A Dedicated Paediatric [18F]FDG PET/CT Dosage Regimen

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A dedicated paediatric [^{18}F]FDG PET/CT dosage regimen

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Abstract

Background

The role of 2-[^{18}F]fluoro-2-deoxy-D-glucose ([^{18}F]FDG) Positron emission tomography / computed tomography (PET/CT) in children is still expanding. Dedicated paediatric dosage regimens are needed to keep the radiation dose as low as reasonably achievable and reduce the risk of radiation-induced carcinogenesis. The aim of this study is to propose a paediatric dosage regimen based on patient size that provides a constant and clinical sufficient image quality at a reasonable effective dose.

Methods

In this retrospective analysis 102 children (54 boys and 48 girls) were included that underwent a diagnostic [^{18}F]FDG PET/CT scan. The image quality of the PET scans was measured by the signal-to-noise ratio (SNR) in the liver. The SNR liver was normalized (SNRnorm) for administered activity and acquisition time to apply curve fitting with body weight, body length, body mass index, body weight/body length and body surface area. Curve fitting was performed with two power fits, a non-linear 2-parameter model $\alpha\ p^{-d}$ and a linear single parameter model $\alpha\ p^{-0.5}$. The fit parameters of the preferred model were combined with a user preferred SNR to obtain at least moderate or good image quality for the dosage regimen proposal.

Results

Body weight demonstrated the highest coefficient of determination for the non-linear ($R^2 = 0.81$) and linear ($R^2 = 0.80$) models. The non-linear model was preferred by the Akaike's corrected information criterion. We decided to use a SNR of 6.5, based on the expert opinion of three nuclear medicine physicians. Comparison with the quadratic adult protocol confirmed the need for different dosage regimens for both patient groups. The amount of administered activity can be reduced with at least 41%

when compared with the current paediatric guidelines.

Conclusion

Body weight has the strongest relation with [^{18}F]FDG PET image quality in children. The proposed non-linear dosage regimen based on body mass will provide a constant and clinical sufficient image quality with a significant reduction of the effective dose compared to the current guidelines. A dedicated paediatric dosage regimen is necessary, as a universal dosing regimen for paediatric and adult is not feasible.

Keywords

Image quality; PET; [^{18}F]FDG activity; dose optimization; patient size; body weight

Background

Currently, the role of 2-[^{18}F]fluoro-2-deoxy-D-glucose ([^{18}F]FDG) Positron emission tomography / computed tomography (PET/CT) imaging is still expanding in the diagnosis and follow-up of paediatric oncologic, infectious and inflammatory diseases (1, 2). This expansion brings a point of concern, since both the CT and the [^{18}F]FDG expose patients to ionizing radiation, which can cause radiation-induced effects later in life (3). The risk of radiation-induced carcinogenesis is higher in children, as they have a longer post-radiation exposure life expectancy compared to adults (3). To reduce this risk, the radiation dose of paediatric PET/CT scans should be as low as reasonably achievable (ALARA) (4) with acceptable image quality and within a reasonable acquisition time. Therefore, optimization and harmonization of paediatric PET/CT imaging protocols is essential(5).

For performing paediatric nuclear medicine procedures, both the Society of Nuclear Medicine and Molecular Imaging (SNMMI) and European Association of Nuclear Medicine (EANM) recommend the

EANM paediatric dosage card (version 5.7.2016) (6, 7) or the 2016 North American Consensus guidelines (NACG) (7, 8). Both these guidelines have, however, several shortcomings as they are derived from adult-based protocols (9-12), and both focus on radiation dose without taking image quality into account (9-13). Moreover, the EANM paediatric dosage card recommends even higher administered activities per kilogram than the adult 2015 EANM [^{18}F]FDG guidelines (14). These optimized adult guidelines recommends dosage regimens based on quadratic(15) or linear relationships (16-20) between administered activity, body weight and acquisition time to obtain a sufficient constant image quality.

In contrast to adult dose regimens, only a few studies have been published on optimizing administered activities in children. Accorsi et al. (10) found that weight was the best patient-dependent indicator for the administered activity necessary to obtain constant sufficient image quality. A pilot study of van Gent et al.(21) focussed on body weight, showed that a linear relationship between body weight and administered activity results in a constant image quality. Other studies have reduced the administered [^{18}F]FDG activity per kilogram of body weight based on simulations of PET low-dose scans by reduction of count rates (11, 22, 23).

The Paediatric Dosage Harmonization Working Group and the 2020 paediatric guideline stated that more data is needed to optimize the current guidelines (7, 24). This can be achieved by dedicated paediatric studies for optimizing the [^{18}F]FDG PET guidelines. The aim of this study, therefore, is to investigate the relation between patient-dependent parameters and [^{18}F]FDG PET image quality and to propose a dedicated paediatric dose regimen that provides a constant and clinical sufficient image quality.

Methods

Patients

This retrospective study included 102 children (54 boys and 48 girls; mean age 12.5 ± 4.6 years; range 0.5-17.9 years), that underwent a diagnostic [^{18}F]FDG PET/CT scan at the Erasmus Medical Centre between January 2017 and July 2020. Inclusion criteria were: preparation according to local protocol; serum glucose < 7.0 mmol/L; administered activity +/- 10% of the recommended activity; PET acquisition time 60 +/- 5 minutes post injection and when disease was present no signs of extensive liver involvement on PET images. The same criteria were used to select 85 adult patients (26 male and 59 female; mean age 57.0 ± 16.5 years) to compare with the paediatric results. The study was approved by the Medical Ethical Committee of the Erasmus Medical Centre (MEC-2021-0078), and procedures were in accordance with the Declaration of Helsinki of 1964, as revised in 2013.

Patient-dependent parameters

For each patient, the patient-dependent parameters were collected or calculated in order to investigate the relationship between these parameters and [^{18}F]FDG PET image quality. Body weight (BW) [kg] and body height (H) [m] were collected from the patient files. Body mass index (BMI), Body weight per body height (BWH) and Body surface area (BSA) were calculated as follows:

Body mass index (BMI): = $\frac{M}{H^2}$ [kg/m^2]

Body weight per body height (BWH): = $\frac{M}{H}$ [kg/m]

Body surface area (BSA): = $0.007184 \times M^{0.425} \times H^{0.725}$ [m^2](25)

[^{18}F]FDG PET/CT

Patients were prepared according to local protocols for [^{18}F]FDG PET/CT in children and adults. Children had to fast for four hours prior to injection and were stimulated to drink water (body weight x 10 ml <10 years or 500-1000 ml >10 years) during the last two hours before injection. Adults had to fast for six hours and drink 1000 ml of water before injection. Additionally, 17 children and 10 adults followed a carbohydrate-restricted diet for 24 hours and fasted the last 12 hours to suppress myocardial [^{18}F]FDG

uptake. Uptake of [^{18}F]FDG in brown adipose tissue was suppressed in 91 children and 17 adults by administering Propranolol (0.33 milligram [mg] x BW with a maximum of 20 mg one hour before the injection for children and a fixed dose of 20 mg for adults. Dosing of [^{18}F]FDG activity was determined with the local linearized quadratic dose regimen of 1.7 megabequerel per kilogram (MBq/kg) (≤ 55kg, 68 children, with a minimum of 14 MBq); 2.3 MBq/kg (55-70kg, 26 children); 3.0 MBq/kg (71-95 kg, 7 children) and 4.0 MBq/kg (≥ 96 kg, 1 child) and was intravenously injected (children median: 82 MBq; range 13-392 MBq and adults median: 138MBq; range 56-532 MBq) followed by resting in a warm and quiet room. PET images were acquired 60 ± 5 minutes for children and 59 ± 3 minutes for adults after tracer injection in supine position on a Siemens Biograph mCT PET/CT scanner (Siemens Healthineers, Erlangen, Germany). According to our local scan protocol, first a whole-body low dose CT with optimized parameters (26-28) was acquired for attenuation correction and localization purposes (Teenager/adult values in brackets). 80 kV (120 kV); Quality reference mAs 140 (40 mAs); Automatic Exposure Control strength strong (average); rotation time 0.5 seconds; pitch 0.8 mm; slice thickness 2 mm (3mm); reconstructed slice thickness 2 mm (3 mm) and a Siemens B19f Low Dose for Emission Computed Tomography kernel. Directly after the low dose CT, PET acquisition started with an acquisition time of 3 minutes per bedposition (mbp) from the inguinal region to the skull base with the arms up (61 children and all adults). Another 41 children (31 arms up, 10 arms down) were scanned from the skull base to the feet with 2 mbp for the additional lower extremities. Once acquisition was finished, PET scans were corrected for scatter and attenuation using the low dose CT, followed by reconstruction using ordered subset expectation maximization (OSEM; 3 iterations; 21 subsets; Point Spread Function (PSF) recovery; Time of Flight (TOF); a 3 mm Gaussian post reconstruction filter on a matrix of 200x200 with a pixel size of 4.1x4.1 mm and 3mm slice thickness.

Image analysis

The reconstructed PET scans were analyzed for image quality based on the approach as described by de Groot et al. (15) and previously used by Cox et al. (29). Image quality was measured with the signal-to-

noise ratio (SNR) in the liver. To determine the SNR liver, a volume of interest (VOI) was placed in a lesion-free homogeneous part of the right liver lobe (diameter 3 cm) using Hermes Hybrid viewer 2.6D software (Hermes Medical Solutions, Stockholm, Sweden). The VOIs were placed at least 1 cm from the edge of the liver to avoid partial volume effects. The SNR liver was calculated by dividing the liver standard uptake value (SUV) mean normalized for body weight (SUVbw) by the standard deviation (SD) (15). The liver SUVmean can also be used as a measure for liver deoxyglucose metabolism (30, 31). In order to compare the liver deoxyglucose metabolism between children and adults, the liver SUVmean normalized by body surface area (SUVbsa) was determined. This value is less dependent on body size and age compared to SUVbw and therefore a better value for liver deoxyglucose metabolism (30, 31).

PET image quality depends on the time per bedposition and the amount of administered activity. The product of these parameters is the dose time product (DTP [MBq·min]). The SNR liver can be normalized (SNRnorm liver [$(\mathrm{MBq}\cdot\mathrm{min})^{-1/2}$]) for the administered activity and scan time per bedposition by assuming Poisson statistics in which noise increases with the square root of the signal (15). The SNRnorm liver is assumed independent of scan time and administered activity.

$$SNRnorm\ liver = \frac{\mathrm{SNR\ liver}}{\sqrt{\mathrm{DTP}}} \qquad \text{(Eq.1)}$$

Statistical Analysis

All statistical analyses were performed using Graphpad PRISM version 9. In order to test for significant differences in liver deoxyglucose metabolism (liver SUVmean) and image quality (SNR liver and SNRnorm liver) between children and adults an unpaired t-test ($\alpha = 0.05$) or a Mann-Whitney U test ($\alpha = 0.05$) after testing the data for normality by a Shapiro-Wilk test ($\alpha = 0.05$) was performed. Furthermore, a Pearson product correlation was run to determine the correlations between SNR liver and SNRnorm liver with age in both patient groups.

The coefficient of determination (Pearson R^2) was used to select the best patient-dependent parameter after curve fitting of each parameter with SNRnorm liver. Curve fitting was applied to the parameters by using a power function (Equation 2) to obtain a non-linear dosage regimen as described before by the Groot et al. (15):

$$SNR_{norm\ liver,fit} = \alpha p^{-d}, \qquad \text{(Eq.2)}$$

where α and d are fit parameters and p is the patient-dependent parameter.

Curve fitting was also performed with equation 3 to obtain a linear dosage regimen:

$$SNR_{norm\ liver,fit} = \alpha p^{-0.5}, \qquad \text{(Eq. 3)}$$

where α is the fit parameter and p is the patient-dependent parameter

Preference between the two models for each patient-dependent parameter was determined by the difference between the Akaike's corrected information criterion values (ΔAICc) (32).

To determine significant differences between the patient-dependent parameter fit with the highest R^2 and the other patient-dependent parameters fits, the relative error between SNRnorm liver and SNRfit liver was calculated for each data point using (SNRfit liver – SNRnorm liver)/SNRfit liver × 100%. The relative error between the fits was tested with One-Way ANOVA test (α = 0.05) or a non-parametric Friedman test with additional post hoc tests after testing for normality (15).

The fit parameters of the best patient-dependent parameter were used for the dose regimen proposal. The fit parameters were entered in the following expressions:

Combining equation 1 and 2 results in the following non-linear expression for the DTP [MBq·min] (15):

$$DTP = \frac{SNR\ liver^2}{\alpha^2} \times p^{2d}. \qquad \text{(Eq.4)}$$

In the linear dosage regimen (d=0.5), DTP [MBq·min] is indicated by the following linear expression:

$$DTP = \frac{SNR\ liver^2}{\alpha^2} \times p. \qquad \text{(Eq.5)}$$

Results

Patient-dependent parameters

The measurements and calculations of the paediatric patient-dependent parameters are displayed in Table 1.

Table 1: Paediatric patient-dependent parameters and SUV values

Parameters	***Mean ± SD***	***Range***	***Median***
Body weight [kg]	45.9±19.9	3.8–96.0	46.5
Body height [m]	1.49±0.26	0.57–1.86	1.58
BMI [kg/m^2]	19.4±4.3	11.7–33.9	18.8
BWH [kg/m]	29.6±9.9	6.7–55.2	29.6
BSA [m^2]	1.5±0.5	0.3–2.5	1.7

Liver deoxyglucose metabolism

An unpaired t-test was performed to compare the liver deoxyglucose metabolism between children and adults. This showed that SUVbsa in children (0.57 ± 0.10) was significant lower (t (185) = 7.82, p < 0.001) compared with SUVbsa in adults (0.69 ± 0.10) with a mean difference of 0.11 (95%CI, 0.09 to 0.14).

Image quality

To compare the SNR liver between children and adults an unpaired T-test was performed, which showed a significant (t (185) = 4.561, p < 0.001) difference in mean SNR liver between children and adults. Also, the Mann-Whitney U test to compare the SNRnorm liver between adults and children revealed a significant (U = 3087, p < 0.001) difference between these two groups as displayed in figure 1. In children the correlation between SNR liver and age showed a weak significant positive correlation (r = 0.272, n = 102, p = 0.006). For adults both SNR liver and SNRnorm liver showed no correlations with age of respectively r = -0.138, n = 85, p = 0.208 and r = -0.092, n = 85, p = 0.400. This is in contrast to

SNRnorm liver in children, which strongly correlated with age in a negative direction (r = -0.795, n = 102, p <0.001).

Figure 1: Scatterplots of the SNR liver (A) and the SNRnorm liver (B) against age.

Curve Fitting

The results of the curve fitting of SNRnorm liver with patient-dependent parameters are presented in figure 2 and table 2. As can be seen body weight shows for both curves the highest R^2 (0.81 and 0.80, respectively). The non-linear model is the preferred model, according to the AICc. For this model, the Friedman test with additional Dunn-Bonferroni post hoc test revealed only a significant difference (p < 0.05) between the fit of body weight and the fit of body height. (Table 2).

Figure 2: Curve fitting to determine the fit parameters for a linear and non-linear dosage regimen of the mean SNRnorm liver ($[MBq \cdot min)^{-1/2}$] versus Body weight (A), Body height (B), BMI (C), BWH (E) and BSA (E). The dashed lines represent the 95% confidence intervals of the fits.

Table 2: Fits of SNRnorm liver with the patient-dependent parameters.

Patient-dependent parameters	***SNRnorm liver,fit = α $p^{-0.5}$***			***SNRnorm liver,fit = α p^{-d}***					
	α	***R^2***	***p value***	***α***	***d***	***R^2***	***p value***	***ΔAICc***	***AIC%***
Body weight [kg]	2.51	0.80	-	2.23	0.46	0.81	-	1.86	23.8 vs 71.20
Body height [m]	0.51	0.47	< 0.001	0.62	1.15	0.78	0.046	88.44	<0.01 vs >99.99
BMI [kg/m^2]	1.82	0.27	< 0.001	13.26	1.19	0.41	> 0.999	18.29	0.01 vs 99.99
BWH [kg/m]	2.20	0.67	< 0.001	4.73	0.74	0.78	> 0.999	33.61	<0.01 vs >99.99
BSA [m^2]	0.50	0.75	0.001	0.51	0.64	0.81	0.085	23.89	<0.01 vs >99.99

We decided to use an SNR liver of 6.5 to obtain acceptable image quality after a review by three independent nuclear medicine physicians. This SNR level will reduce the risk of scans with a poor image quality, which sometimes occurred in children < 20 kg.

The proposed dedicated dosage regimen was obtained by combining equation 4 with an SNR liver of 6.5 and the fit parameters of body mass which are $\alpha = 2.23$ (95% CI 1.90 to 2.51) and $d = 0.46$ (95% CI 0.43 to 0.50). This resulted in the following non-linear expression for the DTP [MBq·min] with a minimum of 26 MBq conform the guidelines (7):

$$DTP = 8.5 \times M^{0.92}. \qquad \text{(Eq.6)}$$

Comparison of the proposed dosage regimen with the adult dosage regimen and the current paediatric dosage regimen in guidelines.

Figure 3 shows the fits of SNRnorm liver versus body weight that corresponds to the proposed non-linear paediatric dosage regimen and the new Erasmus MC quadratic dosage regimen for adults. It can be seen that the non-linear dosage regimen fits perfectly for children (fig. 3A) and not for adults (fig. 3B), whereas a quadratic dosage regimen fits perfectly for adults and not for children. No universal dose regimen could be found for children and adults together neither non-linear nor quadratic (fig. 3C).

Figure 3: Comparison between SNRnorm liver fits that corresponds with the proposed non-linear dosage regimen (parameter d fixed to 0.46) and a quadratic dosage regimen (parameter d fixed to 1) for children (A), adults (B) and both groups (C). The dashed lines represent the 95% confidence intervals of the fits.

In Figure 4, our dosage regimens with an acquisition time of 3 mbp are compared with those of the EANM and NACG guidelines. As can be seen our new dosage regimen (65 MBq and 3.6 mSv (33)) will reduce the amount of administered activity and radiation dose with 41 % (NACG: 111 MBq and 6.2 mSv) and 63 % (EANM: 178 MBq and 9.9 mSv) for a child of 30kg, despite the higher amount of injected activity compared to the dosage regimen used in the current study (51 MBq and 2.9mSv)

Figure 4: Comparison of [^{18}F]FDG dosage regimens. Current study, EANM, NACG and the proposed dose regimen.

Discussion

In this study, the relation between patient-dependent parameters and [^{18}F]FDG PET image quality was investigated in order to propose a dedicated paediatric dose regimen that aims for constant and sufficient image quality. To the best of our knowledge, this study is the first that investigates the relationship between paediatric patient-dependent parameters and [^{18}F]FDG PET image quality based on SNR. This study has demonstrated that body weight is the parameter with the greatest effect on [^{18}F]FDG image quality in children. Another important finding was that SNRnorm values were significant higher in children and correlated more strongly with age than in adults. Furthermore, this is the first study providing insight into the differences between paediatric and adult dosage regimens. This insight emphasizes the need for a dedicated paediatric dosage regimen, especially for young children.

Liver deoxyglucose metabolism in children was shown to be significantly lower than in adults. These results confirm the results obtained in a paediatric study by Yeung et al.(30). The increase in [^{18}F]FDG uptake during growth may be caused by age related changes in liver volume (34) and function of hepatocytes (35, 36). Furthermore, the significant changes in body size, body composition (34, 37) and blood volume during growth (37) could also account for an increase in [^{18}F]FDG uptake. Not only body size and age affected SUV measurements but also differences in uptake period, plasma glucose, recovery coefficient and partial volume artefacts (38). The contribution of these factors may be limited in this study due to the use of standardized protocols.

Despite lower SUVbsa mean values and concomitant lower liver [^{18}F]FDG uptake, small children showed high SNRnorm values, which implies that less activity is needed to obtain sufficient image quality (fig.1A). This is probably caused by less attenuation and scatter due to the smaller body sizes. In contrast to SNRnorm, SNR has almost no correlation with age (fig 1B). This means that, despite the quite large

298 spread (range 4.3-8.1), the currently used dosage regimen already provides a constant image quality
299 throughout our patient population.
300
301 Body weight was the patient-dependent parameter with the highest coefficient of determination for both
302 fit models for SNRnorm. The fit parameters ($\alpha = 2.23$ and $d = 0.46$) of the preferred model are in line
303 with the fit parameters ($\alpha = 3.2$ and $d = 0.52$) obtained by van Gent et al.(21) in a paediatric pilot study of
304 20 patients. The fit of the preferred model was not significantly different from the fits of BMI, BWH and
305 BSA, even though body mass was used to define the optimal dose regimen as it is more practical than
306 BMI, BWH and BSA. Although the selected model explains 81% of variability in SNRnorm among
307 patients, the remaining 19 % was not explained. This variability might be caused by differences in patient
308 size, not covered by body weight. Unknown inhomogeneities within the liver VOIs might also cause
309 variability of SNRnorm. Nevertheless, our results are consistent with earlier adult [^{18}F]FDG studies of de
310 Groot et al.(15) and Menezes et al.(39). These studies determined body weight with the highest
311 coefficient of determination with SNRnorm with respectively R^2's of 0.77 (OSEM 3D + PSF + TOF) and
312 0.86 (OSEM 3D +PSF) using comparable scanners to ours. Body weight was also identified as the best
313 single predictor for image quality by Accorsi et al. (10) at a comparable R^2 of 0.86 using a different
314 camera, reconstruction method, and the noise equivalent count rate density (NECRD) as measure of
315 image quality. The NECRD is derived from the noise equivalent count rate (NECR) method (20), which
316 is considered to be more objectively related to SNR, since it is not affected by possible differences in liver
317 metabolism and reconstruction methods (40-42). Although, at that moment NECRD was not validated
318 with a visual assessment and therefore the estimated sufficient image quality and proposed dosage
319 regimen could be unreliable (43).
320
321 In contrast to the studies mentioned above, this study directly compared the models of children and adults.
322 It was not possible to find a universal dosing regimen linking paediatric and adult protocols (fig. 3). This
323 insight emphasizes the need for a dedicated paediatric dosage regimen, especially for young children.

These results are in agreement with the EANM adult guidelines (14), which recommends using a quadratic dosage regimen, especially for patients > 75 kg, as this compensates for the lower image quality caused by substantial attenuation when using a linear dosage regimen (15). In addition, they recommend that the linear dosage regimen is appropriate to use for patients < 75 kg, but this is not supported by data or references.

Our proposed paediatric [^{18}F]FDG dosage regimen (acquisition time 3 mbp) showed a reduction of the amount of administered activity and effective dose of 41% (NACG) and 63 % (EANM) in a child of 30 kg (fig. 4). Our findings broadly support the work of other studies in this area, which also found reductions of 40-50% (10, 11, 22, 23), although they used other dosage regimens, scanners, and reconstruction methods.

One limitation of our study is that the results are only valid for Siemens Biograph mCT scanners with an OSEM 3D + PSF + TOF reconstruction. Therefore, further investigation will be necessary for other systems and reconstruction methods. Another limitation is the absence of raw data due to the retrospective approach. Therefore, NECR analysis of the raw data to support the SNR data was not possible. The NECR data are more objective since they are not affected by differences in liver deoxyglucose metabolism and reconstruction parameters. An earlier adult study of Menezes et al. (39) determined that both SNR and NECR showed the best correlation with body weight. The clinical SNR analysis could be replicated in a phantom study by de Groot et al. (15) and this showed that the effects of liver glucose metabolism and reconstruction parameters are either rare or not as influential compared to attenuation effects. Furthermore, it should be pointed out that our study has been primary concerned with optimizing radiation dose from [^{18}F]FDG rather than from both [^{18}F]FDG and CT. The low dose CT protocols of our scanners have already been optimized to reduce radiation dose (Child of 30 kg: DLP ± 75 mGy·cm and 1.4 mSv (44)) and to maintain sufficient image quality as with phantom studies in the past (26-28).

Conclusion

Body weight has the greatest effect on [^{18}F]FDG PET image quality in children. The proposed non-linear dosage regimen based on body mass will provide a constant and clinical sufficient image quality with a reasonable radiation dose and present a significant reduction of the administered activity compared to the current guidelines. A dedicated paediatric dosage regimen is necessary, as a universal dosing regimen for paediatric and adult is not feasible.

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Abbreviations

^{18}F-FDG: ^{18}Fluorine-fluoro-2-deoxyglucose

PET/CT: positron emission tomography / computed tomography

SNR: signal-to-noise ratio

SNRnorm: normalized signal-to-noise ratio

ALARA: as low as reasonably achievable

SNMMI: Society of Nuclear Medicine and Molecular Imaging

EANM: European Association of Nuclear medicine

NACG: North American Concensus guidelines

BW: body weight

BMI: body mass index

BWH: body weight per body height

BSA: body surface area

MBq/kg: megabequerel per kilogram

OSEM: ordered subset expectation maximization

PSF: point spread function

TOF: time of flight

VOI: volume of interest

SD: standard deviation

DTP : dose-time-product

AICc: Akaike's corrected information criterion values

ANOVA: analysis of variance

NECRD: noise equivalent count rate density

NECR: noise equivalent count rate

Declarations

Ethics approval and consent to participate

The study was approved by the Medical Ethical Committee of the Erasmus Medical Centre (reference number: 2021-0078).

Consent for publication

Not applicable

Availability of data and material

The data supporting our findings are available upon request.

Competing interests

C.P.W. Cox: not applicable

D.M.E. van Assema: not applicable

F.A. Verburg: not applicable

T. Brabander: not applicable

M. Konijnenberg: not applicable

M. Segbers: not applicable

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Authors' contributions

CC, DA and MC contributed to the study concepts and to the study design. CC contributed to the data collection. CC, MM, MK and MS contributed to the data analyses and statistical analysis. CC, DA, FV, TB, MM and MC contributed to the data interpretation, to the manuscript preparation, to the manuscript editing and reviewing. All authors read and approved the final manuscript.

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Figures

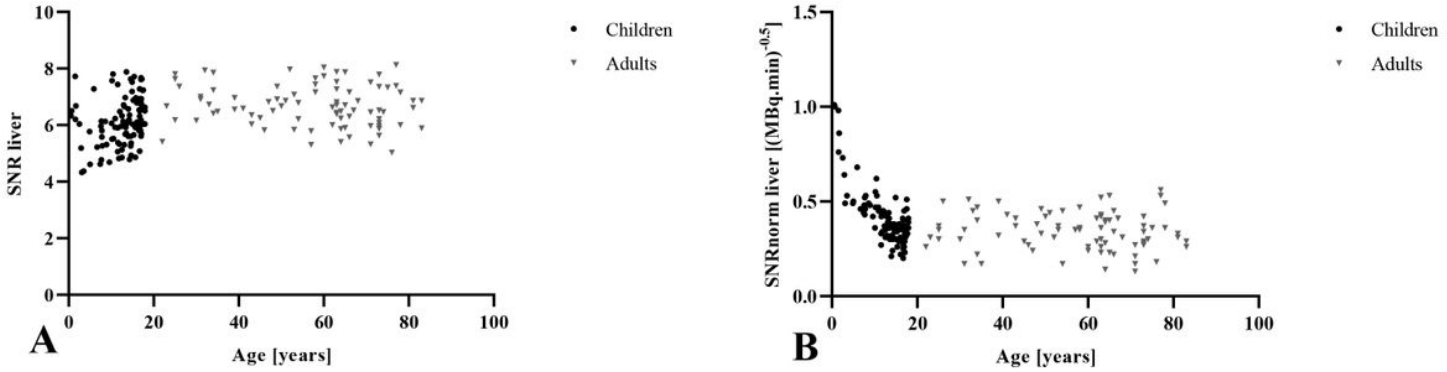

Figure 1

Scatterplots of the SNR liver (A) and the SNRnorm liver (B) against age.

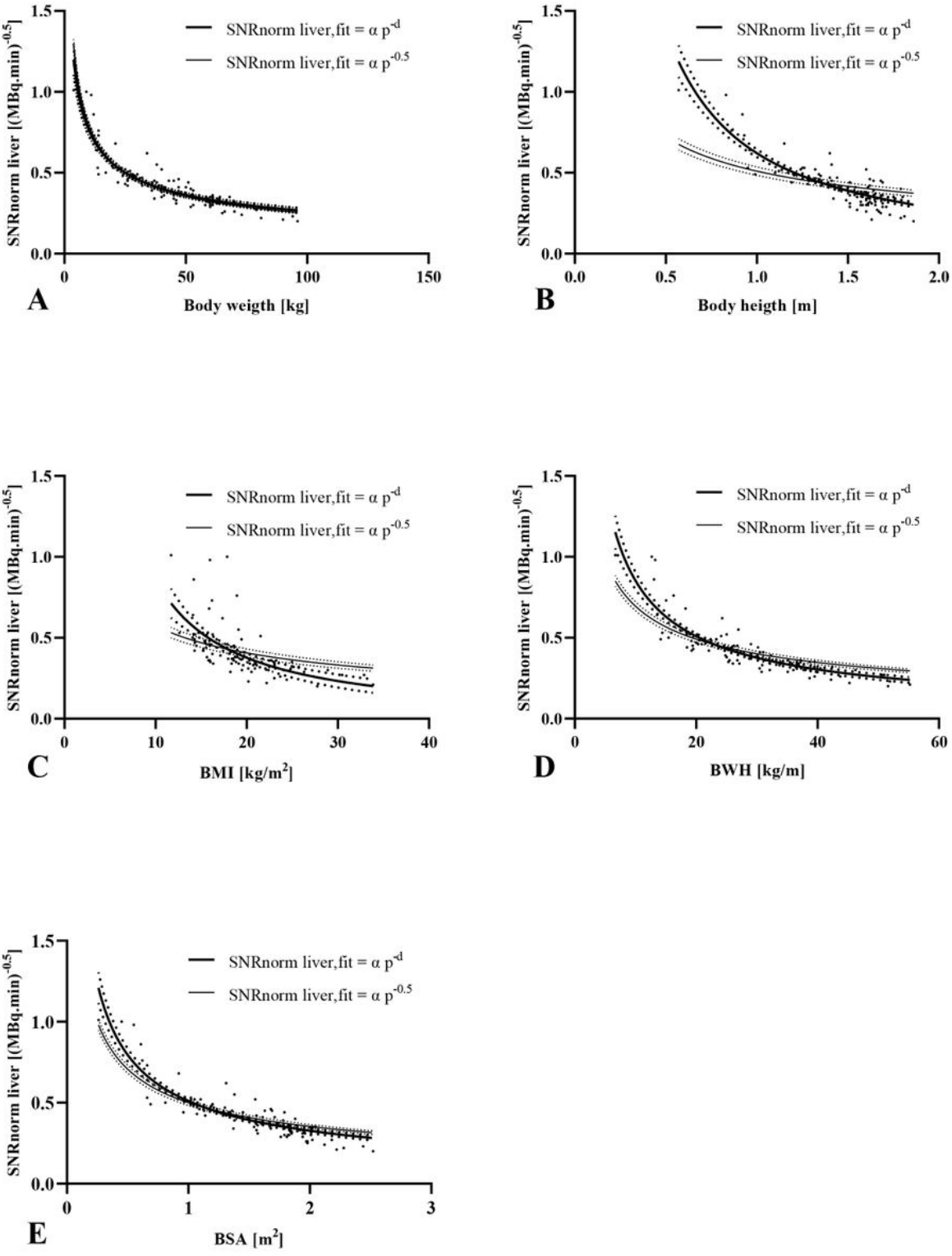

Figure 2

Curve fitting to determine the fit parameters for a linear and non-linear dosage regimen of the mean SNRnorm liver ([MBq·min)−1/2] versus Body weight (A), Body height (B), BMI (C), BWH (E) and BSA (E). The dashed lines represent the 95% confidence intervals of the fits.

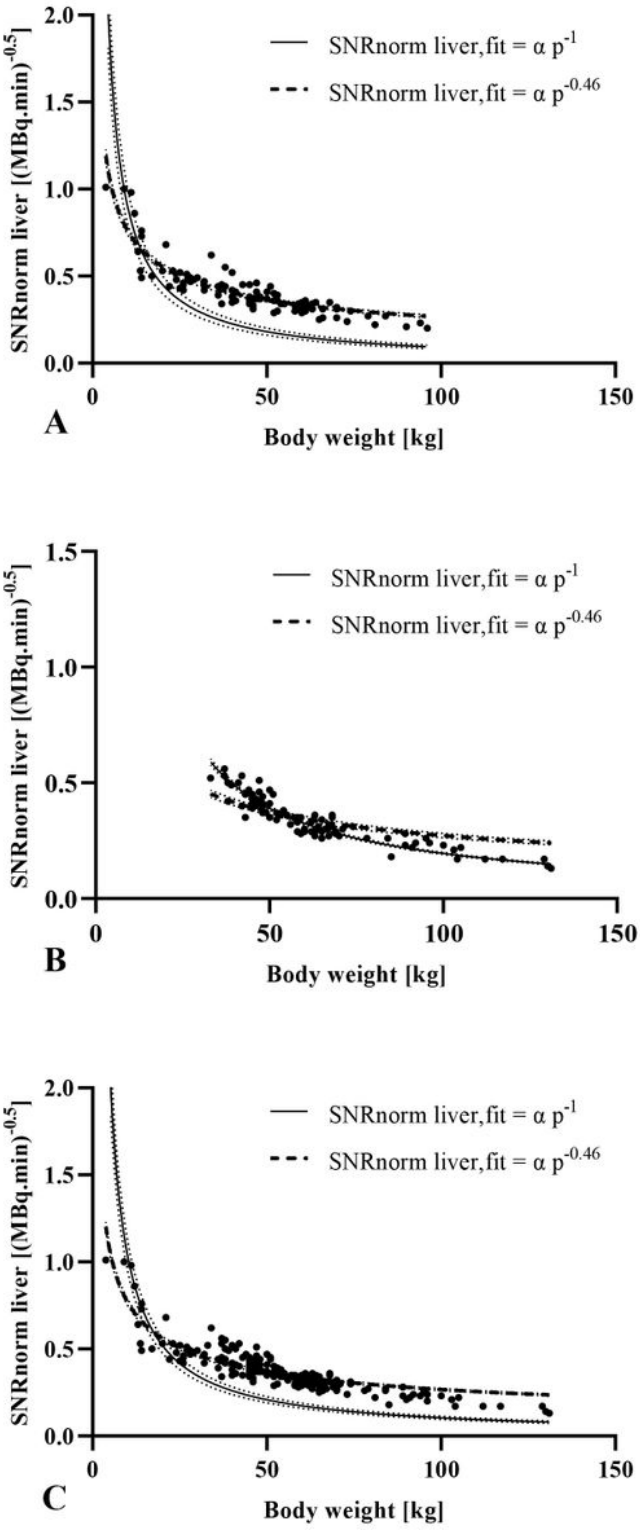

Figure 3

Comparison between SNRnorm liver fits that corresponds with the proposed non-linear dosage regimen (parameter d fixed to 0.46) and a quadratic dosage regimen (parameter d fixed to 1) for children (A), adults (B) and both groups (C). The dashed lines represent the 95% confidence intervals of the fits.

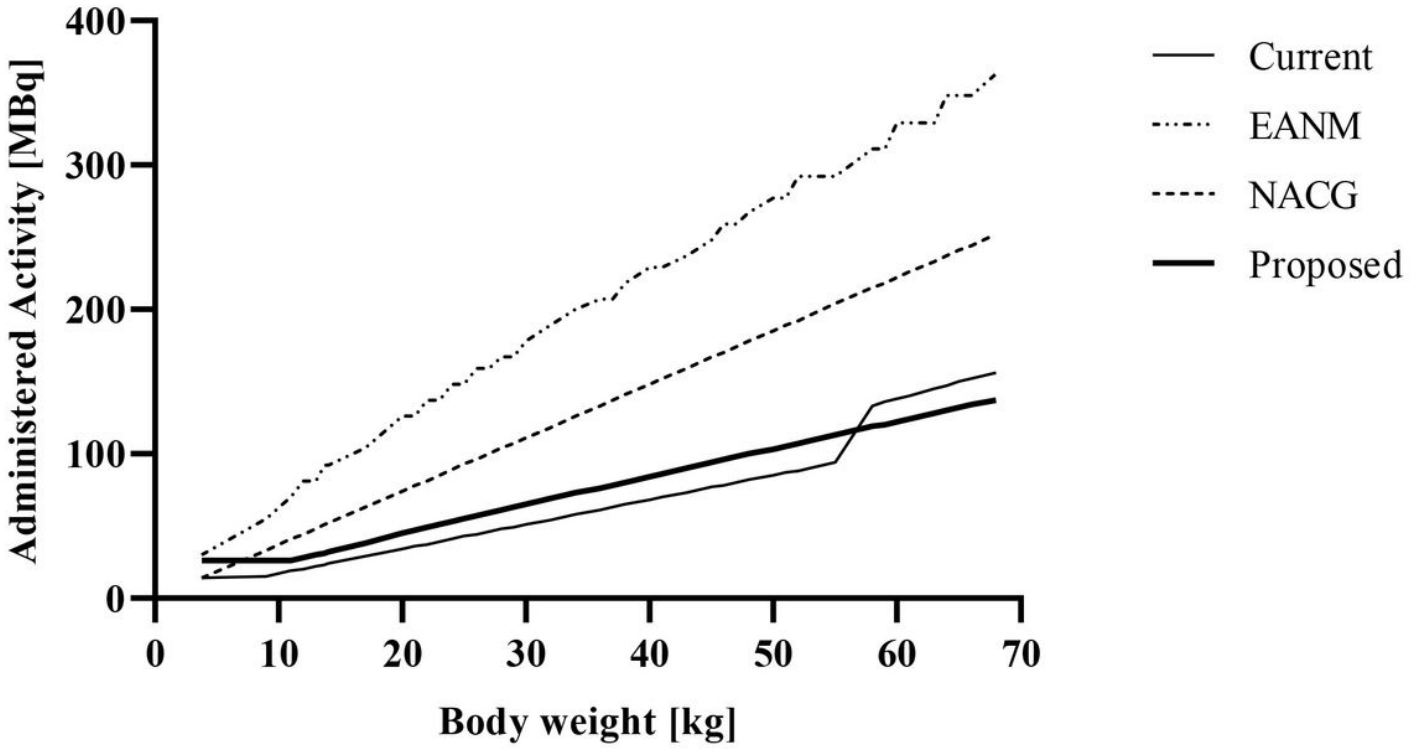

Figure 4

Comparison of [18F]FDG dosage regimens. Current study, EANM, NACG and the proposed dose regimen.