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Unenhanced computed tomography for normal appendix detection: comparison of low-dose with statistical iterative reconstruction and regular-dose with filtered back projection

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ABSTRACT

Purpose: To evaluate the differences in visualization of a normal appendix between regular-dose (RD) and low-dose (LD) unenhanced CT.
Material and methods: 179 patients underwent both RDCT and LDCT for urolithiasis. Two reviewers evaluated the appendiceal visualization on a three-point scale. Sensitivities and interobserver agreement were measured.
Results: There were no significant differences between RDCT and LDCT in sensitivity, regardless of the reviewer. Interobserver agreement was excellent in both RDCT and LDCT.
Conclusion: Unenhanced LDCT is a good tool for detecting a normal appendix and is also useful for less experienced interpreters who are unfamiliar with using LDCT images.

1. Introduction

Acute appendicitis is the most common abdominal emergency, and its overall lifetime risk is 8.6% for males and 6.7% for females in the United States [1]. Computed tomography (CT) is a highly accurate and effective examination with high reproducibility and ease of practice, and its diagnostic performance is >95%, even without the use of oral or intravenous contrast material [2,3]. Currently, CT is the most commonly used primary imaging modality for assessment of suspected appendicitis [4–6]. CT also plays a pivotal role in suspected appendicitis when sonographic findings are equivocal or when a clinical concern for appendicitis remains despite a negative sonographic examination [6–8].

As CT has become more widely used to diagnose acute appendicitis, the concern about radiation hazard has increased. Thus, some investigations have been performed to decrease the radiation dose of CT. This has resulted in a low-dose CT protocol for the evaluation of normal appendix or acute appendicitis and low-dose CT protocol has been not inferior to regular-dose CT protocol [3,9,10]. However, the application of low-dose CT for acute appendicitis is still limited due to concern about misdiagnoses caused by excessive image noise and poor image quality.

In recent years, iterative reconstruction (IR) algorithms have been used to reduce radiation doses while maintaining image quality and have replaced the traditional filtered back projection (FBP). Many studies have shown the potential of IR algorithms in a variety of clinical situations [11–16].

The purpose of this study was to evaluate the differences in detection of a normal appendix between regular-dose and low-dose unenhanced CT.

2. Material and methods

This retrospective study was approved by the institutional review board, and the need for patient informed consent was waived.

2.1. Patient population

This study retrospectively reviewed 179 patients who were enrolled in previous studies [16,17] that investigated the usefulness of LDCT in the diagnosis of urolithiasis between December 2012 and May 2013. An appendectomy history of each patient was confirmed through medical record review or telephone interview.

2.2. CT protocols and data reconstruction

All CT examinations were performed with a 256-MDCT scanner (Brilliance iCT, Philips Healthcare, Cleveland, OH, USA). Both regular-dose CT (RDCT; tube voltage of 120 kV and maximal tube current-time product of 150 mAs) and low-dose CT (LDCT; tube voltage of 100 kV and maximal tube current-time product of 100 mAs) were performed on all patients with an automated *Z*-axis dose modulation by the

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scout image (DoseRight, Philips Healthcare), in accordance with the patient's body mass index. The scan range of both RDCT and LDCT was the same, from the proximal aspect of the T12 vertebra to the distal aspect of the symphysis pubis in the supine position. The remaining scanning parameters were as follows: detector configuration, 128 × 0.625; pitch, 0.915; beam collimation, 80 mm; rotation time, 0.4 s; and helical acquisition.

The raw data of the RDCT protocol were reconstructed into axial and coronal images using the FBP algorithm, while the raw data of the LDCT protocol were reconstructed using iDose level 5 (Philips Medical Systems, Best, Netherlands), which is a commercial statistical IR algorithm. All reconstructed section thicknesses and intervals were 3 mm.

2.3. Radiation dose

The effective radiation doses of each protocol were calculated by multiplying the dose-length product measured on the CT scanner with the conversion coefficient (0.015 mSv/mGy/cm) [18]. The reduction in radiation dose was compared between the two scans.

2.4. Image quality assessment: objective image noise assessment

A radiology resident (one of the two reviewers of the diagnostic performance) measured the standard deviations (SDs) of the Hounsfield units (HU) in the skeletal muscle and the subcutaneous fat area at the same level where the ileocecal valve was seen, by placing a region of interest of 80–110 mm^2. The objective image noise was reflected in this SD.

2.5. Image quality assessment: subjective image assessment

Subjective image assessment of each CT scan was rated by a staff radiologist (one of the two reviewers of the diagnostic performance) and blinded to the detailed technical scanning parameters used. All of the images were displayed in a random fashion, and the subjective image assessment was classified as an acceptable or an unacceptable image.

2.6. CT image review: diagnostic performance of appendix visualization and interobserver agreement

All of the CT images were anonymized and randomized. Two reviewers (a second year radiology resident and a staff radiologist who had 14 years of clinical experience in interpretation of body CT images) independently interpreted the images. The reviewers were aware that some patients had undergone an appendectomy; however, they were unaware of the actual number or proportion. The images obtained from the LDCT scans were interpreted first, followed by the images from the RDCT scans after an interval of at least four weeks. The reviewers were allowed to review axial and coronal images and to change the window and level settings to optimize the visualization of the appendices.

Each reviewer evaluated the appendiceal visualization with a three-point scale [10] (grade 0 = not visualized, grade 1 = partly or unsurely visualized, grade 2 = confidently and entirely visualized) and marked the appendix.

2.7. Independent consensus panel

To validate the reviewers' evaluations of the appendiceal visualization, we used a consensus panel composed of three experienced radiologists who did not evaluate the diagnostic performance of the LDCT images. The three experts evaluated the appendiceal visualization with the same three-point scale for the RDCT scans (Fig. 1). Then, they determined if the structure marked by the two reviewers correctly indicated the appendix.

2.8. Statistical analysis

The radiation doses and objective image noise between the RDCT and the LDCT images were compared through paired *t*-tests.

For the diagnostic performance analysis, patients were divided into two groups: one with an appendectomy history (appendectomy group) and one without an appendectomy history (nonappendectomy group). The appendix was regarded as absent in the appendectomy group and as present in the nonappendectomy group. We set two thresholds of appendix visualization. One included grade 1 (partly or unsurely visualized) or 2 (confidently and entirely visualized) as a positive result, while the other one included only grade 2 (confidently and entirely visualized) as a positive result. Patients with true-positive findings were those who had not undergone an appendectomy and whose appendix was visualized on CT. Patients with true-negative findings were those who had undergone an appendectomy and whose appendix was not visualized on CT. Patients with false-positive findings were those who had undergone an appendectomy and whose appendix was visualized on CT. Patients with false-negative findings were those who had not undergone an appendectomy and whose appendix was not visualized on CT. The sensitivity, specificity, negative predictive value, and positive predictive value for appendix visualization were calculated for each reviewer, imaging protocol, and threshold. Clopper-Pearson 95% confidence intervals (CIs) were calculated. The sensitivities of RDCT and LDCT were compared using the McNemar test. A *p*-value <0.05 indicated a statistically significant difference.

The weighted κ statistic was used to calculate the interobserver agreement between reviewers for appendix detection. Kappa values were interpreted as follows: 0–0.20 = poor; 0.21–0.40 = fair; 0.41–0.60 = moderate; 0.61–0.80 = good; 0.81–1.00 = excellent. All statistical analyses were conducted using SPSS version 18.0 (SPSS, Chicago, IL, USA) and STATA version 9.1 (STATA, College Station, TX, USA).

3. Results

3.1. Patient population

Our study population consisted of 121 men and 58 women. The mean age of the patients was 49.8 years (range, 18–86 years). Nineteen of the 179 patients had undergone an appendectomy; these 19 patients were categorized as the appendectomy group, and the remaining 160 patients were classified as the nonappendectomy group.

3.2. Radiation dose

The average effective radiation doses of the protocols were 6.02 mSv (RDCT) and 1.41 mSv (LDCT), exhibiting a statistically significant difference ($p < 0.001$). The effective radiation dose was reduced by 76.6% in LDCT.

3.3. Objective image noise assessment and subjective image assessment

The objective image noise was significantly higher in LDCT than in RDCT (measured in both muscle and fat, $p < 0.001$; Table 1).

In the subjective image assessment, there were no unacceptable images from either RDCT or LDCT. On average, all of the LDCT images had a higher level of noise, which may be considered as the main cause of the decreased diagnostic performance; however, there was no deterioration in subjective image assessment.

3.4. Visualization of the normal appendix

3.4.1. Diagnostic performance by the two reviewers

All of the appendices marked by the two reviewers were determined to be appendices by the consensus panel.