3                           |
Radiation dose calculations (within 1 meter) conducted in accordance with the formula:

\[ H = \bar{H} \times t \]  

(1)

\( H \) is the radiation dose, \( \bar{H} \) is the radiation level at a distance of 1 meter, and \( t \) is the time of transfer.

The radiation dose at the time of the transfer of 35 mCi of I-131 is the smallest in the box AG-01 and AG-03 0.000527 mSv, whereas the largest 0.000918 mSv at the box ALT-01.

Constrain dose prescribed for the public is 0.5 mSv/year, or 0.01 mSv/week (1 year counted 50 weeks), so it can be calculated frequency or maximum transfer amount that can be done in one week. Box ALT-01 and ALT-02 can be used to transfer a maximum of 11 times in one week, while the ALT box-03 12 times per week. Box AG (01-03) can be used to transfer more 64.8% compared with the ALT box (01-03).

Measurements on Iodine-131 radioactivity 70 mCi, a decline in the number of transfer/week by 48% in box ALT (01-03), while in the box AG (01-03) also decreased 52%. The ratio of the measurement value of the greatest radiation levels obtained in the I-131 radioactivity of 105 mCi, where box ALT (01-03) is greater 113% ± 9% than the box AG (01-03). Box ALT (01-03) can be used to transfer up to 5 times/week with a maximum radiation dose value (Hmax) 0.002176 mSv/transfer. Once the transfer can accommodate I-131 105 mCi divided into 3 syringe @ 35 mCi, and is therefore calculated transfer capacity of up to 15 syringes/week.

Box ALT (01-03) decreased transfer capacity by 20% in the measurement of I-131 radioactivity of 140 mCi. Transfer capacity on the box AG (01-03) of 20 syringes/week with transfer frequency 5 times/week.

Iodine-131 measurements on the radioactivity of 175 mCi, transfer at the box AG (01-03) had no change, which is 20 syringe/week. However, the transfer frequency decreased to 4 times/week. Iodine-131 measurements on the radioactivity of 210 mCi yield maximum radiation dose values the greatest, either on the box ALT (01-03) and box AG (01-03).

4. Discussion

Carrier box that is used can be grouped into two based on the dimension sizes, the box ALT and AG. Box with code AG as a whole better able to withstand radiation when compared with the ALT box. One contributing factor is the thickness of the wall of a larger Ag Box. Lead thicker layer can withstand gamma radiation penetrating power generated by the Iodine-131 with better.

The results of measurements of radiation levels on the surface area of each box indicates the value is quite diverse. Area connection has a radiation level measurement value is greater than the surface area of the other (p> 0.05). The level of radiation in the area of the connection can be caused due to the area is a meeting point of two layers of lead, thus allowing a gap space to pass the emission of gamma radiation. To avoid excessive radiation exposure of transfer radioiodine, should the position of the connection box is placed leading to the clerk of radiation workers who have a threshold limit value higher doses than people.

Constrain doses prescribed for people in the neighborhood of Dr. Kariadi Hospital is 0.5 mSv/year, or 0.001 mSv / week. Delimiter assigned dose is half of people dose constrain per year (1 mSv/year) refers to the dose of BAPETEN guide. This reference are used to determine the maximum capacity of each box. Box capacity is determined by the ability of the box to accommodate Iodine-131 and withstand radiation doses to avoid exceeding the limit allowed. Iodine-131 is used in the form of liquid in the syringe with the respective radioactivity 35 mCi/syringe, referring to guide the ablation therapeutic doses of thyroid cancer patients with low doses.

Customize syringe boxes which evaluated overall in good condition and can be used to transfer Iodine-131 by taking into account the maximum capacity of each box. Box 01-03 ALT effectively used for the transfer of Iodine-131 to 105 mCi divided into 3 syringes in one transfer activities. While the 01-03 AG Boxes have better effectiveness than 01-03 ALT box, which can be used up to 175 mCi divided into 5 syringes in one transfer. Effectiveness and a maximum capacity of 01-03 AG box better
than 01-03 ALT box because a wall thickness greater Box Ag. Larger dimensional space of AG box contributing to provide more space to accommodate the syringe.

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