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The Influence of Beam Filtration and Collimation On CT Number Accuracy in the ACR CT Accreditation Process

E Olariu*, M Supanich, D Bakalyar, Henry Ford Health System, Detroit, MI

Purpose: The ACR accreditation process requires the submission of images of the 200 mm ACR phantom to evaluate CT number accuracy using the institution's adult abdomen protocol. Difficulties in obtaining CT numbers that fall within the allowed limits may be due to the use of a protocol designed for a body significantly larger than the phantom. We show that adjusting the sFOV to a size appropriate for the phantom significantly shifts the CT numbers toward the expected values. We also show that consistent with the hypothesis that an over-correction for scatter results in the increased CT numbers, a reduced collimation, where less scatter correction is required for reconstruction, also shifts the CT numbers in the right direction. Methods: The ACR Gammex phantom was scanned on a 64-slice GE LightSpeed-VCT scanner with various bowtie filters, beam collimation and sFOV using our institution`s routine adult abdomen protocol. Results: Our results show that the CT numbers for water and polyethylene fall well outside the required range if we rigidly adhere to scanning the ACR phantom with the standard protocol. The observed inaccuracy in reported CT numbers is believed to originate from over-corrections due to scatter contributions and beam hardening effects as the phantom is significantly smaller than a typical adult abdomen. CT number accuracy was improved when a small bowtie filter was used instead of the large one. The CT number dropped to 4.02 HU for water and to -87.32 for polyethylene. CT number accuracy further improved when scanning the phantom with a 20 mm beam collimation instead of 40 mm. Conclusions: In performing the ACR image quality assessment task, the employment of a bowtie filter consistent with the size of the phantom resulted in a significant improvement in achieving the CT number accuracy requirements of the ACR.

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Two-Material Decomposition From a Single CT Scan Using Statistical Image Reconstruction

Y Long*, J Fessler, J Balter, University of Michigan, Ann Arbor, MI

Purpose: Dual-energy (DE) CT methods can separate two basis materials (e.g., soft tissue and bone) for applications such as dose calculations. However, typical DECT methods require either two scans or specialized scanners. We propose a statistical penalized weighted least-squares (PWLS) method to reconstruct two basis material images from a single-energy CT scan acquired with a simple split X-ray filter. Methods: We used a pre-patient split-filter that contains 2mm aluminum across half the fan beam and 200 microns molybdenum for the other half. Using a 360-degree rotation of the X-ray source, the whole scanned object is exposed to two incident spectra with different effective energies during a single scan. We propose an optimization transfer method with a separable quadratic surrogate to monotonically decease a PWLS cost function with edge-preserving regularization. We first reconstructed the bone-corrected FBP images using the Joseph and Spital method, and separated the soft and bone components by a threshold to initialize the iterative algorithm. We used the ordered subsets approach to accelerate the convergence to a good local minimum. Results: The test object is a chest NCAT image with 1.0 for soft tissue, 0.5 for lungs, 1.5 for spine, and 2.0 for ribs (the units are physical density: g/cc.). The lungs and soft tissue had the "soft tissue" characteristics and the spine and ribs had the "bone" characteristics. The root-mean-square (RMS) errors of the soft tissue, bone and density map were 0.03, 0.02 and 0.01 for PWLS, compared to 0.06, 0.03 and 0.05 for the FBP initialization for the noiseless simulation. The PWLS method removed the beam hardening artifacts more effectively than the FBP-JS method. Conclusions: The proposed PWLS reconstruction method was able to separate soft tissue and bone images with low RMS errors from a single CT scan using a split-filter.

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Estimation of CT Radiation Profile Width Using An LED-Based Optically Stimulated Luminescence System

C Ruan[1]*, M Rodriguez[1], Y Hu[1], S Ahmad[1], E Yukihara[2], (1) University of Oklahoma Health Sciences Center, Oklahoma City, OK, (2) Oklahoma State University, Stillwater, OK

Purpose: To evaluate the feasibility and accuracy of an LED-based Optically Stimulated Luminescence (OSL) system for measuring computed tomography (CT) radiation profile width. Methods: The OSL detector strips used consisted of a layer of Al_2O_3:C powder incorporated into a plastic tape. The strips were 150 mm long with a width of 4-5 mm and thickness of 0.3 mm. The 64-slice CT dose profiles were measured by irradiating the OSL strips both free-in-air and inside the PMMA head and body phantoms. Three separate OSL strip measurements were performed for each scan condition. The exposed strips were then read out using a custom built LED-based reader system, which operated for 150 mm in 0.25 mm steps, providing 600 data points along the OSL strip in 60 sec. The width of the CT radiation profiles was determined from the full width half maximum (FWHM) at different nominal beam collimations. The results were compared to those obtained from digitized film profiles and ionization chamber point measurements (0.3 cc ionization chamber). Results: By comparing the FWHM values of OSL and digitized film measured free-in-air, the system accuracy was verified with results $< \pm 2.2\%$ for nominal beam widths of 5, 10, 20 and 40 mm. The relative OSL response as a function of phantom positions was verified by comparing the FWHM values in phantom measurements using OSL and ionization chamber. The results agreed well within 7.6%. Conclusions: The proposed method of using an LED-based OSL system to determine the FWHM of the CT radiation profile has a high accuracy and shows good agreement with the conventional film measurements and the more advanced point-dose methodology proposed by TG 111. Combined with the simple calibration, it gives this work a great potential to be used in routine clinical quality assurance check.

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A Novel Phantom for CT Performance Assessment: Towards a Task-Based Measure of Image Quality

S Richard * and E Samei, Ravin Advanced Imaging Lab, Duke University Medical Center, Durham, NC.

Purpose: The advent of CT iterative reconstructions in the clinic has posed an increasing challenge on the community in our ability to assess image quality due to increased non-stationarity and non-linearity of reconstructed images. The purpose of this study is to investigate the potential of a novel phantom aimed to enable a robust assessment of image quality of CT images including iterative reconstructions. Method and Materials: A cylindrical phantom was built from a series of slabs with removable rings to simulate diffrerent patient sizes. The "noise slab" consists of a uniform piece of acrylic for the noise-power spectrum (NPS) measurement. The "resolution slab" consists of an array of spheres of various materials to simulate a range of contrast levels found in CT images. Each set of spheres can be used to measure the modulation transfer function (MTF) as a function contrast, dose, and location. The "dose slab" enables the incorporation of ion chambers, while the last slab contains cylindrical inserts for CNR measurements. The phantom was scanned on a 64 slice CT and reconstructed with filtered-back projection (FBP) and a model-based iterative reconstruction algorithm (MBIR). Images were used to derive the relevant image quality and dose metrics. Results: The NPS measurement enabled the characterization of different textures between FBP and MBIR. Contrast and dose were found to have a significant impact on the MTF for the MBIR data. The task-based detectability index computed from the MTF and NPS agreed qualitatively with image quality and yielded quantitative estimation of dose reduction provided with iterative reconstruction algorithms. Conclusions: Initial results showed that a phantom can be used to measure imaging performance of non-linear reconstruction algorithms. Results suggested that a task-based approach to system performance assessment may be essential to properly compare image quality between different protocols when employing iterative reconstruction algorithms.

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