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Pediatric diagnostic nuclear medicine studies and administered radiopharmaceutical activities at a tertiary hospital: A contrast with activities based on the European association of nuclear medicine dosage card (version 5.7.2016)

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RESEARCH

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ABSTRACT

Background

Pediatric diagnostic nuclear medicine studies provides information regarding the physiological and the molecular processes hence they may play a significant role in diagnosis of child ailments. However, quantification of appropriate pediatric activities may present challenges.

Aims

To investigate the types of pediatric diagnostic nuclear medicine studies and administered radiopharmaceuticals activities (ARAs) at tertiary hospital (TH) and to determine whether they adhered to the European Association of Nuclear Medicine (EANM) Dosage card (version 5.7.2016).

Methods

Archived pediatric patients' data (weight, age, type of diagnostic nuclear medicine study and corresponding ARAs), were documented for all studies undertaken from 2012-2015. For each diagnostic nuclear medicine study conducted, the corresponding ARAs were calculated using the EANM Dosage card (version 5.7.2016). ARAs per kilogram were then calculated for each patient using both dosing guidelines and then compared.

Results

The most commonly conducted pediatric diagnostic nuclear medicine studies included bone scans, thyroid scans, renal scans, hepatobiliary iminodiacetic acid (HIDA) scans, meta-iodobenzylguanidine (MIBG) scans and gastroesophageal reflux scans.

The mean ARAs per kilogram were bone scans (57.7 vs 9.6 MBq/kg), thyroid scans (7.0 vs 1.5 MBq/kg), renal scans (13.9 vs 3.2 MBq/kg), ^{99m}T-HIDA scans (13.7 vs 5.8 MBq/kg), MIBG scans (15.5 vs 9.8 MBq/kg), gastroesophageal reflux scans (2.1 vs 1.1 MBq/kg), following the TH guidelines and the EANM Dosage card respectively. The EANM Dosage Card (version 5.7.2016) guaranteed low variability of ARAs compared to the TH guidelines.

Conclusion

The mean ARAs per kilogram based on the EANM Dosage card (version 5.7.2016) were lower than those calculated using the TH guidelines.

Key Words

Pediatric nuclear medicine, radiopharmaceuticals, administered activities

What this study adds:

1. What is known about this subject?

Children are more sensitive to radiation due to their small growing organs.

2. What new information is offered in this study?

The use of the EANM Dosage Card (version 5.7.2016) as dosing guidelines reduces paediatric doses.

3. What are the implications for research, policy, or practice?

The EANM Dosage Card (version 5.7.2016) should be used as a dosing guideline in order to reduce pediatric doses.

Background

Pediatric diagnostic nuclear medicine studies provide vital clinical information needed for the care of children.[1] However, there is concern that the radiopharmaceuticals used to obtain diagnostic information uses ionizing radiation.[1,2] Ionizing radiation is well-established as carcinogenic.[2] This is further complicated by the fact that children have rapidly growing cells which are more sensitive to ionizing radiation compared to adults. Furthermore, their bones take up radiopharmaceuticals more avidly when compared to adults. Again, children have a longer life span to manifest the stochastic effects of ionizing radiation.[3,4] In this regard, clinicians must make every effort to use pediatric dosing guidelines that guarantee administration of lowest possible radiopharmaceutical activities while achieving good image quality. Among such guidelines is the European Association of Nuclear Medicine (EANM) Dosage Card (version 5.7.2016).[5]

The origin of the EANM Dosage Card can be traced to a report by Piepsz et al.,[6] who presented a schedule of scaling adult to pediatric activity.

A further study by Jacobs et al.,[7] focused on determining whether the scaling factors resulted in weight-independent count rates or weight independent effective dose. This study culminated with the introduction of three clusters A, B and C that represented weight variation. Cluster A represented renal imaging agents while cluster C represented thyroid imaging using radioiodine and cluster B comprised of the remaining radiopharmaceuticals.[7]

The clustering approach was latter used by Lassmann et al.,[5] to develop the EANM Dosage Card. They placed radiopharmaceuticals in three clusters A, B and C. Each radiopharmaceutical was characterized by a corresponding minimum activity and a baseline activity that was scaled down by body weight to give the recommended pediatric radiopharmaceutical activity (dose). For the first time, the pediatric radiopharmaceutical activities were not related to adult reference levels.[5,7] The minimum recommended activity for the particular radiopharmaceutical takes into account the sensitivity of the equipment, the type of examination and the duration of examination.[3,8]

The minimum activity can be defined as the activity below which the study will not produce adequate results.[4] In 2007, the EANM dosage Card saw the addition of iron (^{8}Fe) notes.[9] A latter update of the EANM Dosage Card followed in 2016 resulted in the introduction EANM Dosage Card (version 5.7.2016).[10]

The purpose of this study was to investigate the types of pediatric diagnostic nuclear medicine studies and administered pediatric radiopharmaceuticals activities (ARAs) at tertiary hospital (TH) and to determine whether they adhered to the EANM Dosage Card (version 5.7.2016).

3. Method

Upon approval of the study, the archived pediatric patients' files were solicited from the Nuclear Medicine (NM) department to obtain data that included weight, age, the name of diagnostic nuclear medicine study conducted, quantities for ARAs for each child and the dosing guidelines used. Only data for the children attended during the period 2012-2015 was considered. Using the collected data, ARAs were calculated for each child using the EANM Dosage card (version 5.7.2016) using Equation 1;[10]

$$ARA\ [MBq] = Baseline\ Activity \times Multiple \qquad [1]$$

Where, ARA is the administered radiopharmaceutical activity, the baseline activity corresponds to the radiopharmaceutical class,[10] and the multiple being specific for the specific radiopharmaceutical.

In cases where the calculated ARA based on the EANM Dosage Card (version 5.7.2016) was lower than the minimum activity prescribed for the study, then the minimum prescribed value for that study was used.[10] Jacobs et al.,[7] established that the use of a minimum activity guarantees good image quality since it takes into account the limitations of the gamma camera and positron emission tomography scanners.

A Statistical Package for Social Sciences (SPSS) software was used to calculate the range and the means of ARAs per kilogram for each diagnostic nuclear medicine study based on the TH guidelines and the EANM Dosage Card (version 5.7.2016).

4. Results

The study established that the TH pediatric dosing guidelines were based on either the Webster's or Body Surface Area (BSA) formulas.[11] However, the choice between the two depended on the physician's preference. A total of ninety-five diagnostic Nuclear Medicine (NM) studies were conducted during the study period (2012-2015). These included bone scans (9%), thyroid scans (3%), renal scans 45%, HIDA scans (28%), MIBG scans (28%) and gastroesophageal reflux scans (8%), see Figure 1. Of the ninety-five studies only sixty met the selection criteria (having all the required patient data). The remaining thirty-five studies were excluded because either patient weight was missing or altered. During the study period, there were no Flourine-18 fluoro-deoxyglucose (^{18}F FDG) studies conducted.

Figure 1 Pediatric nuclear medicine studies conducted in the selected tertiary hospital.

The diagnostic NM studies conducted during the study period are presented in Table 1. Also, shown in Table 1 are the range and mean values of administered radiopharmaceutical activities per kilogram (MBq/kg) of commonly performed pediatric diagnostic nuclear medicine studies at the selected TH versus corresponding values calculated using EANM Dosage Card (version 5.7. 2016)

Table 1 Range and mean values of administered radiopharmaceutical activities per kilogram (MBq/kg) of commonly performed pediatric nuclear medicine studies at a selected TH versus corresponding calculated values based on the EANM Dosage Card (version 5.7. 2016)

An analysis of the range Table 1 shows large variability among pediatric ARAs calculated using the TH guidelines compared to those calculated using the EANM Dosage Card (version 5.7. 2016). The low variations for the data sets calculated can be attributed to the fact that EANM Dosage Card (version 5.7. 2016) has been standardized. It can also be observed from Table 1 that the mean values of ARAs per kilogram calculated using the TH guidelines were much higher when compared to those calculated using the EANM Dosage Card (version 5.7. 2016). Figure 2 depicts the differences.

Figure 2 Pediatric administered radiopharmaceutical activities based on a Tertiary Hospital guidelines versus values based on the European Association of Nuclear Medicine Dosage Card (version 5.7. 2016).

From Figure 2, it can be observed that for all the pediatric diagnostic nuclear medicine studies conducted at the TH, children were administered with very high activities compared to values based on the EANM Dosage Card (version 5.7. 2016).

Discussion

Dosing pediatric patients requires a balance between benefit and risk,[2] in order to minimize stochastic effects,[12] since ionizing radiation has cumulative effect.[13]

In this study we compared the efficacy of the TH guidelines based on two formulas (Webster's and BSA),[6] and the EANM Dosage Card (version 5.7. 2016),[10] in terms of the quantity of ARA per kilogram for each pediatric patients. The use of EANM Dosage Card (version 5.7. 2016) resulted in lower pediatric ARAs when compared to the use of the TH guidelines (Figure 2). One of the strengths of the EANM Dosage Card (version 5.7. 2016) is that it has since been standardized and harmonized with the North American Conscious guideless by a group of experts resulting in reduction of pediatric doses.[14-16] Another significant feature of the EANM Dosage Card (version 5.7. 2016) is its contribution to reduction of the variability of ARAs per kilogram (Table 1), this is depicted by the low range established. A notable case being that of bone scans where the range was 0.6 MBq/kg when using the EANM Dosage Card (version 5.7. 2016) compared to 44 MBq/kg, obtained using the TH guidelines. The latter shows a large variability of ARAs for the same diagnostic nuclear medicine study, an indication of lack of standardization. Another advantage of the EANM Dosage Card (version 5.7. 2016) is that it prescribes the minimum activities that take into account the limitations of the imaging system. The use of minimum activity guarantees good quality images without burdening the pediatric patients with much radiation. On the other hand, the TH guidelines were found to burden pediatric patients with high radiation dose (Figure 2).

Conclusion

The adoption of the EANM Dosage Card (version 5.7.2016) is recommended for the TH so as to reduce the ARAs per kilogram for children undergoing diagnostic nuclear medicine studies.

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PEER REVIEW

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CONFLICTS OF INTEREST

The author declares that he has no competing interests.

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ETHICS COMMITTEE APPROVAL

The study was approved by Sefako Makgatho Health Sciences Research Ethics Committee SMUREC/M/80/2017: PG

Figures and Tables

Table 1: The Range and mean values of administered radiopharmaceutical activities per kilogram diagnostic nuclear medicine study

	Pediatric Nuclear Medicine Study											
	Bone Scans ^{99m}**Tc MDP**		**HIDA scans** ^{99m}**Tc DISIDA**		**Renal Scans** ^{99m}**Tc MAG3** (without flow study)		**Thyroid Scans** ^{99m}**Tc pertechnetate**		**MIBG scans** ^{123}**I-MIBG**		**Gastroesophageal reflux scans** ^{99m}**Tc - Tin colloid**	
Pediatric dosing guideline	Range (MBq/kg)	Mean (MBq/kg	Range (MBq/kg	Mean (MBq/kg)	Range (MBq/kg)	Mean (MBq/kg	Range (MBq/kg)	Mean (MBq/kg)	Range (MBq/kg)	Mean (MBq/kg)	Range (MBq/kg)	Mean (MBq/kg)
TH	44	57.7	13.8	13.7	16	13.9	6.1	7.0	15.6	15.5	3.0	2.1
EANM	0.6	9.6	7.7	5.8	2.0	3.2	0.1	1.5	8.9	9.8	1.3	1.1

^{99m}Tc MDP -technetium 99m-methyl diphosphonate
^{99m}Tc DISIDA - technetium 99 m diisopropyliminodiacetic acids,
HIDA - hepatobiliary iminodiacetic acid
^{99m}Tc MAG3 – technetium 99m mercaptoacetyltriglycine
^{123}I-MIBG - Iodine-123-metaiodobenzylguanidine
^{99m}Tc - Tin colloid – technetium 99m tin colloid
^{99m}Tc pertechnetate - technetium 99m pertechnetate

Figure 1: Pediatric nuclear medicine studies conducted in the selected tertiary hospital.

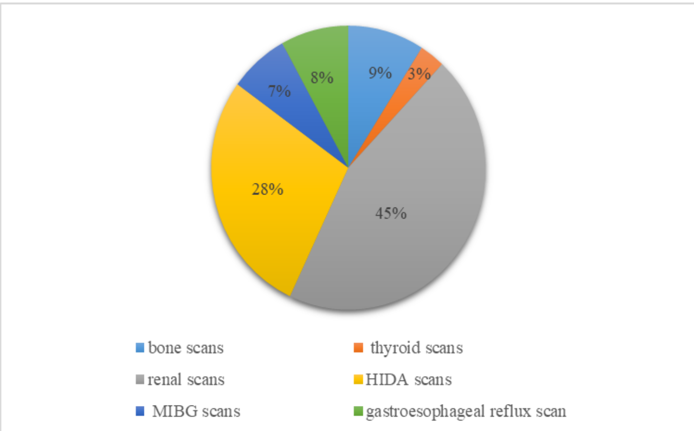

Figure 2: Pediatric administered radiopharmaceutical activities based on Tertiary Hospital guidelines versus values based on the European association of nuclear medicine dosage card (version 5.7. 2016).