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Feasibility of slice width reduction for spiral cranial computed tomography using iterative image reconstruction

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ABSTRACT

Purpose: To prospectively compare image quality of cranial computed tomography (CCT) examinations with varying slice widths using traditional filtered back projection (FBP) versus sinogram-affirmed iterative image reconstruction (SAFIRE).

Materials and methods: 29 consecutive patients (14 men, mean age: 72 ± 17 years) referred for a total of 40 CCT studies were prospectively included. Each CCT raw data set was reconstructed with FBP and SAFIRE at 5 slice widths (1–5 mm; 1 mm increments). Objective image quality was assessed in three predefined regions of the brain (white matter, thalamus, cerebellum) using identical regions of interest (ROIs). Subjective image quality was assessed by 2 experienced radiologists. Objective and subjective image quality parameters were statistically compared between FBP and SAFIRE reconstructions.

Results: SAFIRE reconstructions resulted in mean noise reductions of 43.8% in the white matter, 45.6% in the thalamus and 42.0% in the cerebellum ($p < 0.01$) compared to FBP on non contrast-enhanced 1 mm slice width images. Corresponding mean noise reductions on 1 mm contrast-enhanced studies were 45.7%, 47.3%, and 45.0% in the white matter, thalamus, and cerebellum, respectively ($p < 0.01$). There was no significant difference in mean attenuation of any region or slice width between the two reconstruction methods (all $p > 0.05$). Subjective image quality of IR images was mostly rated higher than that of the FBP images.

Conclusion: Compared to FBP, SAFIRE provides significant reductions in image noise while increasing subjective image in CCT, particularly when thinner slices are used. Therefore, SAFIRE may allow utilization of thinner slices in CCT, potentially reducing partial volume effects and improving diagnostic accuracy.

1. Introduction

Cranial computed tomography (CCT) is the first-line imaging modality of choice to rule out intracranial hemorrhage [1] in patients with suspected stroke or trauma. Until recently, filtered back projection (FBP) was the clinical gold-standard for CT image reconstruction [2]. Traditionally, CCT examinations are reconstructed with relatively high image slice widths (approximately 3–5 mm) when using FBP reconstruction, as thinner slices are associated with linear increases in image noise. Increased noise is particularly detrimental when evaluating gray–white matter differentiation (due to the inherently low contrast between gray and white matter) and the base of the skull (due to prominent beam-hardening artifacts which can obscure cerebellar or brainstem pathology). Unfortunately, reconstruction slice widths thicker than 3 mm are prone to partial volume effects that can make assessment of brain hemorrhage challenging [3], possibly leading to follow-up CCT examinations in order to safely rule out hemorrhage. While it is technically possible to reduce image noise by increasing radiation dose, potentially allowing decreased slice width, CCT examinations are already associated with a high radiation dose [4], and further increases in ionizing radiation should be avoided.

Iterative reconstruction (IR) was first used almost four decades ago [5]; however, computer power has only recently evolved enough to allow IR utilization within a clinically acceptable time-frame. The main benefit of most current IR methods is image noise reduction, which has implications for both improving image quality and decreasing radiation dose [6]. In addition, IR may allow the use of thinner slices while maintaining an acceptable level of image noise. For this study, we were able to use sinogram affirmed iterative reconstruction (SAFIRE), whereby the iterative loops are done

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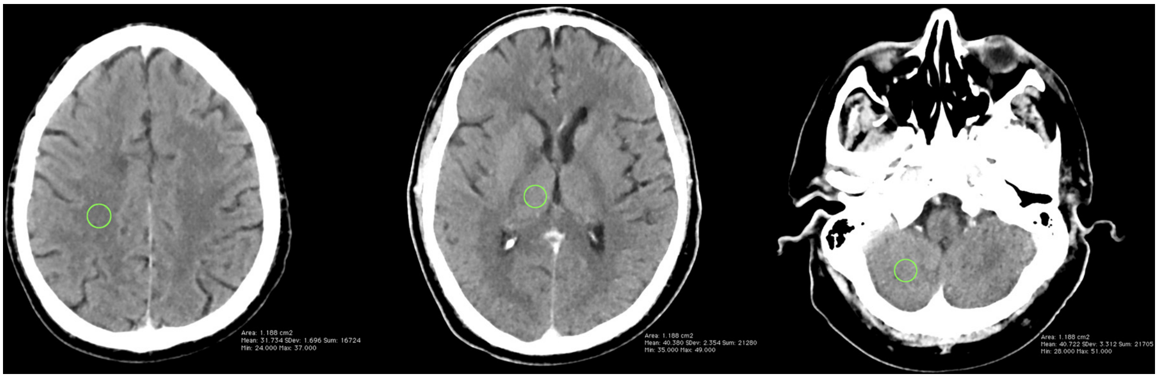

Fig. 1. ROI placement for the objective data analysis. ROIs were placed in the white matter, the thalamus and the cerebellum.

in the raw data space before being converted into the image space. This is in contrast to the previous generation iterative image reconstruction in image space (IRIS) where the data is first converted into the image space before the iterative loops for noise reduction are applied.

Accordingly, the aim of this study was to prospectively compare objective and subjective measures of image quality in CCT examinations reconstructed at varying slice widths with FBP and SAFIRE.

2. Methods

The study protocol was approved by our institutional review board and complies with the Declaration of Helsinki and the Health Insurance Portability and Accountability Act (HIPAA). Since we solely performed additional image reconstruction, the requirement for written informed consent was waived in all patients.

2.1. Patient cohort

A total of 40 examinations between July 2011 and March 2012 were prospectively included in this study. 29 consecutive patients (14 men, mean age: 72 ± 17 years) that were referred to our institution for a CCT examination in this timeframe were enrolled in this study. All patients received a non contrast-enhanced CCT examination for the exclusion of hemorrhage and stroke. Additionally, 11 patients with known malignancy received an additional contrast-enhanced examination to exclude brain metastases.

2.2. CT image acquisition

All patients were examined using a dual-source CT system (SOMATOM Definition, Siemens Healthcare Sector, Forchheim, Germany). All examinations were performed using a spiral acquisition technique with the following scan parameters: $20\,mm \times 0.6\,mm$ detector collimation ($40\,mm \times 0.6\,mm$ effective with *z*-shift), 280 ms gantry rotation time, and 420 mAs per rotation tube current time product. Tube voltage was fixed at 120 kV. Acquisition was cranio-caudal from the top of the cranium to the base of the cerebellum.

Contrast-enhanced examinations were performed with 60–90 ml of iodinated contrast material (Imeron 400, Bracco Imaging S.p.A, Milan, Italy) followed by a 50 ml saline chaser, all injected at 2.5 ml/s through an 18-G intravenous antecubital catheter using a dual-syringe injector (Stellant D, Medrad, Indianola, PA). The scan delay was 5 min.

2.3. FBP and iterative reconstruction series

CCT raw data was anonymized, exported to an external storage medium, and reconstructed using a prototype offline software application provided by the vendor. Each CCT examination was reconstructed using a conventional FBP algorithm and SAFIRE, a commercially available IR technique. A detailed description of the SAFIRE algorithm has been previously described [7]. Reconstruction parameters comprised of a standard cranial "H31s" FBP convolution kernel and a dedicated "J30s" IR kernel (SAFIRE strength 3). Each raw dataset was reconstructed at 5 slice widths (1–5 mm, 1 mm increments) with both FBP and SAFIRE.

2.4. Assessment of image noise, attenuation, and subjective image quality

FBP and SAFIRE image datasets were transferred to an image viewing workstation (Aycan Osirix Pro [aycan Digitalsysteme GmbH, Wuerzburg, Germany]). In each data set, one observer (__)

Table 1
Subjective evaluation parameters and 4 point grading system.

Rating	Subjective Noise	Sharpness	Diagnostic acceptability	Artifacts
1	Little to no noise	Structures well defined with sharp contours	Fully acceptable	No artifacts
2	Optimum noise	Structures can be seen, contours are sharp enough for diagnostic reporting	Probably acceptable	Minor artifacts
3	Noisy, but permits evaluation	Structures can be seen, but not sufficiently for diagnostic reporting	Only acceptable under limited conditions	Major artifacts
4	Noisy, degrades image so that no evaluation possible	Structures cannot be defined	Unacceptable	Major artifacts that make interpretation impossible