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Comparison of image quality in pediatric head computed tomography reconstructed using blended iterative reconstruction versus filtered back projection ☆

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ABSTRACT

We compared image quality in 44 pediatric head computed tomographic exams reconstructed using four levels of blended iterative techniques (iDOSE 1–4) versus filtered back projection. Three radiologists reviewed the 220 series in a randomized, blinded manner. They scored each series based on gray-white matter differentiation, visibility of the pre-pontine cistern, caudate head, image noise, and image quality. Noise was measured in the vitreous and the thalamus. Composite scores were highest with iDOSE 4 ($P<.0001$). Interobserver agreement was fair to moderate. Spearman's rho of the vitreous (-0.62, $P<.001$) and thalamus (-0.58, $P<.001$) confirmed a significant inverse correlation between iDOSE level and noise.

1. Introduction

Image reconstruction algorithms are fundamental in the generation of diagnostic computed tomography (CT) images, and their application impacts the quality of the generated image [1–3]. In the advent of clinical CT, filtered back projection (FBP) techniques gained favor secondary to their speed and ease of use [4], which are critical factors in the clinical domain. As such, FBP techniques remain the dominant reconstruction algorithm to this day.

Trends toward higher resolution imaging, in particular faster acquisition times and increasing temporal resolution, are juxtaposed against the increasing awareness for limiting radiation dose in accordance with the ALARA principle. Within this context, iterative reconstruction algorithms are being explored as an alternative to traditional FBP, as they offer increased signal to noise ratio for a given dose and decreased artifact [5–8].

Although available since the advent of clinical CT [9], pure iterative reconstruction algorithms require extensive computational power and time [5–8] which previously limited their clinical utility. However, improvements in computational hardware as well as using blended techniques of varying levels of FBP and iterative reconstruction, such as iDOSE (Philips Healthcare, Andover, MA), allows the practical clinical use of iterative techniques today. Particularly within the pediatric population where dose limitation is paramount [10], the ability to decrease noise and photon starvation artifacts for a given dose level should allow the reduction of dose while still maintaining diagnostic image quality. The purpose of our study is to compare subjective measures of image quality and objective measures of noise in pediatric head CT images reconstructed from traditional FBP techniques to varying levels of blended iterative reconstruction. This should help improve diagnostic image quality for pediatric institutions already aggressively practicing the "As Low As Reasonably Achievable" (ALARA) [11] principle of the minimal radiation required for diagnostic imaging, as well as to estimate the possibility of further dose reductions.

2. Materials and methods

2.1. Design

This prospective clinical study was approved by our institutional review board and was conducted in compliance with Health Insurance and Portability and Accountability Act guidelines. 50 consecutive clinically indicated head CT exams were acquired in pediatric patients at Riley Hospital of Indianapolis, Indiana from 10/28/2010 through 12/1/2011 utilizing standard of care imaging protocol on a Philips Brilliance iCT scanner. Exams with intravenous contrast were excluded.

2.1.1. Technique

All head CT exams were obtained helically at 120 kVp and 200 mAs on iCT 128 (Philips Healthcare, Andover, MA, beam collimation 80 mm, pitch 0.923, gantry rotation 0.5sec). Average CTDIvol was 28.0 mGy (26.6–33.3) and DLP was 514.4 mGy (453.7–649.2). Images were reformatted into the axial plane at 5 mm slice thickness with FBP and iDOSE levels 1–4, with higher numbers denoting increased ratios of iterative versus FBP reconstruction. Each iDOSE level is denoted by

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percentage of noise removed, beginning at 10.6% at iDOSE level 1–29.3% at iDOSE level 4 [12].

2.2. Image review

Three radiologists [observers A (6 years of experience), B (4 years of experience) and C (1 year of experience)] independently reviewed the reconstructed series in a blinded and randomized manner, utilizing the same picture archiving and communication system workstation (Fujifilm Synapse 3.2.1, Tokyo, Japan) and the same ambient light settings. The observers scored each series based on 5 parameters – differentiation of gray and white matter, visibility of the pre-pontine cistern, visibility of the caudate head, image noise, and overall image quality – using a five-point ordinal scale, with a score of 5 indicating superior performance.

To evaluate noise, regions of interest (ROIs) of 10mm^2 were obtained during a separate session within the thalamus and vitreous of the eye with recording of the resultant mean and standard deviation in Hounsfield units. The noise within the ventricular system was not measured due to the small amount of cerebrospinal fluid space in some patients, not allowing for an ROI of 10mm^2 without averaging the surrounding periventricular parenchyma.

2.3. Statistical analysis

Given the ordinal results, Wilcoxon rank sum test was used (Vassarstats 2013, Poughkeepsie, NY, USA) to compare each iDOSE level to FBP for each individual reviewer and for combined data. A threshold of $P<.05$ was considered significant. As the subjective nature of the scale included non-diagnostic at the lowest end of the scale and superior quality at the top of the scale with smaller gradations in between, weighted quadratic kappa was used (Vassarstats 2013, Poughkeepsie, NY), USA to assess inter-observer variability. Thresholds of agreement based on κ values were as follows: $\kappa<0.20$ indicated slight agreement, $\kappa=0.20–0.40$ indicated fair agreement, $\kappa=0.41–0.60$ indicated moderate agreement, $\kappa=0.61–0.80$ indicated substantial agreement, and $\kappa=0.81–1.0$ indicated near perfect agreement.

Spearman's rank correlation was performed (Microsoft Excel 2011, Redmond, WA, USA) on the standard deviation measurements obtained from ROI placement within the vitreous and thalamus, with a threshold of $P<.05$ considered significant.

3. Results

A total of 44 exams were included. Six studies were excluded due to presence of IV contrast or excessive motion. A total of 220 series were reconstructed and reviewed. Table 1 summarizes the indications for head CT. Of the 44 exams, there were 35 patients (19 female, 16 male, mean age 7 years, range 0.04–22 years) due to repeat exams on a few patients.

Significantly improved gray–white discrimination was demonstrated for observer A with iDOSE levels 2–4, for observer B with all levels of iDOSE, and iDOSE 3–4 for observer C (Fig. 1). Visibility of the pre-pontine cistern was improved only for observer A with iDOSE 2–4. Improved conspicuity of the caudate head was demonstrated for observer A with iDOSE levels 2–4, and for observers B and C with all levels of iDOSE (Fig. 2). Subjective evaluation of SNR improved for observer A with iDOSE levels 2–4, for observer B with all levels of iDOSE, and for observer C with iDOSE levels 3–4 (Fig. 3). Evaluation of overall image quality improved for observer A with iDOSE levels 2–4, all levels of iDOSE for observer B and only iDOSE 4 for observer C. Findings are summarized in Table 2.

Combined data for all three observers demonstrated improved visibility of the caudate head, gray-white discrimination, signal to noise, and overall image quality for all levels of iDOSE. Visibility of the pre-pontine cistern was improved with iDOSE levels 2–4. Composite scores including all categories were highest for iDOSE level 4 for all observers (Table 3).

Inter-observer variability was graded as fair to moderate between observers A and C, between observers A and B as well as between observers C and B (Table 4).

Table 1
Head CT examinations by clinical indications

Hydrocephalus	16	Intracranial hemorrhage	4
Trauma	5	Headache	3
Congenital malformation	5	Intracerebral cysts	2
Tumor	4	Seizure	1
CNS infection	4		

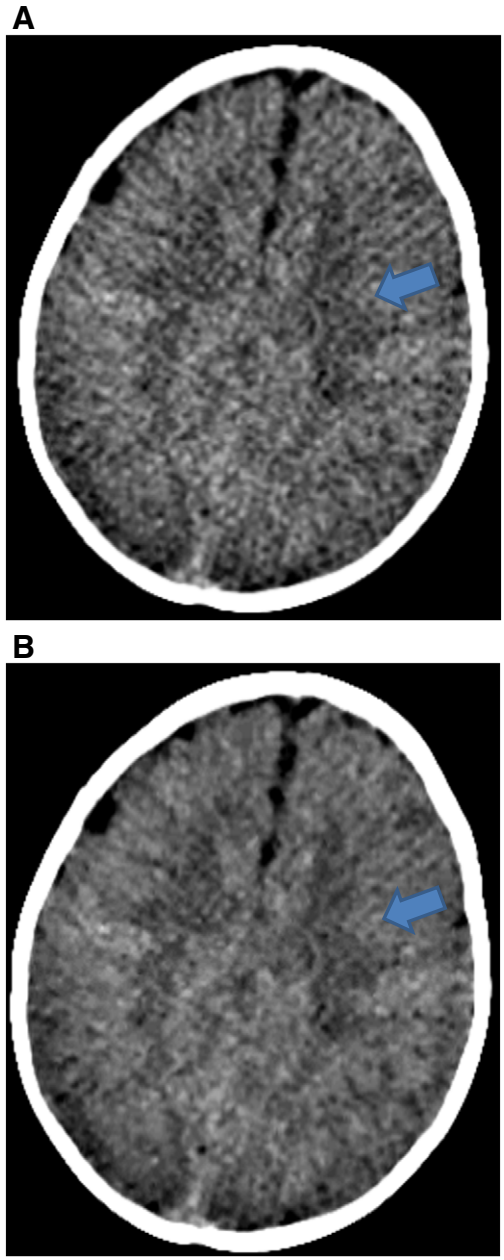

Fig. 1. Ten-month-old male with vomiting after head injury: axial images obtained above the lateral ventricles windowed and leveled at 30 and 30 respectively. This demonstrates the differences in appearance of the gray white junction from decreased noise on iDOSE 4 (B) compared to FBP (A).