

Paediatric radiopharmaceutical administration: harmonization of the 2007 EANM paediatric dosage card (version 1.5.2008) and the 2010 North American consensus guidelines

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Abstract In 2008 the EANM published their paediatric dosage card. In 2011 the North American consensus guidelines recommended a set of administered activities for paediatric nuclear medicine. During the EANM congress in 2012 a working group of the EANM and the SNMMI met to study the possibility of harmonizing these guidelines. The purpose of this work was to identify differences between these guidelines and suggest changes in both guidelines to achieve a level of harmonization. In addition, the new version of the EANM paediatric dosage card (version 01.02.2014) is provided.

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Introduction

In 2006 the EANM published a new version of their paediatric dosage card for 39 radiopharmaceuticals [1]. In 2008 an amendment with respect to the use of FDG was introduced [2]. In addition, an online dosage calculator was released by the EANM (http://www.eanm.org/publications/dosage_calculator.php?navId=285). In 2012, as an offshoot of a recent project of the European Union (www.peddose.net), an application for iPhone/iPad (iAPP) was created for facilitating the calculation of administered activities (<http://itunes.apple.com/us/app/peddose/id492680472?mt=8>).¹ In 2011 the North American consensus guidelines also recommended a set of administered activities for paediatric nuclear medicine [3].

During the 2012 EANM congress a working group comprising members of both the EANM and SNMMI met to study the possibility of harmonizing the guidelines published by the two societies. For most radiopharmaceuticals, the North American consensus guidelines suggest that the EANM dosage card may also be used. The purpose of this work was to identify differences between these guidelines and suggest changes in both guidelines to achieve a level of harmonization between the two. As soon as there is consensus on how to harmonize the dosage recommendations, a new version of the EANM dosage card will be released, and the EANM webpage

¹ In the following text the term “EANM dosage card” refers to the EANM paediatric dosage card version 1.5.2008.

and the iAPP will be updated. Concurrently, the North American consensus guidelines will be updated accordingly. A version of the new EANM dosage card is shown in Fig. 1. The corresponding changes are highlighted in orange in Fig. 1 and indicated in Tables 1–7 in the section “Suggested changes”.

With regard to the administered activities of ^{18}F radiopharmaceuticals, there is a difference between theoretical results [4] and a study in human subjects of various ages [5]. As more data are collected, it is likely that somewhat lower administered activities will be defined for ^{18}F radiopharmaceuticals for use in infants and smaller children. If, in the very near future, for ^{18}F -sodium fluoride and ^{18}F -FDG even smaller administered activities are proposed for use in smaller patients (i.e. infants, preschool children and probably children up to 8 or 10 years of age) as seems likely, revisions of the EANM dosage card and the 2010 North American consensus guidelines will be considered.

Suggested changes

Renal cortical scan

Remark As has been stated in a recent review on biokinetics and dosimetry of commonly used radiopharmaceuticals in diagnostic nuclear medicine [6], the data on $^{99\text{m}}\text{Tc}$ -dimercaptosuccinic acid (DMSA) were collected more than 30 years ago and have never been updated since. This is of particular importance since the data on the effective dose given in ICRP publication 80 [7] rely on these datasets. Therefore, there might be a larger error associated with the effective dose as compared to other radiopharmaceuticals.

In 2011, Sgouros et al. described an approach for balancing diagnostic image quality with cancer risk with the use of $^{99\text{m}}\text{Tc}$ -DMSA [8]. The authors used pharmacokinetic modelling and a paediatric series of nonuniform phantoms to simulate $^{99\text{m}}\text{Tc}$ -DMSA SPECT images. Images were generated for several different administered activities and for several lesions with different target-to-background activity concentration ratios; the phantoms were also used to calculate organ S values for $^{99\text{m}}\text{Tc}$. An analysis of the diagnostic quality of images with different modelled administered activities (i.e. count densities) for anthropomorphic reference phantoms representing two 10-year-old girls of the same weight but different body morphometry was performed. Using BEIR VII age- and sex-specific risk factors, the authors converted absorbed doses to excess risk of cancer incidence and used these to directly assess the risk of the procedure. This study illustrates the implementation of a rigorous approach for balancing the benefits of adequate image quality against the radiation risks and also demonstrates that weight-based adjustment of the administered activity

Recommended Amounts in MBq

Radiopharmaceutical	Class	Baseline Activity (for calculation purposes only) MBq	Minimum Recommended Activity ¹ MBq
^{123}I (Thyroid)	C	0.6	3
^{123}I Amphetamine (Brain)	B	13.0	18
^{123}I HIPURAN (Abnormal renal function)	B	5.3	10
^{123}I HIPURAN (Normal renal function)	A	12.8	10
^{123}I mIBG	B	28.0	37
^{131}I mIBG	B	5.6	35
^{18}F FDG-PET torso	B	25.9	26
^{18}F FDG-PET brain	B	14.0	14
^{18}F Sodium fluoride	B	10.5	14
^{67}Ga Citrate	B	5.6	10
$^{99\text{m}}\text{Tc}$ ALBUMIN (Cardiac)	B	56.0	80
$^{99\text{m}}\text{Tc}$ COLLOID (Gastric Reflux)	B	2.8	10
$^{99\text{m}}\text{Tc}$ COLLOID (Liver/Spleen)	B	5.6	15
$^{99\text{m}}\text{Tc}$ COLLOID (Marrow)	B	21.0	20
$^{99\text{m}}\text{Tc}$ DMSA	B	6.8	18.5
$^{99\text{m}}\text{Tc}$ DTPA (Abnormal renal function)	B	14.0	20
$^{99\text{m}}\text{Tc}$ DTPA (Normal renal function)	A	34.0	20
$^{99\text{m}}\text{Tc}$ ECD (Brain perfusion)	B	32.0	110
$^{99\text{m}}\text{Tc}$ HMPAO (Brain)	B	51.8	100
$^{99\text{m}}\text{Tc}$ HMPAO (WBC)	B	35.0	40
$^{99\text{m}}\text{Tc}$ IDA (Biliary)	B	10.5	20
$^{99\text{m}}\text{Tc}$ MAA / Microspheres	B	5.6	10
$^{99\text{m}}\text{Tc}$ MAG3	A	11.9	15
$^{99\text{m}}\text{Tc}$ MDP	B	35.0	40
$^{99\text{m}}\text{Tc}$ Perchnetate (Cystography)	B	1.4	20
$^{99\text{m}}\text{Tc}$ Perchnetate (Ectopic Gastric Mucosa)	B	10.5	20
$^{99\text{m}}\text{Tc}$ Perchnetate (Cardiac First Pass)	B	35.0	80
$^{99\text{m}}\text{Tc}$ Perchnetate (Thyroid)	B	5.6	10
$^{99\text{m}}\text{Tc}$ RBC (Blood Pool)	B	56.0	80
$^{99\text{m}}\text{Tc}$ SestaMIBI/Tetrofosmin (Cancer seeking agent)	B	63.0	80
$^{99\text{m}}\text{Tc}$ SestaMIBI/Tetrofosmin ² (Cardiac rest scan 2-day protocol min)	B	42.0	80
$^{99\text{m}}\text{Tc}$ SestaMIBI/Tetrofosmin ² (Cardiac rest scan 2-day protocol max)	B	63.0	80
$^{99\text{m}}\text{Tc}$ SestaMIBI/Tetrofosmin ² (Cardiac stress scan 2-day protocol min)	B	42.0	80
$^{99\text{m}}\text{Tc}$ SestaMIBI/Tetrofosmin ² (Cardiac stress scan 2-day protocol max)	B	63.0	80
$^{99\text{m}}\text{Tc}$ SestaMIBI/Tetrofosmin ² (Cardiac rest scan 1-day protocol)	B	28.0	80
$^{99\text{m}}\text{Tc}$ SestaMIBI/Tetrofosmin ² (Cardiac stress scan 1-day protocol)	B	84.0	80
$^{99\text{m}}\text{Tc}$ Spleen (Denatured RBC)	B	2.8	20
$^{99\text{m}}\text{Tc}$ TECHNEGAS (Lung ventilation) ³	B	70.0	100

¹ The minimum recommended activities are calculated for commonly used gamma cameras or positron emission tomographs. Lower activities could be administered when using systems with higher counting efficiency.

² The minimum and maximum values correspond to the recommended administered activities in the EANM/ESC procedural guidelines (Hesse B, Tagil K, Cuocolo A, et al). EANM/ESC procedural guidelines for myocardial perfusion imaging in nuclear Cardiology. Eur J Nucl Med Mol Imaging. 2005 Jul;32(7):855-97.

³ This is the activity load needed to prepare the Technegas device. The amount of inhaled activity will be lower.

Fig. 1 The modified EANM dosage card. Changes to the 2007 version are highlighted in orange

might be suboptimal. At present, this methodology cannot be applied directly to the case of renal cortical scans in paediatric nuclear medicine, but has a great potential for influencing future updates of the respective recommendations.

Table 1 Activity values and effective doses for renal cortical scan with ^{99m}Tc-DMSA (ICRP 80 [7])

	Age				
	1 year	5 years	10 years	15 years	Adult
Nominal weight (kg)	10	19	32	55	70
2007 EANM dosage card [1]					
Administered activity (MBq)	33	48	64	87	100
Effective dose (mSv)	1.22	1.00	0.96	0.96	0.88
North American consensus guidelines [3]					
Administered activity (MBq) ^a	18	35	59	102	130
Effective dose (mSv)	0.68	0.73	0.89	1.12	1.14
2014 EANM dosage card ^b					
Administered activity (MBq)	18 ^c	32	49	84	100
Effective dose (mSv)	0.68	0.67	0.74	0.92	0.88

^a 1.85 MBq/kg

^b Changes to the 2007 version (as denoted in orange in Fig. 1)

^c Minimum activity of the respective guideline

EANM dosage card A reassessment of the data on the effective dose given in ICRP publication 80 [7] shows that the change in the effective dose is between class A and class B given in the paediatric dosage card. In order to make sure that the diagnostic quality is preserved, the decision was taken for the EANM dosage card to assign class A values to this radiopharmaceutical which led to higher activities to be administered as compared to the corresponding class B values. As the North American consensus guidelines show that lower activity values for a given weight do not lead to lower diagnostic quality, the following changes to the EANM dosage card are suggested in order to harmonize the two sets of guidelines:

- (a) Assign class B to DMSA
- (b) Change the baseline activity to 6.8 MBq
- (c) Change the minimum recommended activity to 18.5 MBq

North American consensus guidelines The guidelines will state additionally that the EANM dosage card may also be used. In addition, whether the maximum recommended activity can be set to 100 MBq should be checked.

In Tables 1–7 activity values and effective doses are provided for comparison for (a) the EANM dosage card, (b) the North American consensus guidelines and (c) the suggestions for the modified EANM dosage card.

Radionuclide cystography

EANM dosage card No changes suggested as it reflects present clinical practice in Europe.

North American consensus guidelines The currently recommended activity remains unchanged as it reflects the current North American clinical practice better than the activities given in the EANM dosage card.

Table 2 Activity values and effective doses for radionuclide cystography with ^{99m}Tc sodium pertechnetate

	Age				
	1 year	5 years	10 years	15 years	Adult
Nominal weight (kg)	10	19	32	55	70
2007 EANM dosage card [1]					
Administered activity (MBq)	20 ^a	20 ^a	20 ^a	20 ^a	–
Effective dose (mSv)	0.03	0.02	0.01	0.01	–
North American consensus guidelines [3]					
Administered activity (MBq)	37 ^a	37 ^a	37 ^a	37 ^a	–
Effective dose (mSv)	0.06	0.03	0.02	0.02	–

^a Minimum activity of the respective guidelines

Table 3 Activity values and effective doses for gastric emptying/reflux (solid and liquid) with ^{99m}Tc -labelled colloid (ICRP 80 [7])

	Age				
	1 year	5 years	10 years	15 years	Adult
Nominal weight (kg)	10	19	32	55	70
Solid					
2007 EANM dosage card [1]					
Administered activity (MBq)	10 ^a	13	20	33	40
Effective dose (mSv)	1.40	0.99	0.98	1.01	0.96
North American consensus guidelines [3]					
Administered activity (MBq)	9.25 ^a	9.25 ^a	18.5 ^a	18.5 ^a	18.5 ^a
Effective dose (mSv)	1.30	0.70	0.89	0.57	0.44
Liquid					
2007 EANM dosage card [1]					
Administered activity (MBq)	10 ^a	13	20	33	40
Effective dose (mSv)	1.40	0.99	0.98	1.01	0.96
North American consensus guidelines [3]					
Administered activity (MBq)	9.25 ^a	9.25 ^a	37.5 ^a	37.5 ^a	37.5 ^a
Effective dose (mSv)	1.30	0.70	1.78	1.14	0.88

^a Minimum/maximum activity of the respective guidelines

Gastric emptying/reflux

37 MBq as suggested by the North American consensus guidelines.

EANM dosage card Presently no changes suggested.

North American consensus guidelines The currently recommended activities remain unchanged as they reflect the current North American clinical practice better than the activities given in the EANM dosage card.

North American consensus guidelines The guidelines will state additionally that the EANM dosage card may also be used for all weight classes.

Whole-body ^{123}I -MIBG scan

FDG PET torso

EANM dosage card For FDG PET rewording is suggested:

EANM dosage card For ^{123}I -MIBG the lower limit of activity in the EANM dosage card will be reduced from 80 MBq to

Instead of using “F-18 FDG (2D)” the term “FDG-PET torso” is used. The suggested activity values remain unchanged.

Table 4 Activity values and effective doses for a whole-body scan with ^{123}I -MIBG (ICRP 80 [7])

	Age				
	1 year	5 years	10 years	15 years	Adult
Nominal weight (kg)	10	19	32	55	70
2007 EANM dosage card [1]					
Administered activity (MBq)	80 ^a	130	204	326	400
Effective dose (mSv)	5.4	4.8	5.3	5.5	5.2
North American consensus guidelines [3]					
Administered activity (MBq)	51	99	166	286	364
Effective dose (mSv)	3.5	3.7	4.3	4.9	4.7
2014 EANM dosage card ^b					
Administered activity (MBq)	76	130	204	326	400
Effective dose (mSv)	5.1	4.8	5.3	5.5	5.2

^a Minimum activity

^b Changes to the 2007 version (as denoted in orange in Fig. 1)

Table 5 Activity values and effective doses for ^{18}F -FDG PET of the torso (ICRP 106 [10])

	Age				
	1 year	5 years	10 years	15 years	Adult
Nominal weight (kg)	10	19	32	55	70
2007 EANM dosage card [1, 2]					
Administered activity (MBq)	70	120	189	302	370
Effective dose (mSv)	6.7	6.7	7.0	7.2	7.0
North American consensus guidelines [3]					
Administered activity (MBq) ^a	51	99	166	286	364
Effective dose (mSv)	4.8	5.5	6.2	6.9	6.9

^a 5.2 MBq/kg

For the purpose of this document (and future versions of the EANM dosage card) “Torso” refers to whole-body and/or total-body scanning with a limited anatomical coverage, such as axial coverage from the base of the skull to the mid-thigh. In addition, a statement is added to the EANM dosage card that, for the EU, these values represent typical upper limits. For adults, activity optimization for individual scanners should be performed as a function of several acquisition parameters, as discussed in detail in the EANM procedure guidelines for tumour PET imaging, version 1.0 [9].

North American consensus guidelines The minimum administered activity will be set to 26 MBq.

FDG PET brain

EANM dosage card For FDG PET rewording is suggested:

Instead of using “F-18 FDG (3D), Recommended in Children” the term “FDG-PET brain” is used. The activity values remain unchanged.

North American consensus guidelines The minimum administered activity will be set to 14 MBq.

Table 6 Activity values and effective doses for ^{18}F -FDG PET of the brain (ICRP 106 [10])

	Age				
	1 year	5 years	10 years	15 years	Adult
Nominal weight (kg)	10	19	32	55	70
2007 EANM dosage card [1, 2]					
Administered activity (MBq)	38	65	102	163	200
Effective dose (mSv)	3.5	3.8	3.8	3.9	3.8
North American consensus guidelines [3]					
Administered activity (MBq) ^a	37 ^b	70	118	204	259
Effective dose (mSv)	3.5	3.9	4.4	4.9	4.9

^a 3.7 MBq/kg^b Minimum activity of the respective guideline

^{18}F -Sodium fluoride

Remark After the publication of the EANM dosage card in 2008 newer data for this radiopharmaceutical became available (see the review by Eberlein et al. [6]). The result is that lowering the activity values of ^{18}F -sodium fluoride is possible (as compared to the original EANM dosage card) in a paediatric population without losing diagnostic information [11]. Therefore, the suggested activity values of the EANM dosage card are reduced in order to match the North American values.

EANM dosage card For ^{18}F -sodium fluoride a renaming and a change in the administered activities is suggested:

- The baseline value for the calculation of the activities to administer is set to 10.5 MBq.
- Instead of using “F-18 Fluorine (3D), Recommended in Children” the wording is changed to “F-18 sodium fluoride”.
- The EANM dosage card entry “F-18 Fluorine (2D)” will be deleted.

North American consensus guidelines The minimum administered activity will be set to 14 MBq. The guidelines will state additionally that the EANM dosage card may also be used.

Table 7 Activity values and effective doses for ^{18}F -sodium fluoride (ICRP 80 [7], Gelfand [11])

	Age				
	1 year	5 years	10 years	15 years	Adult
Nominal weight (kg):	10	19	32	55	70
2007 EANM dosage card [1, 2]					
Administered activity (MBq)	38	65	102	163	200
Effective dose (mSv)	5.7	4.9	4.7	4.7	4.8
North American consensus guidelines [3]					
Administered activity (MBq) ^a	22	42	71	122	155
Effective dose (mSv)	3.3	3.2	3.3	3.6	3.7
2014 EANM dosage card ^b					
Administered activity (MBq)	28	49	77	115	150
Effective dose (mSv)	4.2	3.7	3.5	3.3	3.6

^a 2.22 MBq/kg^b Changes to the 2007 version (as denoted in orange in Fig. 1)

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