Knowledge based iterative reconstruction technique reduces noise and improves image quality for low dose thyroid CT

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Aims and objectives

Introduction

Compared to ultrasound (US), computed tomography (CT) is not considered as a conventional approach for thyroid lesion diagnosis. Several articles suggest that lesions which are smaller than 2 cm should be assessed with US, while tumors that are larger than 3 cm and extend outside the gland to adjoining structures need to be assessed with CT imaging [1], and CT imaging can be helpful for observation of lymph node metastasis of central group [2]. But at the same time, thyroid is susceptible to injury from radiation and radiation could be a causative factor in thyroid cancer. Recent investigations indicated that increasing of diagnostic exposures, especially high dose CT examination of head and neck may have a causative relationship with the increasing of thyroid cancer incidence [3,4]. Therefore, low dose techniques for thyroid CT is valuable and urgently needed.

Knowledge based iterative reconstruction technique (IMR, Philips Healthcare) is a new fully model-based iterative reconstruction technique, recent research [5] have indicated that it can simultaneously reduce CT radiation dose and improve image quality for mainly of body parts. In this study, we applied IMR in the realm of low dose thyroid CT imaging and aimed to evaluate its benefit for image quality improvement.
Methods and materials

Patients

This study was approved by the local institutional review board and informed consent was obtained from all participating patients. 107 patients were prospectively enrolled for a low dose carotid angiography study between February 2013 and September 2013 at the Department of Radiology, First Affiliated Hospital of China Medical University. Among them 19 patients (mean age, 45±7 years; male/female=7/12) with 23 thyroid nodules were retrospectively recruited into our study. The mean body mass index (BMI) of them was 21.3± 2.4 kg/m². Patients were considered ineligible for the study if they presented with any of the following criteria at baseline: severe renal inadequacy (creatinine clearance rate, #120µmol/L), pregnancy, known allergies to iodinated contrast agent.

CT Acquisition Protocol

All 19 patients underwent low dose carotid angiography with a 256-slice MSCT (Brilliance iCT, Philips Healthcare, Cleveland, OH, USA). Automatic bolus tracking (Bolus Pro, Philips Healthcare) was used with a region of interest (ROI) in the ascending aorta at the level of the pulmonary artery, then scans initiated under full inspiration 4 seconds after a predetermined signal attenuation threshold of 150 HU was attained. Contrast media (50-60mL; Iopromide; Ultravist 370, Bayer Healthcare) was IV injected at a flow rate of 4-5 mL/s into the patient's antecubital vein through a double tube high-pressure syringe. The carotid CTA scan parameters were as follows: tube voltage, 120 kVp; effective tube current-time product, 60mAs, pitch, 0.16; detector configuration, 128 ×0.625 mm; rotation time, 270 ms; slice thickness, 1.0 mm; slice increment, 0.5 mm. At the same time, a dynamic collimator (Eclipse DoseRight Collimator, Philips Healthcare) which reduces excessive radiation exposure caused by z-over scanning were used to decrease radiation dose. All images were reconstructed by conventional filtered back projection (FBP) technique, hybrid iterative reconstruction (iDose⁴, Philips healthcare) and IMR for thyroid kernel, respectively.

Image Analysis

All images were transferred to a commercially available workstation (Extended Brilliance Workspace, v4.01, Philips Healthcare). Images were displayed in the soft tissue setting (window level, 60 HU; window width, 150 HU) for evaluation.

Objective assessment was performed on CT images reconstructed by 3 different kinds of techniques. A 30-50 mm² ROI was place within thyroid nodules, the CT value (in
Hounsfield units) within the ROI was measured and its SD was used as the image noise of thyroid nodule. The CT value of erector spinae at the same level was measured using the same size of ROI. Contrast-to-noise ratio (CNR) were calculated by the following formula: 
\[ \text{CNR} = \frac{\text{thyroid nodule Hounsfield units} - \text{erector spinae Hounsfield units}}{\text{image noise of thyroid nodule}}. \]

In addition, subjective assessment of image quality was evaluated by 3 radiologists double-blindly. The image quality was evaluated using a 5 point scale (5 = excellent image quality with very good contrast and very good demarcation of structures, noise free; 4 = good image quality with good contrast and good demarcation of structures, slight increase in noise or artifact; 3 = moderate image quality, moderate increase in noise or artifact; 2 = poor image quality with blurred demarcation of structures, severe increase in noise or artifact; 1 = unassessable).

**Radiation Dose Analysis**

Total dose-length product (DLP) which represents the total absorbed dose for all the scans were recorded. Estimated effective dose (ED) was calculated from the product of the DLP and a conversion coefficient \( k(ED = DLP \times k) \), \( k \) is the conversion coefficient for the neck \( (k = 0.0059 \text{ mSv mGy}^{-1} \times \text{cm}^{-1}) \) [6].

**Statistical Analysis**

Statistical analysis was performed using commercially available software (SPSS for Windows, version 17.0). Continuous variables were expressed as mean ± standard deviation. Image noise, SNR, CNR and image quality scores were analyzed by One Way ANOVA test. A p value of less than 0.05 was considered to represent a statistically significant difference.
Results

Both IMR and iDose\(^4\) reduced image noise and improved image quality than FBP significantly, while IMR performed better than iDose\(^4\). CNR increased on both IMR and iDose\(^4\) images than FBP, but there was no difference in CNR between IMR and iDose\(^4\) images (see Table 1). Compared with FBP, both IMR and iDose\(^4\) can display more details of thyroid lesions and largely reduced cervical artifacts, especially IMR can provide much better contrast and demarcation of structures for thyroid lesions (see Fig 4). The mean dose-length product and estimated effective dose of low-dose thyroid CT was 162.3 ± 33.6 mGy·cm, and 0.96 ± 0.20 mSv, respectively. This is about 50% reduced compared with standard dose.

Table 1 Comparison of image noise, CNR and image quality between FBP and iterative reconstructions

<table>
<thead>
<tr>
<th></th>
<th>FBP</th>
<th>iDose(^4)</th>
<th>IMR</th>
<th>p</th>
<th>p</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image noise (HU)</td>
<td>26.0±12.4</td>
<td>20.7±13.7</td>
<td>18.0±11.5</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>CNR</td>
<td>2.81±1.28</td>
<td>3.98±2.15</td>
<td>4.72±2.51</td>
<td>&lt;0.05</td>
<td>&lt;0.01</td>
<td>0.209</td>
</tr>
<tr>
<td>Image quality</td>
<td>3.12±0.73</td>
<td>3.56±0.87</td>
<td>4.08±0.86</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

The comparisons of image noise, CNR and image quality were performed by One Way ANOVA test, pairwise comparisons were made by LSD test.
Fig. 1: Comparison of objective image noise measurements. Group 1 = FBP, Group 2 = iDose4, Group 3 = IMR

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Fig. 2: Fig.2 Comparison of CNR measurements Group1=FBP, Group=iDose4, Group3=IMR

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Fig. 3: Comparison of subjective image quality scores. Group 1 = FBP, Group 2 = iDose4, Group 3 = IMR.

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Fig. 4: (A) FBP, (B) iDose4, and (C) IMR images in a 33 year-old woman with thyroid cystic lesions. Image quality score for the lesions on FBP and iDose4 are both graded
4, while on IMR is graded 5. Objective image noise measured is 28.6 on FBP, 18.6 on iDose4, and 16.9 on IMR images in this patient.

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Conclusion

Both IMR and iDose\textsuperscript{4} allows a major noise reduction and significant image quality improvement in low dose thyroid CT than conventional FBP reconstruction. IMR shows greater potential than iDose\textsuperscript{4} for providing diagnostically acceptable low-dose CT without compromising image quality, and may provide more details of thyroid nodules for radiologists.
References


