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Assessment of minimum activity of ^{124}Iodine in pre-therapeutic uptake measurement prior to radioiodine therapy of benign thyroid diseases

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Short running title: Minimum activity in ^{124}I-PET

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ABSTRACT

The study aimed to assess a hypothetical minimum activity with regard to agreement of ^{124}Iodine uptake (^{124}I-RAIU) measured by positron emission tomography/computed-tomography (PET/CT) with ^{131}Iodine uptake (^{131}I-RAIU) determined by probe measurement which is considered clinical standard. Moreover, the impact of different reconstruction algorithms on ^{124}I-RAIU and the evaluation of pixel noise as parameter for image quality were investigated.

Methods: Different scan durations were simulated by different reconstruction intervals of 600-second-list-mode PET data sets (including 15 intervals up to 600 seconds and five different reconstruction algorithms; filtered-back projection and four iterative techniques) acquired 30 hours after administration of 1MBq ^{124}I. The Bland-Altman method was used to compare mean ^{124}I-RAIU levels *versus* mean 3MBq ^{131}I-RAIU levels (clinical standard). The data of 37 patients with benign thyroid diseases were assessed. The impact of different reconstruction lengths on pixel noise was investigated for all five ^{124}I-PET reconstruction algorithms. A hypothetical minimum activity was sought by means of a proportion equation, considering that the length of a reconstruction interval is equitable to a hypothetical activity.

Results: Mean ^{124}I-RAIU and ^{131}I-RAIU showed high levels of agreement already for reconstruction intervals as short as 10 seconds, corresponding to a hypothetical minimum activity of 0.017MBq ^{124}I. The iterative algorithms proved generally superior to the filtered-back projection. ^{124}I-RAIU showed a trend to higher levels compared to ^{131}I-RAIU if the influence of retrosternal tissue was not considered which was proven to be the cause of a slight overestimation by ^{124}I-RAIU measurement. A hypothetical minimum activity of 0.5MBq ^{124}I obtained with the iterative reconstruction appeared sufficient with regard to pixel noise as well as visually.

Conclusions: This study confirms the potential of ^{124}I-RAIU measurement as alternative method for ^{131}I-RAIU measurement in benign thyroid disease and suggests the option to reduce administered activity. CT information is particularly important in case of retrosternal expansion. The results are relevant because ^{124}I-PET/CT allows additional diagnostic means, i.e., possibility to perform fusion imaging with ultrasound. ^{124}I-PET/CT might be an alternative especially when hybrid ^{123}I-single photon emission computed-tomography (SPECT)/CT is not available.

Key words: ^{124}Iodine, ^{124}Iodine-PET, Reconstruction parameters, Pre-therapeutic uptake measurement, Benign thyroid disorders

INTRODUCTION

Radioiodine therapy (RAIT) with ^{131}Iodine (^{131}I) is a relevant intervention due to the high prevalence of benign thyroid diseases (*1*). While pre-therapeutic radioiodine uptake (RAIU) measurement is usually performed with ^{131}I-probe and considered clinical standard a recent study on the correlation between ^{131}I-probe uptake (^{131}I-RAIU) measurement and ^{124}Iodine positron emission tomography-computed tomography (^{124}I-PET/CT) uptake (^{124}I-RAIU) measurement has shown that application of as little as 1MBq ^{124}I provides RAIU results comparable to those obtained with 3MBq ^{131}I *(2)*. Thus, ^{124}I-PET/CT may become a good alternative for routine evaluations of RAIU in patients with benign thyroid disease, especially because ^{124}I-PET/CT may provide additional diagnostic information. Indeed, ^{124}I-PET shows a superior functional anatomy compared to conventional $^{99m}TcO_4$ thyroid scintigraphy (*3*). Also, the ^{124}I-RAIU method allows a time-efficient PET-based organ volumetry (*4*). In addition, there exists the possibility to perform PET/ultrasound image fusion (*5*-*7*).

Different activities in one patient can be simulated by obtaining a ^{124}I-PET/CT scan in list-mode technique and equalizing reduction of scan time with reduction of activity. The focus of this study was to assess only the uptake aspect of RAIU. No information was obtained about the effective half-life aspect of RAIU. The goals of this study were to assess a hypothetical minimum activity with regard to agreement of ^{124}I-RAIU with ^{131}I-RAIU measurement as clinical standard, to determine the influence of different reconstruction algorithms on ^{124}I-RAIU measurement, and to evaluate pixel noise as parameter for image quality.

MATERIALS AND METHODS

Patients and Ethics

The study included consecutive patients with benign thyroid diseases referred to our institution from April 2012 to June 2014 in preparation for RAIT. The study was designed as a subanalysis within a larger prospective study approved by the local ethics committee and the German Federal Office of Radiation Protection. All participants signed a written informed consent.

Study Protocol

Thyroid Diagnostics. The initial thyroid diagnostic was performed according to current guidelines (anamnesis; measurement of thyroid stimulating hormone (TSH), free T3 and free T4; neck ultrasound; and planar ^{99m}Technetium-Pertechnetate scintigraphy) (*8-10*).

Inclusion and Exclusion Criteria. Criteria for inclusion were the diagnosis of a benign thyroid disease potentially requiring treatment (e.g. RAIT with the aim of volume reduction). Patients were excluded if they had received thyroid-specific treatment in the previous 12 weeks, if their anamnesis was positive for iodine contamination, or if a relevant change in thyroid metabolism (as assessed by TSH levels) occurred between the investigations.

Tracer Preparation. Sodium-^{131}I solution (GE Healthcare Buchler) and Sodium-^{124}I tracer solution (BV Cyclotron VU) were filled into identical capsules (HGK, size 3; GE Healthcare Buchler) onto a crystalline carrier. The tracer activity of the test capsules was measured using a dose calibrator (Isomed 2010; MED Nuklear-Medizintechnik Dresden).

Tracer Administration and RAIU Measurement Schedule. Oral administration of ^{131}I capsules (3MBq) was performed first, ^{124}I capsules (1MBq) were administered 7-14 days later. Each RAIU was measured 30 hours after administration. Prior to this study, phantom experiments demonstrated that residual ^{131}I does not interfere with quantification of ^{124}I in PET/CT examination (*2*).

^{131}I-probe Measurement. The activity in patients was measured using a Thyroid Uptake Counter ISOMED 2162 (MED Nuklear-Medizintechnik Dresden GmbH). The measuring distance between detector and neck was kept at 45 cm using a spacer. The detector fitted with a collimator NZ-136-01 (MED Nuklear-Medizintechnik Dresden) had dimensions of 5x5cm and was connected to a multichannel analyzer through a photomultiplier tube. For quality assurance purposes, each measurement was preceded by a check of the energy spectrum using a ^{137}Caesium test source, as well as by measurement of the background activity. The determined lower limit of detectability was 7kBq.

^{124}I-PET/CT. ^{124}I-PET/CT scans were acquired using a Biograph mCT 40 system (Siemens). The scans were scheduled late in the afternoon after clinical routine to ensure a high adherence to appointed date. ^{124}I-PET imaging was performed in list-mode acquisition by continuous scanning for 600s with every measured value stored as raw data with an exact time stamp to allow reconstruction of intervals of different length as static images, simulating scan intervals of different length.

Patients were scanned in supine position with one bed position. The scan region included the whole neck and the upper thorax. Anatomic co-registration and attenuation correction were performed using a native CT at its lowest tube setting (30mA), with 120kV tube voltage, 3mm scan slice width, and 1.2pitch. The PET system used showed a 3-dimensional sensitivity of 9.5cps/kBq/mL. At 1cm, the axial resolution was 4.4mm and the transverse resolution 4.5mm. The scatter fraction was below 36%. Quality control was performed daily and weekly according to the standards of the National Electrical Manufacturers Association.

^{124}I-PET Reconstruction Intervals (RI). List-mode data was reconstructed using the software HD-TrueX (Siemens), with 15 RI of different lengths, i.e. 600s, 540s, 480s, 420s, 360s, 300s, 240s, 180s, 120s, 60s, 50s, 40s, 30s, 20s and 10s.

^{124}I-PET Reconstruction Algorithms. Images were reconstructed using two basically different processes, i.e., filtered back-projection (FBP) and iterative technique (IT). The IT consisted of different combinations of the four reconstruction parameters, image matrix, iterations, subsets and zoom. One or maximally two parameters were changed according to the locally established reconstruction algorithm (IT-1) (Table 1) (*2-4*). Each RI was reconstructed with the five different reconstruction algorithms.

Quantitative Analysis

^{131}I-RAIU Measurement. The computer-based assessment proceeded by means of the dedicated standard software UPT 2000 (MED Nuklear-Medizintechnik Dresden). The thyroid activity was calculated as ratio of counts measured in the patients' field-of-view (FOV) versus the counts measured in a standard phantom, in both cases after subtraction of the background count rate. ^{131}I-RAIU was calculated dividing measured counts by applied activity, considering decay correction and calibration of the ^{131}I-probe.

^{124}I-RAIU Measurement. The ^{124}I-PET and CT datasets were fused using the software PMOD version 3.408 (PMOD Technologies Ltd) and quantified using the volume-of-interest (VOI) technique. A cylinder-shaped VOI was placed on the neck, ensuring that mandible and any retrosternal thyroid parts were included enabling the measurement of any activity within this region (Fig. 1) (*2*). Mean activity concentration [kBq/ml] and its standard deviation (SD) were measured in each VOI. A background correction VOI was not used due to high specific uptake within the thyroid compared to surrounding tissue. ^{124}I-RAIU was calculated dividing measured activity within the VOI by applied activity. In analogy to other studies, a correction of the

measured activities based on the different decay of ^{124}I and ^{131}I was performed allowing a comparison of the activities of the two radionuclides *(2).*

Data Analysis

Comparison of ^{131}I-RAIU and ^{124}I-RAIU. The impact of the length of RI (as surrogate of the scanning duration) was assessed for the five ^{124}I-PET reconstruction algorithms in terms of consistency to the ^{131}I-RAIU measurement (Fig. 2). A slightly modified version of the Bland-Altman method was applied to estimate the degree of consistency between the ^{131}I-RAIU (considered clinical standard) and ^{124}I-RAIU determined by means of the five different reconstruction algorithms (*11*). In short, relative uptake differences were calculated between ^{124}I-RAIU and ^{131}I-RAIU. A subanalysis was performed splitting the patients into two subgroups, one without and the other one with retrosternal thyroid tissue (Figs. 2B and 2C).

Image Quality. Two image quality aspects were considered. First, visual inspection of the ^{124}I-PET/CT images was performed for the different RI and reconstruction algorithms but not routinely analyzed in terms of visual scoring, because visual assessment is subjective. Therefore, we decided to use a second, objective parameter.

It is generally accepted that high pixel noise contributes to low image quality (*12*). In our setting, reducing the RI leads to an increase of pixel noise and in turn decrease of image quality. As an approach to objectify pixel noise we measured SD of the activity concentration within the VOI. Finally, SD and consecutively pixel noise were observed to increase in this study, corresponding with low image quality. This is exclusively influenced by length of RI and reconstruction algorithms. Since the experience in our institution shows that 1MBq ^{124}I at 600s scan time provides sufficient images in all cases, it serves as reference for image quality in this study *(2,3).* We tested a limit of 10% change in SD to obtain images with probable acceptable quality. The length of the RI at an increase of SD ≤10% was defined as RI of acceptability (RI_{acc})

and this corresponds to a hypothetical minimum activity (Fig. 3; Table 2). The image quality is proportional to the PET scanning time and the activity contained in the scan FOV. Doubling the activity of a PET radiopharmaceutical leads to halving the scanning time, and halving the activity contained in the scan volume requires doubling of the scanning time, resulting in the same image quality (*13*). Accordingly, the determination of RI_{acc} allows the calculation of a hypothetical minimum activity (A_{min}) by means of a proportion equation (Equation1):

$$A_{\mathrm{min}} = \frac{1\ MBq}{600\ s} \cdot RI_{\mathrm{acc}}$$

Therefore, in the presented setting of 600s and 1MBq ^{124}I, an RI_{acc} of 300s is equal to a hypothetical activity of 0.5MBq ^{124}I.

RESULTS

Patients

Of 97 patients screened, 56 fulfilled the inclusion criteria and 37 agreed to participate in the study (Table 3). Part of the data was reported in a previous study (*2*). All participants were fully examined according to protocol. The mean orally administered activities were 3.03±0.13MBq for ^{131}I and 1.02±0.03MBq for ^{124}I. Time interval between both administrations was 10.0±3.1 days. On average the ^{131}I-RAIU measurements took place 30 hours±2 minutes and the ^{124}I-RAIU measurements 30 hours±5 minutes after oral administration of the tracer. Mean ^{131}I-RAIU measured after 30 hours was 29.1%±9.8 and mean ^{124}I-RAIU (IT-1; 600s RI) measured after 30 hours was 29.6%±9.1.

Comparison of ^{131}I-RAIU and ^{124}I-RAIU

A comparison of ^{131}I-RAIU and ^{124}I-RAIU for all patients showed a trend towards overestimation by ^{124}I-PET/CT (Fig. 2A). Therefore, a subanalysis for patients without (Fig. 2B) and with retrosternal tissue (Fig. 2C) was performed. Non-retrosternal subgroup showed a very good agreement between the two RAIU measurements. There was hardly any systematic variability irrespective of the RI and algorithm. Retrosternal subgroup displayed higher ^{124}I-RAIU levels for all reconstruction algorithms, revealing a systematic overestimation.

For ^{124}I-PET reconstruction algorithms in all patients (Fig. 2A) and retrosternal subgroup (Fig. 2B), the limits of agreement were fairly concordant; however a slight enlargement is observed for the RI between 10 and 60s. In general, the reconstruction data obtained with the FBP showed a more pronounced enlargement of the limits of agreement compared with the data obtained by IT (Fig. 2).

Image Quality

Fig. 3 shows an exponential increase of SD at shorter RI. This increase is more pronounced for FBP than for IT. The RI_{acc} were reached from 131s to 456s, and the calculated hypothetical minimum activity was reached from 0.22MBq to 0.76MBq (Fig. 3; Table 2). Image quality was still good at 300s (Fig. 4A) but reducing the number of subsets (IT-4) as well as using FBP lowers image quality visually (Fig. 4B).

DISCUSSION

Different radioiodine isotopes are available for thyroid diagnostics. Hybrid imaging leads to additional benefits (connection between anatomy and functional imaging). ^{123}I and ^{131}I require a single photon emission computed-tomography (SPECT)/CT scanner and ^{124}I a PET/CT scanner. However, in many institutions only one of these two types of scanners is available. If it is not possible to use SPECT/CT, ^{124}I-PET/CT forms a suitable alternative.

As the thyroid RAIU is comparably specific and intense, ^{124}I-PET/CT images obtained with low activity are of good visual image quality compared to ^{124}I-PET/CT performed in patients with differentiated thyroid cancer in a metastasized situation after thyroid removal and/or remnant ablation. Moreover, recent ^{124}I-RAIU measurement studies indicate that activities of

1MBq and a scan time of 600s generate a visually sufficient image for diagnostics and allow reliable RAIU measurement (*2,3*). Concerning radiation exposure of ^{124}I-RAIU evaluation with 1MBq, a thyroid uptake of 25% of is associated to an effective whole-body equivalent dose of ~6.5mSv considering that ~0.3mSv are contributed by the low-dose CT, and a thyroid organ dose of 260mGy (*8*,*14)*. In comparison, the effective whole-body equivalent dose resulting from ^{131}I-RAIU evaluation with 3MBq is ~33mSv, the thyroid organ dose is 1290mGy (*8,14)*. Therefore, radiation exposure caused by ^{124}I-RAIU is approximately one fifth of that of ^{131}I-RAIU measurement. However, the radiation exposure aspect is somewhat relative, concerning the following RAIT. Moreover, in the past activities of as low as 0.2MBq have been shown to be sufficient for ^{131}I-RAIU measurement *(15)*. In the presented setting, standard activities of 3MBq ^{131}I were used according to current guidelines (*9,10)*. However, ^{124}I activity reduction may be desirable for the purpose of decreasing inherent material costs. The present study sought to verify the effects of a hypothetical reduction of ^{124}I activity on ^{124}I-RAIU and pixel noise aspect, as well as the role of different reconstruction algorithms. The investigational use of different activities was unfeasible due to clear methodological constraints in the face of an additional exposure burden for individual participants; therefore we chose an indirect methodological approach determining hypothetical minimum activities.

Simulating different scan times with the help of list-mode data has already been used in studies aimed at assessing the optimal activity for pediatric ^{18}F-Fluorodeoxyglucose-PET; however, the reconstruction times were limited to 1 to 5 minutes (*13*). A phantom study with ^{18}F-Fluorodeoxyglucose examined the relationship of image quality with (simulated) acquisition times, but only with intervals of 1 to 4 minutes (*16*). The present study differs from the above publications in that not only ^{124}I was used, but also a larger time span with more time intervals.

Comparison of ^{131}I-RAIU and ^{124}I-RAIU

Mean ^{124}I-RAIU and ^{131}I-RAIU were fairly concordant. Length of RI and reconstruction algorithms did neither influence the level of agreement nor the standard deviation of the measured RAIU (Fig. 2). An RI of as short as 10s (corresponding to an activity of 0.017MBq ^{124}I, Equation 1) did not show a difference between mean ^{124}I-RAIU and ^{131}I-RAIU. However, images of 10s RI are visually insufficient (Fig. 4A). Therefore, the difference between ^{124}I-RAIU and ^{131}I-RAIU cannot be used as a parameter to determine a reasonable lower limit for ^{124}I activity.

The subgroup analysis separately investigating patients without and with retrosternal thyroid tissue proved that the slight trend to higher ^{124}I-RAIU is caused by patients with retrosternal tissue only (Fig. 2). In fact, ^{131}I-RAIU measurement may be associated to some gamma absorption in the sternum and hence in underestimation of RAIU. In addition, ^{131}I-RAIU measurement may not completely include the whole retrosternal part as positioning is not image guided, probably resulting again in underestimation of the RAIU. ^{124}I-RAIU measurement, in contrast, always identifies possible retrosternal portions and includes them in the RAIU measurement. The trend to higher ^{124}I-RAIU was more pronounced at shorter RI (10s to 60s), leading to a slight statistic deviation. This finding is difficult to assess, an explanation lies conceivably in the IT calculation model.

Image Quality

The impact of the RI length on the increase of pixel noise was examined as a parameter of image quality, given that very short scanning times (simulated by short RI) are associated to a higher background noise and poorer image quality (*17-20*). The concept of using increase of SD as a parameter of image quality was chosen because an exact assessment of image quality with parameters such as spatial resolution, signal-to-noise-ratio or noise equivalent count rate was not applicable to the underlying in-vivo data (*21,22*). These parameters can only reliably be determined using a phantom with defined structures of focal hot and cold spots of different sizes.

A modified neck-shaped Jaszczack-phantom meeting the needs of the proposed study setting is currently constructed in our clinic and corresponding studies are planned.

During the last years, we used 1MBq ^{124}I for imaging of benign thyroid diseases in unclear situations with guideline-conform thyroid diagnostics *(2,3)*. Based on these experiences, we know that activities as low as 1MBq produce high-quality PET/CT images which are able to clearly depict thyroid metabolism and are sufficient for image fusion with ultrasound (*23,24*). As a deviation of +/-10% in terms of applied activity is usually accepted in nuclear medicine, we allowed 10% increase of SD of mean uptake with regard to the 600s RI which is the locally established reconstruction algorithm. Increase of SD was considered a surrogate parameter for pixel noise and thus, representing image quality. The length of the RI at which all patients show an increase of SD≤10% is 287s for IT-1 and this corresponds to a hypothetical minimum activity of 0.48MBq (Table 2). Thus, it can be concluded that activities as low as 0.5MBq might be sufficient for good quality images.

Visual interpretation in terms of visual scoring was not in the focus of the current study. However, it is important to look at these images because diagnostics rely on visual assessment. The influence of different RI and reconstruction algorithms is shown exemplarily for one patient (Fig. 4). Given that ^{124}I-PET/CT can be used for PET/ultrasound fusion imaging, it is very important to obtain a sufficiently high image quality (*23,24*). Images with an RI of 300s still are appropriate to clearly define thyroid metabolism in the chosen example (Fig. 4A). Decreasing the RI length leads to a significant loss in image quality. As expected, it can be concluded that FBP is inferior to IT with regard to image quality which has been extensively reported previously (*25,26*). Additionally, the reduction of equivalent iterations i.e. the product of iterations and subsets (IT-4), softens the image on the one hand, but leads to an increase of blurring and therefore reduction of image quality on the other hand (*27-29*). IT-1 to IT-3 do not differ with regard to image quality; therefore, we assume that zoom and matrix do not influence the image quality directly.

Limitations

The present study has some clear limitations. The number of patients was limited and the benign thyroid diseases were of different nature. As this research was designed as an initial subanalysis within a larger study, results were valid only for a timepoint of 30 hours after radioiodine administration. Kinetic information (i.e. information on effective half-life) which would be available in the case of multiple RAIU measurements was not obtained in the present data. As comparison with intratherapeutic measurements was not carried out, conclusions on the superiority of ^{124}I-RAIU on ^{131}I-RAIU are not possible. Since the study focused on activity aspects, functional topography of hypo- or hyperfunctional areas was not systematically considered. These aspects are nonetheless very important for the use of PET/CT or PET/ultrasound image fusion. Finally, a routine ^{124}I-RAIU measurement is hindered by several factors. The use of ^{124}I-PET/CT is complex and not ubiquitously available and, compared with ^{131}I-probe, considerably more expensive regarding ^{124}I-PET/CT examination time and the higher price for ^{124}I, which is about 20% above the cost for ^{131}I in our institution. The use of very low activities might be a possibility to contribute to cost reduction (*2*).

CONCLUSION

In summary, the present study confirmed the potential of ^{124}I-PET/CT as alternative method for RAIU measurement in patients with benign thyroid diseases, and this irrespective of additional benefits such as functional anatomy aspects, reliable volumetry, and possibility to perform image fusion with ultrasound. A hypothetical activity reduction to approximately 0.5MBq ^{124}I obtained with the locally established reconstruction algorithm IT-1 appeared sufficient when considering pixel noise in parallel. Further studies with more timepoints and higher patient number as well as clearly defined disease groups divided by uptake level are warranted, especially if validated by intra-therapeutic measurements.

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Disclosure of conflict of interest

The authors do not have any relevant conflict of interest to disclose.

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TABLES

TABLE 1

	FBP	IT-1	IT-2	IT-3	IT-4
Matrix	512	512	512	128	512
Iterations	N/A	4	4	4	1
Subsets	N/A	24	24	24	12
Zoom	2	2	1	1	2

TABLE 1: Overview of reconstruction algorithms and parameters. FBP, filtered back-projection; IT, iterative technique; N/A, not available. Locally established reconstruction algorithm (IT-1) is emphasized in gray.

TABLE 2

Reconstruction algorithm	RI_{acc}, s	Calculated hypothetical minimum activity of ^{124}I, MBq
FBP	456	0.76
IT-1	287	0.48
IT-2	282	0.47
IT-3	184	0.31
IT-4	131	0.22

TABLE 2. RI_{acc} and calculated hypothetical minimum activity for the different PET reconstruction algorithms. FBP, filtered back-projection; IT, iterative technique; PET, positron emission tomography; RI_{acc}, reconstruction interval of acceptability. Locally established reconstruction algorithm (IT-1) is emphasized in gray.

TABLE 3

Characteristic	Value	
Age, years	Median (range)	75 (52-85)
	Mean±SD	73.3±7.3
Females, n (%)		24 (64.9%)
Thyroid disorder, n (%)	Unifocal autonomy	6 (16.2%)
	Multifocal autonomy	18 (48.6%)
	Non-toxic goiter	13 (35.2%)
Thyroid volume, ml	Median (range)	87.5 (24-299)
	Mean±SD	103±60
Retrosternal part, n (%)		12 (32.4%)
TSH, mU/ml	Median (range)	
	before ^{131}I-RAIU measurement	0.33 (0.01-2.86)
	before ^{124}I-RAIU measurement	0.33 (0.01-2.71)
	Mean±SD	
	before ^{131}I-RAIU measurement	0.54±0.84
	before ^{124}I-RAIU measurement	0.52±0.77

TABLE 3: Patients' characteristics. TSH, thyroid stimulating hormone; SD, standard deviation.

FIGURES/ FIGURE LEGENDS

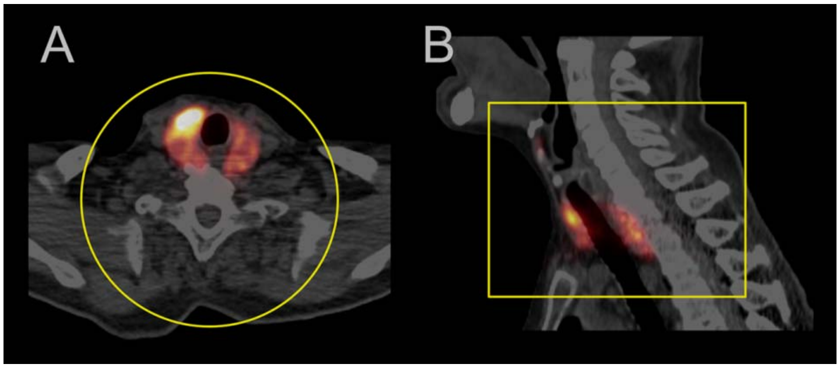

FIGURE 1: Transversal (A) and sagittal (B) ^{124}I-PET/CT images (IT-1 reconstruction; 600s). Cylinder-shaped VOI (yellow line).

IT, iterative technique; ^{124}I-PET/CT, ^{124}Iodine positron emission tomography-computed tomography; VOI, volume-of-interest.

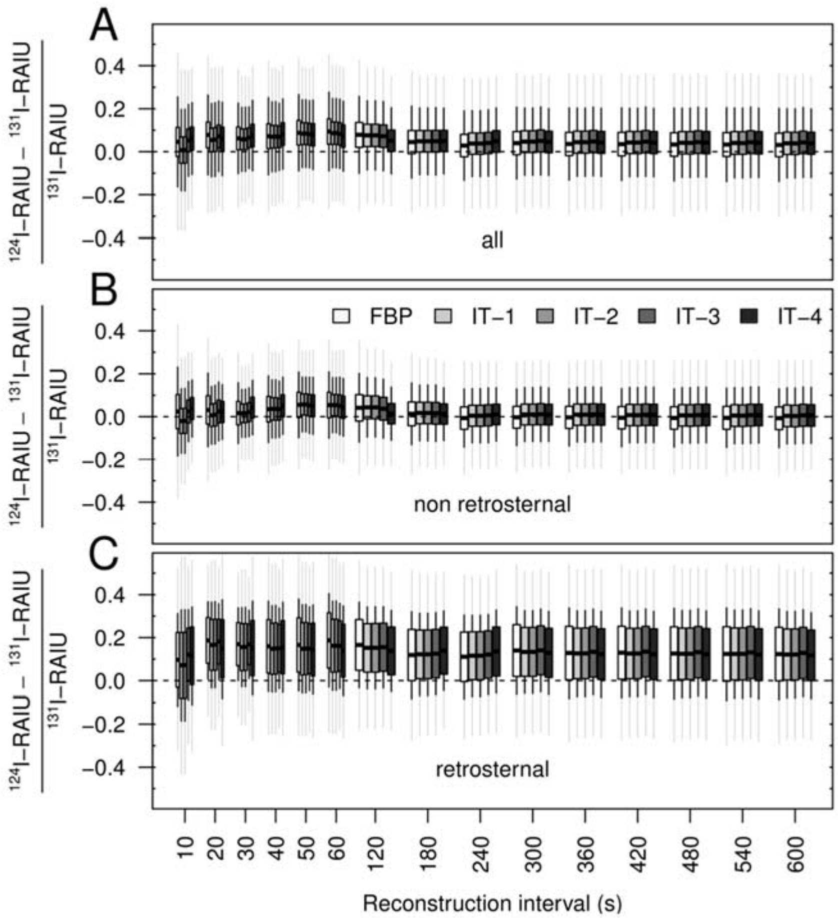

FIGURE 2: Relative uptake differences of ^{124}I-PET from ^{131}I-probe (clinical standard, line of equality at “0”) for all patients (A) as well as for the subgroups without (B) and with (C) retrosternal tissue. Modified Bland-Altman plots show relative uptake differences (equation shown as y-axis label) for five different ^{124}I-PET reconstruction algorithms at 15 reconstruction intervals. Boxes and horizontal lines show the mean relative uptake difference and its 95% confidence interval. If the box includes the line of equality there is no systematic over- or underestimation. The thin grey line of the whiskers represents the 95% limits of agreement according to Bland-Altman (1.96-fold SD), whereas the thick black line of the whiskers shows common SD.

FBP, filtered back projection; IT, iterative technique; ^{124}I-PET, ^{124}Iodine positron emission tomography; RAIU, radioiodine uptake.

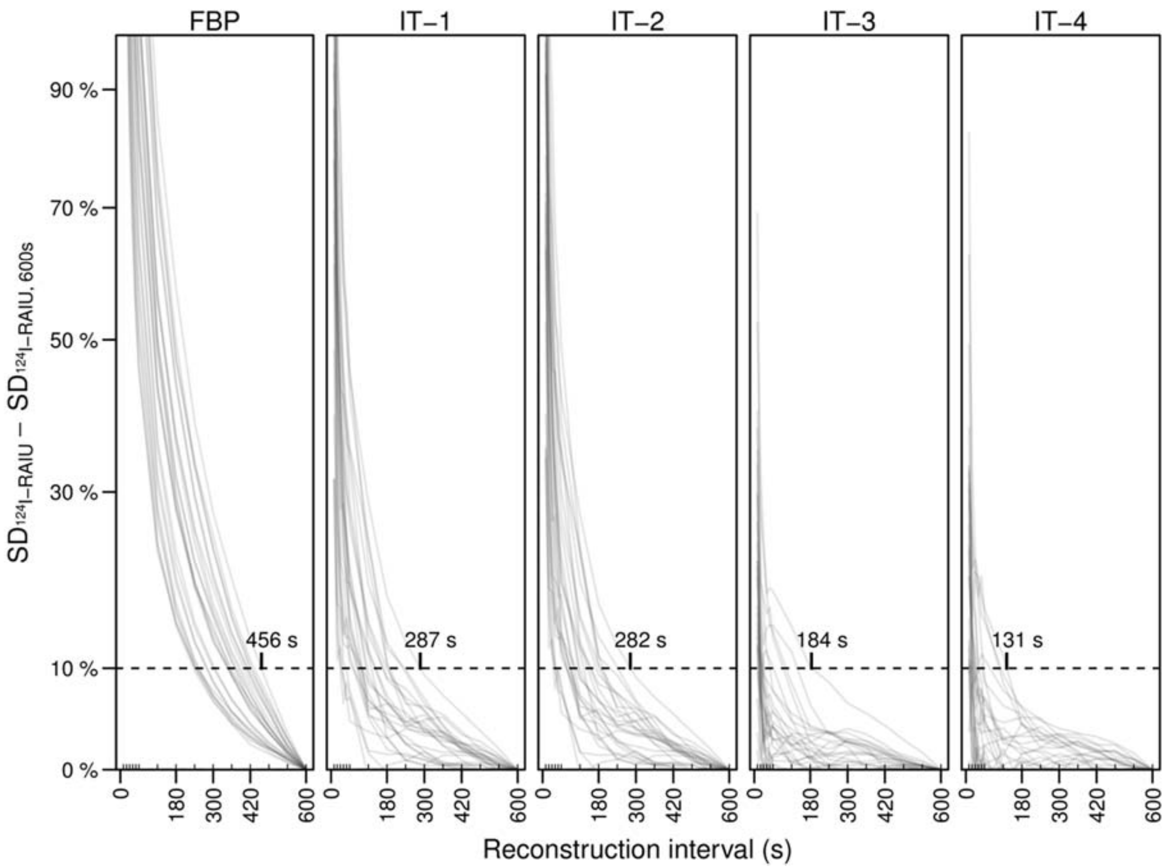

FIGURE 3: Difference between SD of ^{124}I-RAIU and SD of ^{124}I-RAIU at 600s depending on length of RI and reconstruction algorithms. Each patient was plotted separately as one grey line. Image quality was considered acceptable if the increase of SD of all scans remained ≤10%, the length of the RI at which this criterion was met was defined as RI_{acc}.

FBP, filtered back-projection; IT, iterative technique; RAIU, radioiodine uptake; RI_{acc}, reconstruction interval of acceptability; SD, standard deviation.

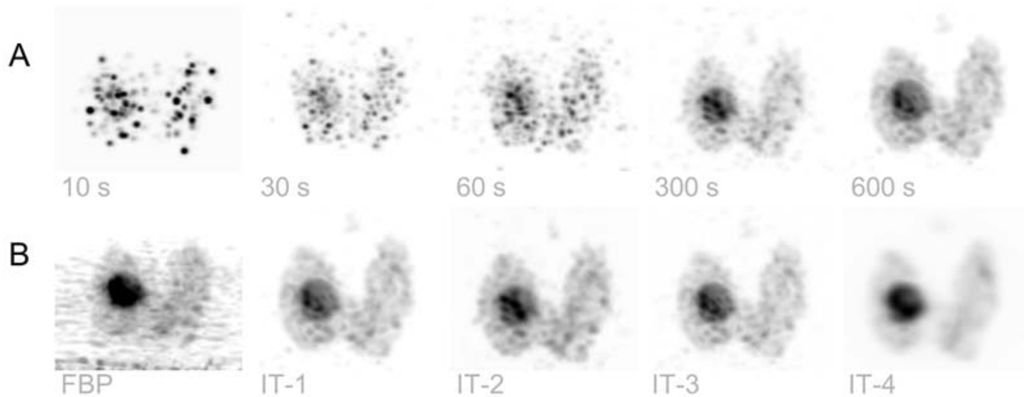

FIGURE 4: Maximum intensity projection of ^{124}I-PET of a patient with autonomous adenoma according to reconstruction interval (A) and algorithm (B).

FBP, filtered back projection; ^{124}I-PET, ^{124}Iodine positron emission tomography; IT, iterative technique.