Original Investigation

Impact of Radiation Dose Reduction in Abdominal Computed Tomography on Diagnostic Accuracy and Diagnostic Performance in Patients with Suspected Appendicitis: An Intraindividual Comparison

Corinna Storz, MD, Manuel Kolb, MD, Jong Hyo Kim, PhD, Jakob Weiss, MD, Wolfgang G. Kunz, MD, Konstantin Nikolaou, MD, Fabian Bamberg, MD, MPH, Ahmed E. Othman, MD

Rationale and Objectives: To determine the intraindividual impact of radiation dose reduction in abdominal computed tomography (CT) on diagnostic performance in patients with suspected appendicitis.

Materials and Methods: This study was approved by the institutional review board. Seventy-five patients who underwent standard contrast-enhanced abdominal CT for suspected appendicitis between 2004 and 2009 were retrospectively included. Low-dose CT reconstructions with 75%, 50%, and 25% of the original radiation dose level were generated by applying realistic reduced-dose simulation. Two blinded, independent readers assessed image quality, signal-to-noise ratio, and diagnostic confidence on each dataset. Diagnostic accuracy for detection of appendicitis and complications were calculated for each reader. Paired univariate tests were used to determine intraindividual differences.

Results: Among 75 subjects included in the analysis (57% female, mean age: 41 ± 18 years), the prevalence of histopathologically confirmed appendicitis was 59%. Signal-to-noise ratio and subjective image quality of 50% and 25% reduced-dose CTs were significantly lower than the reference datasets (all $P < .005$). Appendicitis was correctly identified in all reference and low-dose datasets (sensitivity: 100%, negative predictive value: 100%). Presence of complications was correctly detected in all reference, 75%, and 50% datasets, but was decreased in 25% datasets (sensitivity: 77.8% and negative predictive value: 97.4%). Diagnostic confidence was high for original and 75% datasets, but significantly lower for 50% and 25% datasets ($P < .001$).

Conclusions: Our results indicate that diagnostic accuracy in abdominal CT acquisitions acquired at 75% and 50% of radiation dose is maintained in patients with suspected appendicitis, whereas further reduction of radiation exposition is associated with decreased diagnostic performance.

Key Words: Abdominal Imaging; computed tomography; image quality.

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From the Department of Diagnostic and Interventional Radiology, University of Tübingen, Hoppe-Seyler-Straße 3, 72076 Tübingen, Germany (C.S., M.K., J.W., K.N., F.B., A.E.O.); Department of Radiology (J.H.K.); Department of Transdisciplinary Studies, Graduate School of Convergence Science and Technology, Seoul National University, Seoul, South Korea (J.H.K.); Institute of Clinical Radiology, Ludwig-Maximilians-University Hospital, Munich, Germany (W.G.K.). Received August 19, 2017; revised September 10, 2017; accepted September 12, 2017. **Address correspondence to:** F.B. e-mail: fabian.bamberg@uni-tuebingen.de

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INTRODUCTION

Acute appendicitis is one of the most frequent diagnoses in acute nontraumatic abdominal pain, affecting mostly patients in the second and third decade of life, with a cumulative lifetime risk of 9.0% (1–3). Established clinical signs, laboratory blood values, and transabdominal ultrasound may help in confirming or excluding the diagnosis of appendicitis; however, several studies underline the predominant benefit of computed tomography (CT) compared to ultrasound in the diagnostic workup, with excellent sensitivity and

negative predictive value (4). Additionally, previous research reported a decline in negative appendectomy rates, which can be attributed to the use of CT in the diagnostic management of appendicitis (4,5).

Taking into consideration that patients in whom appendicitis is suspected are often young adults or children, the exposure to ionizing radiation is of particular concern, and CT protocols with reduced radiation exposure are mandatory. Although low-dose CT protocols are often associated with a decrease in image quality and thus potential deterioration of diagnostic accuracy, several studies demonstrated no hampering of diagnostic performance for detection of appendicitis in low-dose CT compared to standard-dose CT (6–8). Kim et al. also reported that low-dose CT is noninferior to standard-dose CT with respect to negative appendectomy rates (3.5% vs 3.2%, respectively) (6). However, these and other studies on low-dose CT in patients with appendicitis are based on between-group comparisons without intraindividual reference and without taking into account associated conditions and complications, which may explain the limited implementation of these low-dose CT protocols in clinical practice.

Therefore, the purpose of our study was to determine the intraindividual impact of radiation dose reduction in abdominal CT on diagnostic performance in patients with suspected appendicitis. We therefore used a realistic low-dose simulation technique to generate simulated CT datasets at different radiation dose levels. Our hypothesis was that low-dose CT is comparable to standard-dose CT regarding the detection of appendicitis.

MATERIALS AND METHODS

Subjects and Data Acquisition

All consecutive patients with suspected appendicitis presenting at our institution between 2004 and 2009, after inconclusive ultrasound, were retrospectively identified by searching the clinical information system and were included in the study. All patients underwent contrast-enhanced abdominal CT in the portal venous phase (120 kV, CARE dose reference 200 mAs). Abdominal CT examinations were performed on a 64-slice CT system (Siemens SOMATOM Sensation 64, Siemens AG Healthcare, Erlangen, Germany) with intravenous contrast medium. Intravenous contrast agent (Ultravist 370, Bayer Vital GmbH, Leverkusen, Germany) was applied body weight adapted in an antecubital or hand vein intravenous access through a 20-gauge intravenous access (flow rate 2.2 mL/s) using a dual-syringe injector. Time delay for portal-venous CT acquisition was fixed at 90 seconds after contrast agent injection. Information regarding clinical history, ultrasound and intraoperative surgical findings, as well as postoperative complications were collected from our clinical information system. Inclusion criteria were as follows: (i) clinically suspected appendicitis; (ii) inconclusive ultrasound at admission; and (iii) available abdominal CT. Exclusion criteria were (i) unenhanced CT (eg, due to history of allergic reaction to iodine contrast, renal failure, hyperthyroidism); (ii) nondiagnostic CT data (eg, due to severe artifacts); and (iii) incomplete clinical history or missing surgical or histopathological diagnosis.

Reference Standard

Patients were classified as positive for appendicitis if histopathological findings were positive after appendectomy or the patient improved after medical treatment, for example, with antibiotic administration. Complications accompanying an acute inflammation of the appendix were defined as free intraabdominal air, representing a perforation of the appendix, or periappendiceal encapsulated fluid, defining an abscess formation. Patients were classified as negative for appendicitis if they showed clinical improvement without medical or surgical treatment (except for analgesia) or if intraoperative or histopathological findings were negative for appendicitis after appendectomy.

Low-dose Simulation

For simulating low-dose abdominal CT data, we used a realistic reduced-dose CT simulation method based on a sinogram synthesis and reconstruction technique generated from DICOM CT images (9). This technique can be applied without raw sinogram data or reconstruction systems and enables the generation of realistic noise patterns appearing on low-dose CT. This approach has been previously shown to provide realistic simulation results under reduced-dose conditions with regard to noise magnitude and textural appearance, which were indistinguishable from standard-dose CT (9). Additionally, this technique has been validated previously and enables realistic low-dose images with a sufficient level of accuracy indistinguishable from real low-dose CT (9,10). Using this simulation method, we generated three CT datasets with 75%, 50%, and 25% of the original mAs (radiation) levels to enable intraindividual comparisons of these datasets.

Qualitative and Quantitative Analyses

Two independent blinded readers with 2 (CS) and 3 (MK) years of experience in abdominal CT imaging performed the qualitative and quantitative analyses in axial slices of the original CT images and the 75%, 50%, and 25% dose-reduced images, respectively, using a dedicated postprocessing workstation (syngo.via, Siemens Healthineers, Erlangen, Germany). All datasets were anonymized and evaluated in a random order. The intervals between the assessment of the original CT dataset and the dose-reduced datasets were between 2 and 6 months to reduce recall bias.

For the quantitative analysis, circular regions of interest (ROIs), each with a size of 200 mm^2, were placed in the liver, the major psoas muscle, and the abdominal aorta, assessing the average Hounsfield unit (HU) values of the corresponding tissues. These ROIs were saved as a template set in the