SSC11

ISP: Physics (Diagnostic X-ray Imaging I: New Techniques/Systems)

Scientific Papers

PH

AMA PRA Category 1 Credits ™: 1.50

ARRT Category A+ Credits: 1.50

Mon, Dec 1 10:30 AM - 12:00 PM Location: S504CD

Participants

Moderator
Andrew Karellas PhD : Research collaboration, Koning Corporation
Moderator
Wei Zhao PhD : Research Grant, Siemens AG

Sub-Events

SSC11-01 Physics Keynote Speaker: New X-Ray Imaging Technology in Established and New Clinical Applications

Andrew Karellas PhD (Presenter): Research collaboration, Koning Corporation

SSC11-03 In vivo X-ray Phase-contrast and Dark-field Small-animal CT Imaging

Andre Yaroshenko (Presenter): Nothing to Disclose , Astrid Velroyen : Nothing to Disclose , Katharina Hellbach MD : Nothing to Disclose , Martin Bech : Nothing to Disclose , Felix G. Meinel MD : Nothing to Disclose , Konstantin Nikolaou MD : Speakers Bureau, Siemens AG Speakers Bureau, Bracco Group Speakers Bureau, Bayer AG , Maximilian F. Reiser MD : Nothing to Disclose , Oliver Eickelberg : Nothing to Disclose , Ali Onder Yildirim : Nothing to Disclose , Franz Pfeiffer : Nothing to Disclose

CONCLUSION

The obtained results are proof-of-principle results, demonstrating the feasibility to acquire in vivo small-animal phase-contrast and dark-field CT scans with a grating interferometer. The obtained results reveal the high potential and diagnostic value of x-ray dark-field lung imaging. The estimated animal dose is compatible with longitudinal studies.

Background

X-ray phase-contrast and dark-field imaging are two imaging modalities that have the potential to significantly increase the soft-tissue contrast and yield complementary information. Recently a method has been developed that makes it possible to acquire these imaging modalities with a conventional polychromatic laboratory source. The approach is based on the introduction of a three-grating Talbot-Lau interferometer into the beam. However, it has been questioned weather this approach is applicable for in vivo CT scans, where interferometer stability, image acquisition speed and patient dose have to be taken into account.

Discussion

The dark-field CT reveals information about structures below the resolution limit of the system. Thus, dark-field can visualize the alveolar network of the lung. The regions affected by pulmonary emphysema could be clearly visualized and a substantial difference in the signal was observed compared to the healthy animal. Thus, dark-field CT offers additional diagnostic value for pulmonary imaging.

Evaluation

An in vivo CT of the thorax region of a healthy 10-week-old C57BL/6N mouse was acquired. Subsequently, a mouse with pulmonary emphysema was imaged. To induce a phenotype of human-like emphysema, a solution of pancreatic elastase was applied orotracheally (80 U per kilogram of body weight) to the mouse. During image acquisition the mice were breathing freely. The measurements were performed with a compact preclinical small-animal CT scanner. The scanner acquires conventional x-ray absorption simultaneously with phase-contrast and dark-field images. The reconstructed tomography results were evaluated with respect to the diagnostic value and compared to histological findings. The scan dose was estimated using a phantom.

SSC11-04 Direct Conversion X-ray Imager with 25 Micron Pixel Resolution for Medical Imaging Applications

Christopher C. Scott BSC (Presenter): Research Grant, Teledyne Technologies Incorporated , Shiva Abbaszadeh : Research Grant, Teledyne Technologies Incorporated , Sina Ghanbarzadeh : Nothing to Disclose , Gary Allan PhD : Employee, Teledyne Technologies Incorporated , Michael Farrier : Contract, Teledyne Technologies Incorporated , Ian A. Cunningham PhD : Founder, DQE Instruments Inc , Karim S. Karim PhD : Research Grant, Teledyne Technologies Incorporated

CONCLUSION

We believe this detector stands as one of the highest spatial resolution x-ray detectors reported to date for

diagnostic x-ray energies and shows promise for high DQE, low dose imaging.

Background

The high inherent spatial resolution of amorphous selenium (a-Se) makes it naturally suited for modalities such as mammography, micro-angiography, and micro-CT where the feature sizes of significance are small. However, the resolution of commercial a-Se detectors is limited entirely by pixel size (e.g. 70-85 micron) and not by the fundamental material limit. The real challenge with smaller pixel sizes is lower signal-to-noise ratio where image quality is at risk of being limited by the noisy amorphous silicon backplane used in all commercially available a-Se detectors. We have developed a high resolution detector by integrating a-Se with a complementary metal-oxide-semiconductor (CMOS) backplane. CMOS technology allows for detector operation with much lower electronic noise, facilitating a reduction in pixel size to 25 micron for an increase in resolution without degradation of signal-to-noise performance.

Evaluation

To predict detector performance both the modulation transfer function (MTF) and detective quantum efficiency (DQE) were modeled. Images for the performance evaluation were captured using a tungsten x-ray source operated at 40 kV. The MTF was calculated from the measured edge-spread function. DQE is a work in progress, although estimates are made based on measured MTF and a predicted noise power spectrum.

Discussion

The detector MTF was measured to be 0.93, 0.75, 0.57 and 0.41 at 5, 10, 15, and 20 lp/mm respectively. These values are consistent with our predictions and indicate very high resolution. Our 92 micron a-Se layer has non-optimal absorption efficiency for a 40 kV spectrum. However, the DQE modeled at 28 mR exposure is relatively high over a large frequency range with values of 0.50, 0.43 and 0.22 at 0, 10 and 20 lp/mm. When the model is evaluated for a scenario representative of standard mammography (30 kV Mo, 200 micron a-Se layer, 12 mR exposure) the DQE is 0.81, 0.65, and 0.33 at 0, 10 and 20 lp/mm. These results represent a significant improvement over current a-Se technology.

SSC11-05 Grating Based Differential Phase Contrast Imaging in Digital Breast Tomosynthesis: Imaging Performance with an Analyzer Grating

John W. Garrett MS (Presenter): Nothing to Disclose , Wei Zhao PhD : Nothing to Disclose , Yongshuai Ge : Nothing to Disclose , Ke Li PhD : Nothing to Disclose , Guang-Hong Chen PhD : Research funded, General Electric Company Research funded, Siemens AG Research funded, Varian Medical Systems, Inc Research funded, Hologic, Inc

PURPOSE

Grating-based X-ray differential phase contrast imaging (DPCI) has the potential to add two additional imaging contrasts (in addition to x-ray attenuation) to digital breast tomosynthesis (DBT): differential phase contrast and dark field. An analyzer grating used in this method is characterized by a high aspect ratio and essentially acts as a one-dimensional anti-scatter grid. The purpose of this work is to determine the impact of this grating on scatter rejection and overall image quality of absorption DBT images.

METHOD AND MATERIALS

Monte-Carlo modelling (GATE 6.2.0 simulation toolkit) was used to predict the scatter performance of a DBT system (Hologic Selenia Dimensions, Hologic, Inc.) with and without an analyzer grating present. A novel in-house design for the G2 grating was used; for simulation, a 40% duty cycle was used for the grating with a depth of 50 μm Au. The width of the gold septa was 2.12 μm. A 5 cm-thick phantom simulating 50/50 adipose/glandular breast tissue was placed on the breast support 2.5 cm above the detector. The scatter-to-primary ratio (SPR) and contrast-to-noise ratio (CNR) were quantified with and without the presence of the analyzer grating in the x-ray beam. Experimental validation with the same system setup was performed to validate the SPR and CNR values without the gratings.

RESULTS

The Monte-Carlo prediction for the SPR in the 5 cm thick breast matched the measured values within about 10% across the image field of view. The introduction of the analyzer grating stopped about 37% of post-phantom photons while reducing the SPR from 0.45 to 0.20. This resulted in an equivalent CNR to that without the grating for a given exposure. No grid lines were observed in the measured image due to the ultra-fine pitch of the grating when compared with the detector pixel size. The one-dimensional grating structure that was aligned parallel to the chest wall so as not to block additional x-rays incident from oblique angles during the DBT data acquisition.

CONCLUSION

A carefully designed Talbot-Lau interferometer can be introduced in existing DBT systems to provide two additional imaging contrast mechanisms without degradation the imaging performance of absorption contrast DBT imaging.

CLINICAL RELEVANCE/APPLICATION

The introduction of a Talbot-Lau interferometer in a digital breast tomosynthesis system provides additional diagnostic information without degrading imaging performance for a fixed exposure.

SSC11-06 Non-invasive Microcalcification Classification Using X-ray Phase-contrast Mammography

Zhentian Wang PhD : Nothing to Disclose , Nik Hauser MD : Nothing to Disclose , Gad Singer MD : Nothing to Disclose , Rahel A. Kubik-Huch MD : Nothing to Disclose , Marco Stampanoni PhD (Presenter): Nothing to Disclose

PURPOSE

Microcalcifications are an important indicator in breast cancer diagnosis. Two kinds (Type I and Type II) of microcalcifications of different chemical composition are known to correlate with benign and malignant breast lesions. We developed a method (Nature Communications, in press) to distinguish among them in a non-invasive way. In this work we test the hypothesis that the positive predictive value of our method is about 2x larger than that of conventional mammography.

METHOD AND MATERIALS

Phase contrast mammography using grating interferometry provides absorption, phase and small-angle scattering contrast of the breast simultaneously. Our microcalcification classification approach relies on the observation that Type I and Type II microcalcifications show opposite absorption and small-angle scattering signals. Compared with conventional mammography, the new approach reflects the internal crystal structure of the microcalcifications in addition to their morphological information. We are currently testing our hypothesis on biopsy samples (8 Gauge) of 20 patients (statistical power/significance of 0.8/0.05) referred for suspicious microcalcifications, classified as BIRADS-3 and -4, undergoing vacuum assisted breast Mammotome biopsy.

RESULTS

The new approach has 100% specificity and sensibility when applied to phantom data as shown in our recent work. At the RSNA, we will provide evidence of the solidity of the technique by statistically analyzing its discrimination power when applied to fixed tissue specimens.

CONCLUSION

We report a non-invasive approach to classify microcalcifications based on phase contrast X-ray imaging. The proposed method might be further developed to improve early breast cancer diagnosis and has the potential to increase the diagnostic accuracy and reduce the number of breast biopsies, or, in case of widespread microcalcifications, to select the optimal biopsy site before intervention.

CLINICAL RELEVANCE/APPLICATION

Phase contrast X-ray imaging using Talbot-Lau grating interferometry can distinguish two types of microcalcification non-invasively, providing additional diagnostic hints for early breast cancer detection.

SSC11-07 Open Trajectory Cone-beam CT Acquisition Improves Liver Visualization during IR Procedures

Ruediger Egbert Schernthaner MD (Presenter): Nothing to Disclose , MingDe Lin PhD : Employee, Koninklijke Philips NV , Rafael Duran MD : Nothing to Disclose , Julius Chapiro MD : Nothing to Disclose , Zhijun Wang MD : Nothing to Disclose , Jean-Francois H. Geschwind MD : Consultant, BTG International Ltd Consultant, Bayer AG Consultant, Guerbet SA Consultant, Nordion, Inc Grant, BTG International Ltd Grant, F. Hoffmann-La Roche Ltd Grant, Bayer AG Grant, Koninklijke Philips NV Grant, Nordion, Inc Grant, ContextVision AB Grant, CeloNova BioSciences, Inc Founder, PreScience Labs, LLC CEO, PreScience Labs, LLC

CONCLUSION

The open trajectory CBCT acquisition allows more complete depiction of the whole liver.

Background

Cone-beam CT (CBCT) facilitates intra-procedural visualization and assessment of liver cancer during intra-arterial therapies (IAT). However, high BMI patients present a challenge to the image acquisition in terms of capturing the liver region of interest while still allowing for the C-arm to rotate around the patient. The geometric motion of the C-arm at our institution (Allura FD20, Philips Healthcare, Best, The Netherlands) was modified to rotate from 55 to -185 degrees (open trajectory) instead of 120 to -120 degrees (closed trajectory). All other imaging parameters are the same. This opens up room for asymmetrical positioning of the patient, allowing for centering of the liver, rather than the spine, in the field of view (FOV).

Evaluation

The purpose of this study was to evaluate the open trajectory in visualizing more of the liver. 10 patients who underwent two sessions of IAT had CBCT acquisitions with both the closed (during 1st IAT session) and open (during 2nd IAT session) trajectories. The volume of the whole liver as seen on intra-procedural CBCT for both trajectories and the pre-IAT MRI were measured using a 3D segmentation software. The CBCT volumes were compared to the corresponding pre-interventional MRI in terms of measured liver volume and number of missed or partially depicted lesions. MRI was used as the standard given its larger FOV to capture the entire liver and all lesions.

Discussion

Two patients had severe breathing artifacts during CBCT acquisition and had to be excluded, leaving 8 patients for further analysis. The median BMI of these patients was 27.5 (range 15.8-39.3). The closed CBCT trajectory covered a median liver volume of 89% (1630 cc) that of the MRI, whereas the open trajectory covered 96%

(1711 cc). In 3 out of 8 patients (37.5%), intrahepatic lesions were either missed or only partially depicted due to the limited coverage of the close trajectory. All lesions (100%) were completely depicted using the open trajectory.

SSC11-08

Renal Stone Assessment with X-ray Dark-field Radiography

Marian Willner (Presenter): Nothing to Disclose , Kai Scherer : Nothing to Disclose , Michael Chabior : Nothing to Disclose , Eva Braig : Nothing to Disclose , Konstantin Willer : Nothing to Disclose , Julia Herzen : Nothing to Disclose , Alexander Andre Fingerle MD : Nothing to Disclose , Matthias Johannes Eiber MD : Speaker, Siemens AG Speaker, Astellas Group Speaker, Johnson & Johnson , Peter B. Noel PhD : Nothing to Disclose , Ernst J. Rummeny MD : Nothing to Disclose , Franz Pfeiffer : Nothing to Disclose

PURPOSE

Knowledge of the composition of urinary calculi is a fundamental part of the preoperative patient evaluation and this information influences treatment plans and recurrence prevention. The most common techniques for stone analysis are in-vitro and require removal of exemplary stones. Recently, the characterization of renal stones has been demonstrated to be feasible using dual-energy computed tomography. The objective of this study is to evaluate the potential of the lately developed X-ray dark-field (scattering) contrast to differentiate most common types of urinary calculi in radiographic imaging.

METHOD AND MATERIALS

A total of 113 extracted urinary calculi from 18 patients were imaged at a compact laboratory setup using a three-grating Talbot-Lau interferometer and a conventional X-ray tube operated at 40 kV. Corresponding attenuation and dark-field (scattering) signals were evaluated and matched to the respective stone compositions determined by Fourier-transform infrared spectroscopy. The analysis included 63 calciumoxolate stones from nine patients, 10 uric acid stones from four patients and further 40 stones of diverse composition from five patients.

RESULTS

Calciumoxolate and uric acid stones could be clearly differentiated by their distinct attenuation and scattering behaviour. While the calcified calculi present as high absorbing masses with rather low dark-field contrast, the uric acid stones yield a strong scattering signal due to their crystalline inner structure. The discrimination of the two types of calculi could be repeated with stones embedded in renal tissue of 4 cm thickness and an applied dose exposure below 5 mSv. The mixed stones showed intermediate attenuation-scattering ratios.

CONCLUSION

Our work demonstrates the potential of the dark-field (scattering) signal as additional imaging contrast to perform renal stone assessment in X-ray radiography.

CLINICAL RELEVANCE/APPLICATION

X-ray dark-field (scattering) contrast might complement conventional radiographic imaging to allow for characterization of urinary calculi.

SSC11-09

Physiologically Gated Stationary Chest Tomosynthesis System Using CNT X-ray Source Array

Jing Shan (Presenter): Nothing to Disclose , Laurel Burk : Nothing to Disclose , Yueh Z. Lee MD, PhD : Research Grant, Carestream Health, Inc , Michael David Heath : Nothing to Disclose , Xiaohui Wang PhD : Employee, Carestream Health, Inc , David Foos MS : Employee, Carestream Health, Inc , Jianping Lu : Research Grant, Carestream Health, Inc , Otto Zhou PhD : Board of Directors, XinRay Systems Inc Research Grant, Carestream Health, Inc

PURPOSE

We investigated the feasibility of physiologically-gated stationary chest tomosynthesis (s-DCT) with carbon nanotube (CNT) x-ray source array, and studied the image quality improvement from prospective gating.

METHOD AND MATERIALS

A bench-top s-DCT system was constructed using a CNT source array and a flat panel detector (Varian Medical Systems Inc., CA). We demonstrated the feasibility of s-DCT using CNT source array. CNT X-ray sources can be electronically switched on/off rapidly, allowing physiological signal gated tomosynthesis imaging. Pig lungs and heart were ventilated inside of an anthropomorphic chest phantom to simulate lung respiration motion with respiration cycle periods and volumes comparable to typical human breath. A pneumatic pressure based respiration signal was acquired using BioVet (m2m Imaging Corp., OH). Small metal beads placed on the lungs quantitatively measured image blur from respiratory motion. AP chest projection images were acquired at various imaging acquisition speeds, breath periods, and respiratory phases, with and without gating. Multiple gated images were acquired per respiration cycle. Tomosynthesis images were reconstructed using commercial software (Realtime Tomography LLC, PA) and analyzed to evaluate the effect of gating on image quality.

RESULTS

Tomosynthesis images acquired of non-gated ventilated lung show blurred airways and vascular structures. Without gating, the beads were blurred to 3.75mm compared to 2mm in motionless control images. When X-ray beams were prospectively gated to end of inhalation phase or the end of exhalation phase of respiration cycle, image quality was greatly improved, with sharper airway edges and more visible structural details. Bead width was 2.25mm for both cases, an 85.7% decrease of motion blur.

CONCLUSION

When tomosynthesis scanning time equals or exceeds a respiration period, image quality is degraded by motion. We demonstrated the feasibility of physiological gated s-DCT imaging using CNT source array. The

s-DCT system allows prospective gating to any phase of the respiration cycle, substantially reducing blur associated with lung motion even with image acquisition over several respiration cycles.

CLINICAL RELEVANCE/APPLICATION

Imaging quality can be greatly improved with physiological gated s-DCT, which can improve the imaging outcome for patients who cannot easily maintain their breath hold.