SSG14

## Physics (CT IV-New Development 1)

Tuesday, Dec. 1 10:30AM - 12:00PM Location: S403B

CT PH

*AMA PRA Category 1 Credits* ™: 1.50
ARRT Category A+ Credits: 1.50

FDA Discussions may include off-label uses.

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**Sub-Events**

### SSG14-01 Lung Cancer Screening (LCS) in Ultra-low-dose CT (U-LDCT) by Means of Massive-Training Artificial Neural Network (MTANN) Image-Quality Improvement: An Initial Clinical Trial

Tuesday, Dec. 1 10:30AM - 10:40AM Location: S403B

Wataru Fukumoto, Hiroshima, Japan (*Presenter*) Nothing to Disclose
Kenji Suzuki, PhD, Chicago, IL (*Abstract Co-Author*) Royalties, General Electric Company; Royalties, Hologic, Inc; Royalties, MEDIAN Technologies; Royalties, Riverain Technologies; Royalties, Toshiba Corporation; Royalties, Mitsubishi Corporation; Research Consultant, Alara Systems; Stockholder, Alara Systems; Research Consultant, AlgoMedica; Stockholder, AlgoMedica; ; ; ; ; ; ; ;
Toru Higaki, PhD, Hiroshima, Japan (*Abstract Co-Author*) Nothing to Disclose
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#### PURPOSE

We developed a method for improving the image quality of U-LDCT by means of a supervised patch/pixel-based machine-learning technique called an MTANN. The MTANN can create the virtual higher-dose CT (v-HDCT) from U-LDCT by learning the relationship between U-LDCT and higher-dose CT. The purpose of this study was to investigate the clinical feasibility of U-LDCT with the MTANN technology for LCS.

#### METHOD AND MATERIALS

Thirty subjects (median age: 66 y.o.; range: 55-74) underwent CT LCS with both low-dose CT (LDCT) and U-LDCT using a 320-detector-row CT scanner (Aquilion One, Toshiba, Japan). LDCT were performed under our LCS protocol (120 kVp, automatic tube-current control with 22 noise index, 0.5 mm x 80 detector row, 1.39 pitch factor, 2 mm reconstruction slice thickness and interval), while U-LDCT were done with the same parameters except a tube-current-time-product of 5 mAs. Effective radiation doses for LDCT and U-LDCT were approximately 2.0 and 0.2 mSv, respectively. Both LDCT and U-LDCT were reconstructed with the filtered-back-projection algorithm. Our MTANN converted U-LDCT images to v-HDCT images. Two radiologists reviewed LDCT images, and "gold-standard" pulmonary nodules 4 mm or larger in diameter were determined in consensus. We evaluated v-HDCT in comparison to the "gold-standard" by using a 3-point subjective scale, i.e., Grade 3: a nodule and its type (solid nodule [SN] or ground-glass nodule [GGN]) were accurately identified on v-HDCT; Grade 2: a nodule but not its type was identified confidently; Grade 1: a nodule could not be identified.

#### RESULTS

We identified 18 nodules (16 SN; 2 GGN) on LDCT images in the 30 subjects. All 16 SNs on v-HDCT were classified as Grade 3, whereas the 2 GGNs were Grade 2.

#### CONCLUSION

All SNs and GGNs could be identified on MTANN v-HDCT, but a nodule type for 2 GGNs was difficult to be determined confidently.

#### CLINICAL RELEVANCE/APPLICATION

MTANN may be useful for further reduction of radiation dose in LDCT for lung cancer screening.

### SSG14-02 Motion Compensation from Short-Scan Data in Cardiac CT

Tuesday, Dec. 1 10:40AM - 10:50AM Location: S403B

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Thomas Allmendinger, Forchheim, Germany (*Abstract Co-Author*) Nothing to Disclose
Herbert Bruder, Forchheim, Germany (*Abstract Co-Author*) Nothing to Disclose
Marc Kachelriess, PhD, Heidelberg, Germany (*Abstract Co-Author*) Nothing to Disclose

#### PURPOSE

To reduce motion artifacts of the coronary arteries (CAs) and to increase the temporal resolution (TR) while utilizing only the minimal amount of rawdata needed for a short-scan reconstruction.

#### METHOD AND MATERIALS

The TR in diagnostic single source cardiac CT lies in the order of 0.15 s. In cases with higher heart rates, however, motion artifacts remain in the region of the CAs. Motion compensation (MoCo) algorithms estimate and apply motion vector fields (MVFs) and can, potentially, reduce such artifacts by effectively improving the TR. Most of the MoCo algorithms described so far require scan data significantly larger than the short scan interval to estimate the motion parameters. We propose a new approach to increase the TR in the region of the CAs. It consists of three steps: a) performing an initial reconstruction and segmenting the CAs, b) estimating the motion from the short scan interval (180° + fan angle) and c) performing the MoCo. The last two steps are based on the decomposition of the initial volume into N overlapping limited angle reconstructions. As an initial MVF guess the barycenters of the CAs are determined slice-wise in the limited angle image volumes. The MVFs are iteratively refined using a cost function maximizing the image sharpness. To validate the algorithm a dynamic CA simulation study is employed. Furthermore the algorithm is applied to clinical patient data with heart rates between 60 bpm and 90 bpm. Motion-compensated reconstruction is performed in several heart phases.

#### RESULTS

In the simulated and measured cases the value N = 30, yielding limited angle images covering a 12° projection range each, turned out to be sufficient. The TR could be increased which was found by comparison with simulations at faster rotation speeds. Regarding the patient data we found that 10 coronary segments showed motion artifacts and with our MoCo method we were able to remove the artifacts in all but two cases.

#### CONCLUSION

We presented a cardiac MoCo algorithm providing an improved delineation of the coronary arteries. The findings have been evaluated based on a simulation study and on patient data, where the visibility of the coronary arteries increased due to an increased temporal resolution.

#### CLINICAL RELEVANCE/APPLICATION

Increasing the temporal resolution in cardiac CT imaging and thereby reducing motion artifacts improves the accuracy in the diagnosis of coronary artery disease.

## SSG14-03 XACT: A New Imaging Modality Based on Ultrasonic Detection of X-ray Absorption

Tuesday, Dec. 1 10:50AM - 11:00AM Location: S403B

**Awards**
**Trainee Research Prize - Fellow**

Shanshan Tang, PhD, Norman, OK (*Presenter*) Nothing to Disclose
Hong Liu, PhD, Norman, OK (*Abstract Co-Author*) Nothing to Disclose
Liangzhong Xiang, PhD, Norman, OK (*Abstract Co-Author*) Nothing to Disclose

#### PURPOSE

Absorption based X-ray imaging including CT is an invaluable tool in medical diagnostics. However, the use of conventional CT is limited by two factors; one is the limited spatial resolution, and the other is the relatively high radiation dose. The purpose of this study is to explore X-ray induced acoustic computed tomography (XACT), a new imaging modality, which take advantages of the X-ray absorption contrast at low radiation dose and high ultrasonic resolution in a single modality.

#### METHOD AND MATERIALS

First, a theoretical model was built to analyze the sensitivity to X-ray absorption by comparing with XACT and conventional X-ray imaging. Second, an XACT imaging system was developed to evaluate the X-ray induced acoustic signal generation. 60-nanosecond x-ray pulses were generated from an X-ray source operated at the energy of 150 kVp with a 25-Hz repetition rate. The X-ray induced acoustic signals were captured by a commercial ultrasonic transducer (2.25 MHz in central frequency).

#### RESULTS

Theoretical analysis shows that X-ray induced acoustic signal has 100% relative sensitivity to the X-ray absorption. It naturally filters out the X-ray scattering. Less background from the ultrasonic detection of X-ray absorption will increase the imaging sensitivity. In the experiment, a lead wire and a piece of bone were irradiated to demonstrate the X-ray induced acoustic signals generation, respectively. A major peak is readily observed in the signals. We found that the pulse width of the acoustic signal was about 0.66 us; which correspond with the target size of 1 mm. The radiation dose of a single pulse is 0.03 mGy. It is only 1/100 less radiation dose of the normal X-ray CT.

#### CONCLUSION

In XACT imaging, we detect the acoustic signal generated by X-rays instead of detecting X-rays themselves. The acoustic signal is sensitive only to the X-ray absorption, and not to X-ray scattering. Using this principle, we improve the imaging sensitivity of X-ray absorption. Taking advantage of the high ultrasonic resolution, we can also perform 3-D imaging with a single x-ray pulse and without any mechanical motion of the imaging system. We can thus reduce the radiation dose by a factor of 100, and image 100 times faster when compared to the conventional X-ray CT. This new modality has the potential to revolutionize x-ray imaging applications in medicine and biology.

#### CLINICAL RELEVANCE/APPLICATION

Dedicated breast XACT for breast cancer screening.

## SSG14-04 Assessment of Dose Performance of a New Technique for Single Source Dual Energy Acquisition

Tuesday, Dec. 1 11:00AM - 11:10AM Location: S403B

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#### PURPOSE

Dual Energy (DE) scanning has skyrocketed in scientific relevance and diagnostic importance. The goal of this research is to determine if a novel, yet simple technique for DE utilizing a single x-ray tube by applying a split filtration to the x-ray beam in scan direction enabling simultaneous acquisition of different spectra, allows for dose efficient CT acquisitions compared to other single source DE approaches and standard single energy scanning.

#### METHOD AND MATERIALS

Two water equivalent phantoms, an anthropomorphic phantom (20cmx30cm) and a circular phantom (30cm), both equipped with an iodine insert (15mg I/cm³) in the center, were used for measurements. Four different scan acquisitions at matched dose (CTDIvol) were utilized for comparison; split filter DE (SFDE) utilizing 120kV, Dual Scan DE (optimized mA between kVs. DSDEopt), Dual Scan DE (fixed mA between kVs, DSDEfixed), and 120kV single energy (SE). Each phantom was scanned 5 times for each acquisition to gather statistical meaning. All measurements were performed on systems with highly integrated circuit detectors (Stellar, Siemens AG, Forchheim, Germany). Image noise and iodine contrast-to-noise ratio (CNR) were measured in mixed images generated by linear combination of the high and low kV images resulting in minimal image noise.

#### RESULTS

At equal CTDIvol the image noise in SFDE approach tends to be lower than in the other approaches. For the anthropomorphic phantom: σSFDE = 11.6 < σSE. = 13.9 < σDSDEfix.. = 14.4 < σDSDEopt.. = 14.5 HU. For the circular phantom: σSFDE = 17.7 < σSE. = 21.5 < σDSDEfix.. = 22.4 < σDSDEopt.. = 23.1 HU. At equal CTDIvol the iodine CNR tends to be highest for DSDEopt followed by SFDE. For the anthropomorphic phantom: CNRDSDEopt = 27.9 > CNRSFDE = 24.9 > CNRSE = 24.2 > CNRDSDEfix = 22.4. For the circular phantom: CNRDSDEopt = 15.4 > CNRSFDE = 14.9 > CNRSE = 14.0 > CNRDSDEfix = 12.7.

#### CONCLUSION

SFDE provides an effective solution to simultaneously acquire high and low energy data without dose penalties compared to standard single scanning, thus enabling routine Dual Energy scanning.

#### CLINICAL RELEVANCE/APPLICATION

Dose efficient dual energy scanning has been limited to dual source systems. SFDE allows for dose efficient scans on a single source systems, further enabling routine Dual Energy in clinical practice.

### SSG14-05 Value of Scout-View Based Personalized Scan Protocol Selection of Spectral CT Imaging Individual Contrast Medium Protocol

Tuesday, Dec. 1 11:10AM - 11:20AM Location: S403B

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Ailian Liu, MD, Dalian, China (*Abstract Co-Author*) Nothing to Disclose
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#### PURPOSE

To investigate the value of scout-view based personalized scan protocol selection of gemstone spectral imaging and personalized contrast medium protocol (400mgI/kg) in enhanced abdomen CT, comparison the image quality with routine 120 kV and contrast medium protocol.

#### METHOD AND MATERIALS

83 patients suggested with abdomen enhanced CT scan were enrolled and all were divided into two groups randomly. Group A (n=49) used tube voltage of 120kV and automatic exposure control (AEC), according to the body mass index (BMI), the noise index (NI) of AEC were setted as 10 (BMI<23), 12(23≤BMI≤26) and 14(BMI>26) respectively. The contrast medium concentration was 350mgI/ml,the injection volume and speed was 100ml and 5ml/s respectively. Group B (n=34) underwent plain CT scanning using AEC with BMI based NI setting (BMI<23,NI=10;23≤BMI≤26,NI=12;BMI>26,NI=14). According the maximum mA and average mA, choosing corresponding GSI protocols with approximate CTDIvol. The maximum mA corresponded CTDIvol approximate GSI protocol was used for arterial phase and vein phase. The average mA corresponded CTDIvol approximate GSI protocol was used for parenchyma phase. Monochromatic images at 60keV blending with 40% adaptative statistical iterative reconstruction (ASiR) were reconstructed. The CT value and SD value of abdomen aorta and erector spinae were measured and the contrast-noise-ratio was calculated. Data was compared with student T-test.

#### RESULTS

The image noise and the CT value of aorta and erector spinae showed no significant difference between two groups (both P>0.05). The CNR of two groups have no significant difference (43.89±19.08 vs 38.29±9.44, P>0.05). The DLP of group B was lower than that of group A (460.91±225.18 vs 390.69±129.03, P<0.05). The total contrast volume of group B had an average 25.29% decrease than that of group A (74.71±11.04 vs 100ml±0.00, P<0.05).

#### CONCLUSION

Personalized scan and contrast medium protocol in spectral CT imaging significant reduce radiation dose and contrast medium dose without compromising image quality.

#### CLINICAL RELEVANCE/APPLICATION

Spectral CT imaging provides a high-quality angiographic technique, which allows use of a lower contrast agent compared with conventional 120-kVp SECT.

### SSG14-06 Fluence Field Modulation for Low-dose X-ray Computed Tomography using Compact Multiple Aperture Devices

Tuesday, Dec. 1 11:20AM - 11:30AM Location: S403B

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**PURPOSE**

CT scanning at low doses is limited by the scanner's ability to adapt to specific patients and imaging tasks. Current clinical CT permit exposure reductions via x-ray technique selection and current modulation. While dynamic fluence field modulation (FFM) has been proposed to greatly expand the capability of CT systems to customize acquisitions and minimize dose, design constraints including actuation speed, g-forces, and available space make practical solutions difficult. In this work, we propose a novel, compact FFM system based on multiple aperture devices (MADs) that can meet these practical requirements to provide patient-specific low-dose acquisitions.

**METHOD AND MATERIALS**

We develop a theoretical framework for design and simulation of MADs and construct prototype devices for initial characterization. MADs are essentially binary filters (entirely blocking or transmitting the x-ray beam on a fine scale). Spatial modulation is established through appropriately sized, space-variant aperture design. Dynamic FFM is possible when two devices are placed in series, and translated relative to one another. Various design options are explored - especially those that minimize undesirable high-frequency field modulations while enforcing the desired low-frequency modulations. Prototype devices were constructed using tungsten sintering and characterized on a CT test bench.

**RESULTS**

Various multiple apertures devices were studied including designs meant to yield flat fluence patterns for circular and elliptical objects of various sizes. In testbench studies using prototype devices, flattened fields are demonstrated in physical phantoms, minimized high-frequency aperture patterns are observed, and artifact-free tomographic reconstructions are produced and shown to have similar image quality as compared to traditional (static) bow-tie filters.

**CONCLUSION**

With relative motion requirements of less than a millimeter/quarter rotation, minimum thicknesses of several millimeters, and a rigid filter material, practical device placement within a clinical CT gantry is achievable. Combined with good image quality in initial reconstruction results, multiple aperture devices are a potential solution to practical FFM in CT.

**CLINICAL RELEVANCE/APPLICATION**

The proposed dynamic FFM system is practical for clinical CT scanners and will facilitate customized patient scans, maximizing diagnostic imaging performance at minimum radiation exposures.

## SSG14-07 Quantitative Assessment of Coronary Artery CT Images with Full Iterative Reconstruction Performed on a 320 Detector-row Scanner

Tuesday, Dec. 1 11:30AM - 11:40AM Location: S403B

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Akira Taniguchi, RT, Otawara, Japan (*Abstract Co-Author*) Employee, Toshiba Corporation
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**PURPOSE**

To compare the spatial resolution, image noise, and image quality of volume scans performed on a 320 detector-row CT scanner with filtered back projection (FBP), hybrid iterative reconstruction (IR), and a new full IR algorithm.

**METHOD AND MATERIALS**

Using a 320-detector scanner (Aquilion One Vision, Toshiba) we scanned Catphan- and pulsating coronary artery (CA) phantoms (diameter 4 mm) with plaque-, calcium plaque-, and Cypher stent stenosis. The phantoms contained an iodine solution (CT number 350 HU at 120 kV) and were scanned in the volume scan mode, non-gated. Scanning was at 50-, 100-, and 150 mAs. Reconstruction was with filtered back projection (FBP) and quantum denoising filters, hybrid IR (Adaptive Iterative Dose Reduction-3D: AIDR 3D), and full IR (FIRST). We recorded the image noise (standard deviation [SD] of the CT number and the noise power spectrum), image resolution (contrast of the ladder pattern and the modulation transfer factor [MTF]), and the full width at half maximum (FWHM) of the inner diameter of the simulated CAs and performed Tukey's multiple comparisons among the different scan parameters.

**RESULTS**

The image noise on images acquired at 150 mAs was 7.9 (FBP), 10.0 (AIDR 3D), and 8.1 (FIRST) and the [WU1] 50% MTF was 0.45, 0.49, and 0.78. The mean absolute percentage error of the FWHM was 4.2, 4.7, and 6.6% (50% plaque stenosis model), 4.4, 3.7, and 2.1% (50% CA stenosis model), and 26.2, 25.8, and 14.4% (stent model). The FWHM [k2] of the stent model [WU3] on images reconstructed with FIRST was significantly larger than with FBP or AIDR 3D ($p<0.01$). On images reconstructed with FIRST, the image quality was improved by 15-20% compared with FBP or AIDR 3D.

**CONCLUSION**

On scans of the simulated pulsating CA, FIRST yielded better image noise and spatial resolution than FBP or AIDR 3D.

**CLINICAL RELEVANCE/APPLICATION**

Full iterative reconstruction (FIRST) yields better image noise and spatial resolution than FBP or AIDR 3D and facilitates the accurate quantitative analysis of CT images of the coronary artery.

## SSG14-08 Phase Retrieval and De-wrapping in Grating-based X-ray Differential Phase Contrast CT with Twin-peaks in Phase-stepping Curves

Tuesday, Dec. 1 11:40AM - 11:50AM Location: S403B

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Weixing Cai, PhD, Rochester, NY (*Abstract Co-Author*) Nothing to Disclose
Hui Mao, PhD, Atlanta, GA (*Abstract Co-Author*) Nothing to Disclose
Xiangyang Tang, PhD, Atlanta, GA (*Abstract Co-Author*) Research Grant, Sinovision Technologies Co Ltd

**PURPOSE**

In x-ray differential phase contrast (DPC) CT implemented with Talbot interferometry, phase-stepping procedure is widely employed to extract the phase signal for imaging. Since the fabrication process may cause defects in analyzer grating G2, the actual period of G2 may double the nominal period of G2, and the experimental determined phase-stepping curve (PSC) exhibits two distinct peaks within an actual period 2g2. For such a DPC-CT system with twin-peak PSCs, we develop an approach to retrieve and unwrap the phase signal.

**METHOD AND MATERIALS**

Based on the paraxial Fresnel-Kirchhoff theory, we derive an analytical formula to characterize the PSCs of an x-ray Talbot interferometry with flawed analyzer grating. We also conduct an experimental investigation into the phase retrieval and de-wrapping in x-ray DPC-CT with twin-peak PSCs. An x-ray Talbot interferometry with 4.6 micron of g2 is utilized to scan a mouse and a phantom that consists of tubes filled with water, cotton, sugar and air.

**RESULTS**

Fourier analysis of the PSC demonstrates that its first-order Fourier component with spatial frequency 1/2g2 is non-negligible, although it is smaller in magnitude than the second-order Fourier component with spatial frequency 1/g2. Consequently, experimental results show that in comparison with scanning G2 over its nominal period g2, stepping G2 over its actual period 2g2 can provide data to enable a significantly improved reconstruction of the phase-contrast CT images.Furthermore, with the use of the phase signal retrieved from the first-order Fourier component, the possible phase wraps in the phase signal retrieved from the second-order Fourier component can be removed.

**CONCLUSION**

Our theoretical analysis and experimental investigation show that for an x-ray DPC-CT imaging system with twin-peak PSCs, the PSCs should be determined by scanning G2 over the double of its nominal period g2; and then the PSCs can be utilized to retrieve and unwrap the phase signal for imaging.

**CLINICAL RELEVANCE/APPLICATION**

The preliminary results reported in this study may be of relevance to the preclinical and eventually clinical applications of grating-based x-ray phase contrast CT.

## SSG14-09 Third-generation Dual-source CT of the Neck Using Automated Tube Voltage Adaptation in Combination with Advanced Modeled Iterative Reconstruction: Evaluation of Image Quality and Radiation Dose

Tuesday, Dec. 1 11:50AM - 12:00PM Location: S403B

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**PURPOSE**

To evaluate image quality and radiation dose in third-generation 192-slice dual-source computed tomography (DSCT) of the neck using automated tube voltage adaptation (TVA) with an advanced modeled iterative reconstruction (ADMIRE) algorithm.

**METHOD AND MATERIALS**

CT studies of the neck in 116 patients were retrospectively evaluated. Group A (n=59) was examined on a second-generation DSCT with automated TVA and standard filtered back projection (FBP). Group B (n=57) was examined on a third-generation DSCT with automated TVA and ADMIRE. Age, neck diameter, and attenuation and noise of sternocleidomastoid muscle, internal jugular vein (IJV), submandibular gland, tongue, subscapularis muscle, and cervical fat were measured. Signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) were calculated. Size-specific dose estimates (SSDE) were assessed. Diagnostic acceptability was rated by three readers on a five-point scale.

**RESULTS**

Age (Group A, 57.9±18.1 years; Group B, 57.4±17.7 years; p=0.87) and effective body diameter (Group A, 15.1±1.6 cm; Group B, 15.8±1.9; p=0.075) did not differ significantly. Tube voltage in Group A was automatically set by TVA to 100 kV for all patients in group A (n=59), and to 70 kV (n=2), 80kV (n=5), and 90kV (n=50) in Group B. Average image noise was reduced and CNR was increased significantly (both p<0.001) in group B compared to group A. Diagnostic acceptability was rated consistently high in both groups with significantly better ratings for Group B than for Group A (4.83 vs. 4.56; p<0.001). Average SSDE was reduced by 34%

in Group B compared to Group A (20.38±1.63 mGy vs. 13.04±1.50 mGy, $p<0.001$).

## CONCLUSION

Combination of automated TVA and ADMIRE reconstruction in neck CT using third-generation DSCT results in a 34% radiation dose reduction compared to second-generation DSCT with automated TVA and FBP reconstruction with substantially lower image noise and significantly increased CNR and subjective image quality.

## CLINICAL RELEVANCE/APPLICATION

Automated TVA in combination with ADMIRE should be routinely applied to neck DSCT in clinical routine to reduce radiation exposure and image noise, and to increase image quality.