THEORETICAL CALCULATION OF EFFECTIVE DOSE OF RADIOPHARMACEUTICALS FOR PREGNANT WOMEN IN NUCLEAR MEDICINE

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Diagnostic or treatment using radiopharmaceuticals are rarely prescribed for pregnant women because of the risks of radiation effect to the fetus. However, in extremely rare clinical conditions or in case of failed pregnancy test , pregnant women may be exposed to radiation. Henceforth, in addition to the fetus, assessment of an effective dose received by a patient is essential. This report presents a method of calculating effective dose of 30 radiopharmaceuticals for the internal organs with the longest radiation resident time. The calculations are for Vietnamese pregnant women, using the kinetic information of radiopharmaceuticals studied by Russell and the average organ weight of Vietnamese people collected by IAEA, using OLINDA/EXM software.

Keywords: Pregnant women, effective dose, pharmaceutical, residence time, OLINDA/EXM.

I. INTRODUCTION

Although radiopharmaceuticals have been useful in diagnosis and treatment, they still bring risks to patients, especially to pregnant women. Energy from radiopharmaceutical causes severe damage to the fetus, depending on the baby's gestational age and the dose received by the fetus. During the first fourteen days after conception, radiation can cause embryonic death [1]. In the next stage, especially when organs are developping, radiation can cause deformities, premature death, and intellectual deficiency in babies [2]. Using hospital records, Doll et al concluded that “radiation doses even in the order of 10 mSv received by the fetus in utero lead to an increase in the risk of getting childhood cancer“ [1]. According to GoncanG. Burial et al, “In the 16- to 25-week stage, the average IQ loss is approximately 13-21 points per Gy (per 100 rads) at doses above 0.7 Gy (70 rads)“ [2]. Due to the dangers of exposure to radiation, pregnant women are often not assigned to diagnosis or treatment with radiopharmaceuticals. For that reason, dose calculation for pregnant patients has received much less emphasis.

However, there are cases that pregnant women are irradiated due to the necessity of their clinical conditions (although it is extremely rare), or when the pregnancy test failed. So consideration for diagnostic benefits and radiation risks is necessary [2, 3]. When used

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appropriately, the benefits of nuclear imaging procedures usually outweigh the minimal risks associated with small amount of radiation even in pregnant patients [2]. Beside of the fetus, calculation of effective doses for other internal organs of a pregnant patient is a essential task.

To calculate an effective dose, in addition to the anatomical information of a patient, information about the kinetics of radiopharmaceutical in the human body is required. However, the information in pregnant women is scarce, most of what is known came from animal studies, combined with the best available kinetic data for many pharmaceutical products[4]. When injected into the body, the resident time of a pharmaceutical differs in different organs [4]. The longer the residence time is, the higher the risk to the organ.

This report presents a method of calculating effective doses of 30 radiopharmaceuticals for internal organs which have the longest resident times, applied to Vietnamese pregnant women. Calculation is done by MIRD schema [5] and OLINDA/EXM software [6], based on the average data of Vietnamese women according to the IAEA research [7] and information of the kinetics of radiopharmaceutical in pregnant women studied by Russell et al [4].

II. METHODS

1. Study

In this section, the method of calculating effective doses for internal organs of Vietnamese pregnant women is presented. Calculation is applied to internal organs which have the longest residence times.

2. Materials and methods

The MIRD schema

Based on the source and target models, the MIRD schema [5] is a simple and widely accepted method of dose calculation. Accordingly, the absorbed dose for a target is calculated as follows:

$$\frac{\overline{D}_{target}}{A_0} = \sum \tau_{source} \times S_{source \to target}$$

And:

$$S_{source \to target} = \sum_i \Delta_i \times \frac{\phi_i}{m_{target}}$$

where

$\overline{D}_{target}$: Mean absorbed dose for the target organ;

A_0: Administered activity for the pregnant woman;

τ: Resident time (the cumulated activity in source region per unit administered activity unit);

$S_{source \to target}$: The mean absorbed dose per cumulated activity unit;

Δ_i: The mean energy of radiation type i emitted per nuclear transformation;

ϕ_i: The absorbed fraction for radiation i;

m_{target}: The mass of target volume.

The effective dose will be inferred from absorbed dose by multiplying the absorbed dose with radiation and tissue weighting factors (ICRP publications 60 and 103 [8]).

Calculating effective dose for pregnant woman using OLINDA/EXM software

Using the MIRD schema, OLINDA allows users to perform the dose calculation with several steps via a simple interface [6]. Proceed is as follows:

- Choose the nuclide
- Choose the phantom
- Enter the kinetic information of the radiopharmaceutical

OLINDA 1.0 provides 10 types of phantoms. The pregnant phantom is chosen. To correct the calculations for Vietnamese woman, it is necessary to select the "modify input data" function and adjust the mass of the internal

organs of Vietnam phantom. The mean organ weight of Vietnamese female is based on the research of IAEA by autopsy. The individuals selected were those who died suddenly, with no pathology in any organ such as inflammation, anemia, tumors (all of which tend to cause the changes in their organ weight) [7]. The kinetic information of the radiopharmaceutical is entered as the residence time in the internal organs.

3. Ethics

Following the research ethics, the study has no effect on patients' health.

III. RESULTS

From the average internal organ weight of Vietnamese female, the effective dose calculated for the organs which have the longest resident time is presented in Table 1.

Table 1. Effective dose per administered activity unit for the organs which have the longest residence time, applied for Vietnamese pregnant women

Radiopharmaceuticals	Organ with the longest resident time	The resident time (h)	Effective dose per administered activity unit (mSv/MBq)
Co-57 Vitamin B-12 Normal-Flushing	Liver	1.71E3	1.40E0
Co-57 Vitamin B-12 Normal-No Flushing	Liver	2.56E3	2.10E0
Co-57 Vitamin B-12 PA-Flushing	Liver	2.20E2	1.81E-1
Co-57 Vitamin B-12 PA-No Flushing	Liver	3.23E2	2.66E-1
Co-58 Vitamin B-12 Normal-Flushing	Liver	6.03E2	2.29E0
Co-58 Vitamin B-12 Normal-No Flushing	Liver	9.04E2	3.43E0
Co-58 Vitamin B-12 PA-Flushing	Liver	7.80E1	3.01E-1
Co-58 Vitamin B-12 PA-No Flushing	Liver	1.14E2	4.38E-1
I-123 IMP	Lungs	1.46E0	7.92E-3
I-123 MIBG	Liver	3.45E0	4.82E-3
I-125 HSA	Lungs	2.07E1	8.69E-2
I-125 Sodium Iodide	Thyroid	2.74E2	5.72E0
I-131 HSA	Lungs	1.89E1	4.98E-1
I-131 MAA	Liver	2.60E1	4.44E-1
I-131 MIBG	Liver	9.98E0	5.54E-2
I-131 Sodium Iodide	Thyroid	6.10E1	1.02E1
In-111 Pentetreotide	Kidneys	4.66E0	1.75E-2
In-111 Platelets	Spleen	2.18E1	1.59E-1
In-111 White Blood Cells	Red marrow	3.92E1	7.83E-2

Radiopharmaceuticals	Organ with the longest resident time	The resident time (h)	Effective dose per administered activity unit (mSv/MBq)
Tc-99m HMPAO	Liver	9.38E-1	9.23E-4
Tc-99m Human Serum Albumin	Lungs	8.47E-1	2.82E-3
Tc-99m MAA	Lungs	4.89E0	1.25E-2
Tc-99m RBC-in vitro	Lungs	5.97E-1	2.67E-3
Tc-99m Sulfur Colloid-Liver Disease	Liver	2.78E0	2.23E-3
Tc-99m Sulfur Colloid-normal	Liver	7.37E0	5.63E-3
Tc-99m White Blood Cells	Red marrow	3.47E0	3.25E-3
Tl-201 Chloride	Kidneys	4.02E0	2.23E-3
Xe-133 5 minute rebreathing 10 liter spirometer volume	Lungs	1.3E-2	2.15E-4
Xe-133 5 minute rebreathing 5 liter spirometer volume	Lungs	2.2E-2	3.64E-4
Xe-133 5 minute rebreathing 7.5 liter spirometer volume	Lungs	1.7E-2	2.79E-4

IV. DISCUSSION

The highest effective doses are “I-131 Sodium Iodide” in the thyroid (1.02E1 mSv/MBq), “I-125 Sodium Iodide” in the thyroid (5.72E0 mSv/MBq) and “Co-58 Vitamin B-12 Normal-No Flushing” in liver (3.43E0 mSv/MBq). The lowest ones are “Xe-133 5 minute rebreathing 10-litre spirometer volume” (2.15E-4 mSv/MBq), “Xe-133 5 minute rebreathing 7.5-litre spirometer volume” (2.79E-4 mSv/MBq) and Xe-133 5 minute rebreathing 5-litre spirometer volume” (3.64E-4 mSv/MBq) also in the lungs.

However, in many cases, nothing is known about the placental crossover of the compound. These calculations are only for maternal organs, regardless of the contribution of the dose from the placenta and the fetus. Therefore, this calculation will underestimate the dose that the organs absorb, especially when the amount of radiopharmaceutical transported into the placenta is large.

By default, OLINDA calculates the dose for the phantom. With the average organ weight of Vietnamese female, surveyed by IAEA, it can adjust the doses for Vietnamese people. Nevertheless, among Vietnamese individuals, anatomical characteristics are also different. If information about organ masses of a specific patient is known, the optimal calculation results can be obtained.

V. CONCLUSION

When a pregnant woman has to exposed to Ionizing radiation, the calculation of effective doses for the organs which have a long residence time is necessary. With OLINDA/EXM software, the calculation of dose distribution for internal organs can be done quickly and simply, based on source and target models of the MIRD schema.

The effective doses for Vietnamese female are based on the kinetic information of radiopharmaceuticals on pregnant human researched by Russell et al and internal organ weight of Vietnamese people studied by IAEA. The organs which have the highest doses are thyroid (I-131 Sodium Iodide and I-125 Sodium Iodide) and liver (Co-58 Vitamin B-12 Normal-No Flushing). The cloud on the horizon is the real doses received by these organs may be higher than what are calculated. In case nothing is known about the placental crossover of pharmaceutical, the calculation may underestimate the effective dose for the organs.

The internal organ weight of Vietnamese in this report was investigated in 1988-1993. There have been many changes today. Therefore, the above calculation results are for reference only. If the information about internal organ weight as well as the remainder of the body of a patient is known, it can be entered to the OLINDA software to get a more optimal dose to assess the risks for the patient.

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