How does iterative reconstruction influence image quality and dose in CT for evaluation of potential renal donors?

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Aims and objectives

Due to an extensive shortage of available cadaveric organs for transplantation purposes [1], living related donor kidney allografts play an important and growing role in transplantation [2]. Potential renal donors have to undergo an extensive medical evaluation before deemed suitable as actual donors. In most transplantation centers, this work-up includes CT scans prior to operation in order to find possible criterions for exclusion such as most organ illnesses and to evaluate the anatomical status (vascular conditions, e.g. additional vessels) [3,4]. These potential donors are anamnestically healthy people that are exposed to a non-negligible radiation dose. In order to minimize any risk involved in the application of x rays, the necessary evaluation CT exam should apply the lowest possible radiation dose while remaining adequate image quality that allows to read all information necessary to perform the planned surgery. The consistently growing number of CT scans leads to a rising exposure dose in general public [5]. To minimize any carcinogen risk due to medical radiation, different techniques for dose reduction were developed and successfully implemented in clinical CT routine [6,7]. Recently, iterative reconstruction has become focus of interest as a promising technique for reducing applied radiation dose [8-10].

Aim of this study is the analysis of ASIR (adaptive statistical iterative reconstruction) technique regarding an effective dose reduction and its impact on image quality in evaluation CTs of potential kidney donors.
Methods and materials

Patients and study design:

Over a 7-month period from 5/2013 until 11/2013 a prospective study was conducted at our university hospital that analyzed a total of 53 patients who were subjected to CT scans of their abdomen prior to a possible kidney donation. These anamnestically healthy subjects were randomly divided into 2 groups:

Group A (n=26) was examined with an adaptive statistical iterative reconstruction (ASIR) protocol, with application of 40% ASIR in the raw data material.

Group B (n=27) was examined using a standard filtered back projection (FBP) protocol and served as a control group.

Group matching:

Both patient groups were analyzed concerning statistically significant differences regarding body diameter and scan length.

CT examination:

All examinations were performed with a 64-slice multi-detector CT scanner (Lightspeed VCT, GE Healthcare, Milwaukee, USA). A split bolus technique was used, applying 20 ml of contrast agent 7 minutes prior to scanning and an additional bolus of 100 ml right before scanning using arterial bolus tracking. Thus not only the vascular situation but also the urinary system could be evaluated in a 2 phase CT examination (arterial phase: delay 30 s and venous phase: delay 100 s). Image acquisition was conducted with the following parameters: tube voltage: 120 kV, collimation: 64 x 0,625 mm, pitch: 1,375, noise index: 15, tube current modulated automatically (min. 100 mA and max. 500 mA).

Data Analysis

Both quantitative and qualitative image analysis was performed. Former was achieved by drawing a region of interest (ROI) in 18 different defined organ regions. The obtained attenuation values (in HU) then were analyzed by calculating signal-to-noise (SNR) and different contrast-to-noise (CNR) ratios.

Qualitative analysis was performed by two blinded radiologists who assessed image quality. Image quality was evaluated in five categories: noise, contrast, artifacts, detectability of small structures and overall diagnosability. Each category was evaluated
separately by using a five-point Likert scale. Technical information on the image was obscured in order to reduce expectation bias.

For radiation dose estimation, the CTDIvol and DLP values were recorded and effective dose was calculated by multiplying DLP values by an age-specific conversion factor being 0.017[1] on page for the analyzed body region.

Statistical analysis

Statistical analysis was performed using SPSS Statistics, version 19 (SPSS Inc, Chicago, IL). Ordinal data were tested for significance using the Mann-Whitney U-test. Interval data were tested using an independent t-test with 95% confidence intervals. Descriptive data are given as mean values and standard deviations. Statistical significance was assumed at a $p$-value of $< 0.05$.

[1] on page This factor derives from the recommendations of publication no. 60 and no. 103 of the International Commission on Radiological Protection (ICRP).
Results

Group matching:

There were no statistically significant differences between group A and B concerning maximal frontal plane body diameter, maximal sagittal body diameter, frontal plane body diameter obtained at portal vein level, sagittal body diameter at portal vein level and scan range.

Quantitative image grading:

Mean SNR in group A was significantly higher than in group B. CNRs for renal cortex vs. renal parenchyma, renal cortex vs. fat tissue, renal parenchyma vs. fat tissue, renal arteries vs. fat tissue and ureter vs. fat tissue were slightly higher in group A without statistically significant difference (see Tab.1).

Qualitative image grading:

Mean of both reviewers’ quality ratings was calculated and showed no statistically significant difference. Cohen’s kappa test showed good (>0.6) to very good (>0.7) interreader agreement. Overall diagnosability as well as artifacts were excellent throughout all cases in both groups (see Tab. 2). Both reviewers agreed that ASIR images delivered a slightly smoother image impression (see Fig. 1) caused for example through a humble softening of sharp bone edges. Subtle findings such as the renal vessel supply could be surely identified using ASIR images (see Fig. 2).

Dose reduction:

In Group A DLP was 478.5 ± 224.6 mGy x cm, in Group B 651.5 ± 377.9 mGy x cm (p = 0.04), correlating to a reduction of about 26 %. Corresponding effective doses were 7.5 ± 3.73 mSv in Group A and 10.1 ± 5.98 mSv in Group B (p = 0.07) (see Tab. 3).

Tab. 1: Quantitative image grading.

SNR: signal-to-noise ratio.

CNR: contrast-to-noise ratio.
<table>
<thead>
<tr>
<th></th>
<th>Group A (ASIR)</th>
<th>Group B (FBP)</th>
<th>p values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SNR Liver</strong></td>
<td>14.40 ± 5.05</td>
<td>12.38 ± 4.81</td>
<td>p = 0.122</td>
</tr>
<tr>
<td><strong>SNR Pancreas</strong></td>
<td>11.29 ± 3.99</td>
<td>9.31 ± 4.46</td>
<td>p = 0.088</td>
</tr>
<tr>
<td><strong>SNR Renal-cortex</strong></td>
<td>25.55 ± 10.04</td>
<td>20.50 ± 7.80</td>
<td>p = 0.055</td>
</tr>
<tr>
<td><strong>SNR Renal-parenchyma</strong></td>
<td>14.38 ± 5.37</td>
<td>11.48 ± 4.91</td>
<td>p = 0.046</td>
</tr>
<tr>
<td><strong>SNR Ureter</strong></td>
<td>106.07 ± 47.41</td>
<td>80.72 ± 39.09</td>
<td>p = 0.083</td>
</tr>
<tr>
<td><strong>SNR Bladder</strong></td>
<td>3.70 ± 5.81</td>
<td>3.01 ± 3.69</td>
<td>p = 0.970</td>
</tr>
<tr>
<td><strong>SNR Mean</strong></td>
<td>27.03 ± 10.80</td>
<td>21.24 ± 8.82</td>
<td>p = 0.042</td>
</tr>
<tr>
<td><strong>CNR renal cortex - renal parenchyma</strong></td>
<td>11.21 ± 5.08</td>
<td>9.01 ± 3.73</td>
<td>p = 0.088</td>
</tr>
<tr>
<td><strong>CNR ureter - fat tissue</strong></td>
<td>120.01 ± 60.48</td>
<td>92.09 ± 42.24</td>
<td>p = 0.073</td>
</tr>
<tr>
<td><strong>CNR renal cortex - fat tissue</strong></td>
<td>39.49 ± 14.45</td>
<td>32.44 ± 11.37</td>
<td>p = 0.094</td>
</tr>
<tr>
<td><strong>CNR renal parenchyma - fat tissue</strong></td>
<td>28.32 ± 9.83</td>
<td>23.42 ± 8.70</td>
<td>p = 0.075</td>
</tr>
<tr>
<td><strong>CNR renal arteries - fat tissue</strong></td>
<td>55.79 ± 22.11</td>
<td>51.66 ± 22.39</td>
<td>p = 0.488</td>
</tr>
</tbody>
</table>

**Tab. 2: Qualitative image grading.**

Scores are given as mean of both reviewers` analyses.

<table>
<thead>
<tr>
<th></th>
<th>Group A (ASIR)</th>
<th>Group B (FBP)</th>
<th>p values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Interreader agreement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kappa value</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>noise</strong></td>
<td>4.30 (3-5)</td>
<td>4.35 (3-5)</td>
<td>p = 0.766</td>
</tr>
<tr>
<td><strong>contrast</strong></td>
<td>4.28 (3-5)</td>
<td>4.35 (3-5)</td>
<td>p = 0.552</td>
</tr>
<tr>
<td><strong>small structures</strong></td>
<td>4.42 (4-5)</td>
<td>4.54 (3-5)</td>
<td>p = 0.219</td>
</tr>
<tr>
<td>artifacts</td>
<td>5</td>
<td>5</td>
<td>p = 1</td>
</tr>
<tr>
<td>overall diagnosability</td>
<td>5</td>
<td>5</td>
<td>p = 1</td>
</tr>
</tbody>
</table>

5= excellent image quality - 1= nondiagnostic image quality
(range) = min and max of range.

**Tab. 3: Applied Dose.**

Total DLP and estimated effective dose.

<table>
<thead>
<tr>
<th>Dose</th>
<th>Group A (ASIR)</th>
<th>Group B (FBP)</th>
<th>Difference in %</th>
<th>p values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total DLP (mGy x cm)</td>
<td>478.5 ± 224.6</td>
<td>651.5 ± 377.9</td>
<td>26.6</td>
<td>p = 0.048</td>
</tr>
<tr>
<td>Effective Dose (mSv)</td>
<td>7.5 ± 3.73</td>
<td>10.1 ± 5.98</td>
<td>25.2</td>
<td>p = 0.070</td>
</tr>
</tbody>
</table>
Fig. 1: Fig. 1: A) ASIR image. B) FBP image. Image quality of both shown patients was rated excellent. All subtle structures could be evaluated clearly. Visual impression of ASIR image appears to be slightly smoother than FBP.

Fig. 2: Fig. 1: A) ASIR image. B) FBP image. Image quality of both shown patients was rated excellent. All subtle structures could be evaluated clearly. Visual impression of ASIR image appears to be slightly smoother than FBP.

Fig. 3: Fig. 2: MIP (A) and 3D (B) reconstruction of the kidney region illustrate double renal artery supply as an important information for potential transplanation, reliably detected using 40% ASIR with reduced radiation exposure.

Conclusion

Reducing radiation dose while improving or at least maintaining adequate diagnostic image quality is a main goal in recent CT technique development. Raising numbers of CT examinations worldwide show the need for a significant decrease in radiation exposure. While there were only about 3 million CT scans in the United states in the early 80’s, this number has grown to almost 80 million in 2010 with an estimated growth of 8-10 % per year [11]. A similar trend is observed in Europe [12]. Since CT exams are responsible for almost 50 % of all applied medical radiation [13], there is a growing debate about possible associated risks involving the development of malign illnesses [14,15].

A promising approach to reduce radiation exposure is the statistical iterative reconstruction technique (IR). Different CT manufacturers use their own reconstruction algorithms that are based on the aforementioned recalculation of the obtained FBP image information.

To our knowledge, our study is the first one to show that in the evaluation CT of healthy potential kidney donors, ASIR 40 % does not lead to any loss of image quality or any relevant problems in image reading. Delicate structures such as the exact course of a doubled renal artery supply could be evaluated without any challenge (see Fig. 2). Moreover, the IR technique allows a possible dose reduction of about 26 percent, correlating well with previously published studies [18] and supposedly reflecting a realistic potential of dose saving.

Especially when imaging young and healthy individuals, it is essential to keep radiation exposure to a minimum. These requirements fully apply to the examined group of potential kidney donors being a relatively young subject collective without any known diseases. Our results suggest that ASIR can contribute to that goal.

ASIR can contribute to a relevant dose reduction without any loss of image quality in CT scans for evaluating healthy potential kidney donors.
References

This eposter contains text parts, tables and image material from the article Kahn J et al. CT for evaluation of potential renal donors - how does iterative reconstruction influence image quality and dose? Eur J Radiol. 2014;83(8):1332-6.


