SSK15

Physics (CT VI-Cone Beam CT)

Wednesday, Dec. 2 10:30AM - 12:00PM Location: S403B

CT PH

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

Participants
Stephen J. Glick, PhD, Silver Spring, MD (*Moderator*) Nothing to Disclose
Bruce R. Whiting, PhD, Pittsburgh, PA (*Moderator*) Nothing to Disclose

Sub-Events

SSK15-01 Accurate Perfusion Maps from C-arm Cone Beam CT Perfusion Acquisition: A Canine Study

Wednesday, Dec. 2 10:30AM - 10:40AM Location: S403B

Participants
Kai Niu, MS, Madison, WI (*Presenter*) Nothing to Disclose
Pengfei Yang, Shanghai, China (*Abstract Co-Author*) Nothing to Disclose
Beverly A. Kienitz, MD, DDS, Madison, WI (*Abstract Co-Author*) Nothing to Disclose
Ke Li, PhD, Madison, WI (*Abstract Co-Author*) Nothing to Disclose
Sebastian Schafer, Madison, WI (*Abstract Co-Author*) Consultant, Siemens AG
Kevin Royalty, PhD,MBA, Hoffman Estates, IL (*Abstract Co-Author*) Employee, Siemens AG
Charles M. Strother, MD, Madison, WI (*Abstract Co-Author*) Research Consultant, Siemens AG Research support, Siemens AG License agreement, Siemens AG
Guang-Hong Chen, PhD, Madison, WI (*Abstract Co-Author*) Research funded, General Electric Company; Research funded, Siemens AG

PURPOSE

C-arm cone beam CT perfusion (CBCTP) has shown promise to generate relatively accurate perfusion parameters. However, high noise, inadequate temporal resolution and temporal sampling due to the inferior detector dynamic range and slow gantry rotation can limit this accuracy. In this study we address these problems using newly developed techniques.

METHOD AND MATERIALS

Seven canines underwent endovascular surgery with IACUC approval. Acute ischemic stroke was introduced in five of the subjects through large vessel occlusion, with the remaining two subjects serving as controls with no stroke imparted. CTP was performed 3.5 hours post-induction and immediately followed by a CBCTP acquisition with a biplane system. CTP images were reconstructed using vendor's software, CBCTP images were reconstructed and post processed to reduce noise (using Prior Image Constrained Compressed Sensing (PICCS)) and to enhance temporal resolution and sampling (using the TEmporal REsolution and SAmpling Recovery (TERESAR)). The CTP and CBCTP images were coregistered, reformatted into 5mm slices and processed with the same software to compute perfusion maps. Arterial input functions (AIF) were selected at the same region (basilar artery) for both datasets. The maps were then randomized and reviewed by two experienced interventional neuroradiologists. Image quality scores as well as the confidence of diagnostic decision were recorded.

RESULTS

The noise in the post-processed CBCTP images was greatly reduced and 0.5s temporal resolution and sampling was achieved. The AIF was well recovered compared to the CTP dataset. Image quality scores show no statistical difference between CTP and CBCTP maps, and the confidence evaluations indicate strong agreement between the two imaging modalities for making stroke diagnoses.

CONCLUSION

By improving contrast to noise ratio and enhancing both temporal resolution and sampling density for CBCTP scans, perfusion maps were generated that correlate well with conventional CTP acquisitions. With the ability to produce accurate perfusion maps with C-arm systems in interventional suites, we now have the possibility to perform CBCTP scans pre- and post-interventional treatment for rapid patient diagnosis without transferring the patient.

CLINICAL RELEVANCE/APPLICATION

The workflow of endovascular treatment for acute ischemic stroke patient can be further optimized using this technique, potentially delivering improved patient outcomes.

SSK15-02 Time-resolved Contrast-enhanced Cone Beam CT Imaging of Livers in Rabbits

Wednesday, Dec. 2 10:40AM - 10:50AM Location: S403B

Participants
Yuncheng Zhong, PhD, Houston, TX (*Abstract Co-Author*) Nothing to Disclose
Sanjay Gupta, MD, Houston, TX (*Abstract Co-Author*) Nothing to Disclose
Chao-Jen Lai, PhD, Houston, TX (*Abstract Co-Author*) Nothing to Disclose
Tianpeng Wang, Houston, TX (*Abstract Co-Author*) Nothing to Disclose
Chris C. Shaw, PhD, Houston, TX (*Presenter*) Nothing to Disclose

PURPOSE

Currently available cone beam CT (CBCT) imaging methods do not allow temporal information with a single scan. We investigated the use of a time-resolved CBCT method to generate multiple phase imaging with a single post-injection scan and measured the contrast time-density curves in rabbit livers. Such information may help guide and transcatheter arterial interventional procedures.

METHOD AND MATERIALS

Contrast agents were injected into hepatic artery of rabbits with implanted VX-2 hepatic tumors with a rate of 0.5 ml/second and 8 ml in total. Two CBCT scans were made before and after the injection. Two flat panel (Varian 4030CB and Perkin Elmer 1621) x-ray imaging systems oriented at right angle to each other were used to simultaneously acquire two sets of projection images over 360° at a rate of 7.5 frames/second during each scan. Following the scans, regular CBCT image sets were reconstructed from the projections and the pre-injection image set was subtracted from the post-injection image set to form a 3D contrast map. Each of the two orthogonal post-injection projection sets was then divided into 12 subsets, thus creating 12 orthogonal pairs of 30° limited angle projection sets which were then reconstructed to form 12 3D image sets corresponding to 12 consecutive phases over the scanning time. A maximum likelihood estimation iterative algorithm was applied for image reconstruction with the contrast map used as the constraint.

RESULTS

We have successfully reconstructed 4D images of contrast flow and used them to obtain time-density curves over various regions-of-interest (ROIs). We have demonstrated differences of flow patterns between implanted tumors and normal tissues with the time-density curves measured from the reconstructed 4D image data.

CONCLUSION

Dual-gantry image acquisition and constrained iterative reconstruction algorithm may help obtain multi-phasic CT images with a single post-injection scan allowing contrast flow to be dynamically imaged and quantified, which may help guide transcatheter arterial interventional procedures for liver tumors. This work was supported in part by research grants: CA104759 and CA124585, EB000117 from NIBIB, CA138502A1, and a subcontract from NIST-ATPs.

CLINICAL RELEVANCE/APPLICATION

Our method provides the capability of imaging contrast injection process in organs and the measured time-density curves may be of interest to differentiate malignant and benign tumors.

SSK15-03 Evaluation of H(L)ctr on CBCT with a Stationary Source

Wednesday, Dec. 2 10:50AM - 11:00AM Location: S403B

Participants
Sarah E. McKenney, PhD, Washington, DC (*Presenter*) Consultant, RadCal Corporation
Donovan M. Bakalyar, PhD, Detroit, MI (*Abstract Co-Author*) Nothing to Disclose
Vivek Singh, PhD, Detroit, MI (*Abstract Co-Author*) Nothing to Disclose

Background

The equilibrium dose Deq and rise to equilibrium H(L) are recognized as dose metrics that more fully capture the contributions of scattered radiation in multi-detector CT (MDCT). Deq and H(L) are not limited to MDCT, these metrics can be used to characterize cone beam CT (CBCT) systems as well.

Evaluation

Five sections from two TG200/ICRU polyethylene phantoms, with a total length of 1 m, were used as the scattering material. The phantom was centered at isocenter of an interventional system (Axiom Artis dTA, Siemens). A 0.6 cc thimble chamber with a real-time digitizer was centered within the middle section of the phantom. Because of symmetry at isocenter, rotation of the source was unnecessary. Serial integrated dose measurements were made with a series of 10 s exposures at collimation widths of 25-250 mm at 81 kV and 0 mm of Cu. A real-time dose profile, using the same technique factors, was obtained by translating the patient gantry at a constant speed of 14.7 cm/s. H(L)ctr was calculated from the dose profile. Additional acquisitions of the dose profile were performed at tube potentials of 50 kV; the maximum and minimum collimation; and 0.9 mm Cu beam filtration.

Discussion

Significant cone-angle effects at the wide collimation lengths require an offset, dependent on collimation width, for equivalence to the H(L)ctr determined using the real-time dose measurements. Because of the limited fan angle, the beam does not intercept the entire diameter of the phantom and so the radial dose behavior differs substantially in form from that typical of MDCT, particularly near the edge.

Conclusion

Though the radial dose distribution is altered near the edge due to the small beam angle, CBCT can still be characterized along the longitudinal axis. A series of measurements with known collimation widths can be used to determine H(L)ctr . While measurements performed with the real-time dosimeter can be obtained with a single exposure, a correction must be applied.

SSK15-04 Development of a Dedicated Cone-beam CT System for Imaging of Intracranial Hemorrhage

Wednesday, Dec. 2 11:00AM - 11:10AM Location: S403B

Participants
Jennifer Xu, Baltimore, MD (*Presenter*) Research Grant, Carestream Health, Inc
Alejandro Sisniega, PhD, Baltimore, MD (*Abstract Co-Author*) Research Grant, Carestream Health, Inc
Wojciech Zbijewski, PhD, Baltimore, MD (*Abstract Co-Author*) Research Grant, Carestream Health, Inc
Hao Dang, Baltimore, MD (*Abstract Co-Author*) Research Grant, Carestream Health, Inc
Joseph W. Stayman, PhD, Baltimore, MD (*Abstract Co-Author*) Research Grant, Elekta AB; Research Grant, Varian Medical Systems, Inc
Xiaohui Wang, PhD, Rochester, NY (*Abstract Co-Author*) Employee, Carestream Health, Inc
David Foos, MS, Rochester, NY (*Abstract Co-Author*) Employee, Carestream Health, Inc
Nafi Aygun, MD, Baltimore, MD (*Abstract Co-Author*) Nothing to Disclose
Vassiliss Koliatsos, MD, Baltimore, MD (*Abstract Co-Author*) Nothing to Disclose
Jeffrey H. Siewerdsen, PhD, Baltimore, MD (*Abstract Co-Author*) Research Grant, Siemens AG; Consultant, Siemens AG; Research Grant, Carestream Health,Inc; License agreement, Carestream Health,Inc; License agreement, Elekta AB; ; ;

PURPOSE

Prompt detection of intracranial hemorrhage (ICH) is essential to accurate diagnosis of traumatic brain injury (TBI) and stroke. This work reports development of a dedicated cone-beam CT (CBCT) system that overcomes conventional limitations to low-contrast imaging performance to provide reliable detection of acute ICH at the point of care.

METHOD AND MATERIALS

An imaging performance model for task-based detectability index provided the foundation for system design and optimization, including system geometry, imaging technique, and detector choice. Experimentation on a CBCT bench investigated the influence of three important factors on image quality and dose: (1) bowtie filters formed from Al and Ti with various degrees of beam flattening; (2) optional incorporation of an antiscatter grid with grid ratio ranging from 6:1 to 12:1; and (3) selection of detector readout mode (low-gain (LG), high-gain (HG), and dynamic gain (DG) readout). Performance was quantified in CBCT images of an anthropomorphic head phantom with simulated ICH inserts in terms of image uniformity, noise magnitude and correlation, CNR, and spatial resolution, and dose was measured using a Farmer chamber throughout a 16 cm CTDI phantom.

RESULTS

CBCT images of the head acquired using optimal system geometry (source-axis and source-detector distance 75 and 110 cm, respectively) and technique (90 kV, 0.625 mAs / projection) exhibited good visualization of low-contrast ICH inserts: LG readout yielded CNR = 5.5; HG readout provided a 15% increase in CNR (6.3) but suffered skin line artifacts and HU inaccuracy due to bare-beam saturation; DG readout yielded a 12% increase in CNR (6.2) and avoided saturation artifacts. Use of an Al bowtie filter in HG mode improved CNR by 23.4% (6.8), permitting lighter grids (or no grid) and reducing CTDIW by ~47% (10.1 mGy).

CONCLUSION

A CBCT head scanner designed according to task-based performance optimization and physical experimentation exhibited image quality suitable to ICH detection. Further improvement will be gained by integration with model-based image reconstruction and artifact correction. The work supports development of a scanner prototype now underway for clinical studies.

CLINICAL RELEVANCE/APPLICATION

A dedicated CBCT system will permit detection of acute ICH and improve diagnosis and treatment of patients with brain injuries at the point of care in the ICU, urgent care, and mobile environments.

SSK15-05 Respiratory and Cardiac Motion-Compensated 5D Cone-Beam CT (CBCT) of the Thorax Region

Wednesday, Dec. 2 11:10AM - 11:20AM Location: S403B

Participants
Sebastian Sauppe, Heidelberg, Germany (*Presenter*) Nothing to Disclose
Marcus Brehm, Baden-Dattwil, Switzerland (*Abstract Co-Author*) Employee, Varian Medical Systems, Inc
Pascal Paysan, PhD, Baden-Dattwil, Switzerland (*Abstract Co-Author*) Employee, Varian Medical Systems, Inc
Marc Kachelriess, PhD, Heidelberg, Germany (*Abstract Co-Author*) Nothing to Disclose

PURPOSE

To provide motion artifact-free 5D CBCT images from a conventional flat detector-based CBCT scan.

METHOD AND MATERIALS

Image quality of retrospectively respiratory- and cardiac-gated volumes from flat detector cone-beam CT scans is deteriorated by severe sparse projection artifacts. These artifacts further complicate motion estimation, as it is required for motion compensated (MoCo) image reconstruction. For high quality 5D CBCT images at the same x-ray dose and the same number of projections as today's 3D CBCT we developed a double motion compensation approach based on the motion vector fields (MVFs) of respiratory as well as cardiac motion. In a first step our previously published artifact-specific cyclic motion-compensation (acMoCo) approach is applied to compensate for the respiratory patient motion, thus leading to high fidelity 4D CBCT images. With this information a cyclic phase-gated deformable heart registration algorithm is applied to the respiratory motion-compensated 4D CBCT data, thus resulting in cardiac MVFs and thereby in respiratory and cardiac motion-compensated 5D CBCT images. Our new 5D MoCo approach is validated using simulated rawdata obtained by deforming a clinical patient dataset by realistic deformation fields, and by processing patient data acquired with the TrueBeam 4D CBCT system (Varian Medical Systems), as it is used in radiation therapy.

RESULTS

The typical streak artifacts in gated, but non motion-compensated 4D CBCT reconstruction become even more severe when cardiac gating is additionally applied: In scenarios with a 10% respiratory and a 10% cardiac window only 1% of the initial data are available for reconstruction. Our double MoCo approach turned out to be very efficient and removed nearly all streak artifacts due to making use of 100% of the projection data for each reconstructed frame. The simulations show that the 5D MVFs represent the ground truth very well. The 5D MoCo patient data show fine details and no motion blurring, even in regions close to the heart where motion is fastest.

CONCLUSION

Our preliminary results indicate that the proposed double motion-compensated 5D CBCT results in high quality 5D images with full dose usage. This is guaranteed because now all data contribute to each time frame.

CLINICAL RELEVANCE/APPLICATION

High quality 5D images are a prerequisite for precise adaptive radiation treatment. Our approach may also be useful for interventional imaging with C-arm systems.

SSK15-06 Polyenergetic Known Component Reconstruction (KCR) for Flat-panel CBCT with Unknown Material Compositions and Unknown X-ray Spectra

Wednesday, Dec. 2 11:20AM - 11:30AM Location: S403B

Participants

Shiyu Xu, Carbondale, IL (*Presenter*) Nothing to Disclose
Wojciech Zbijewski, PhD, Baltimore, MD (*Abstract Co-Author*) Research Grant, Carestream Health, Inc
Ali Uneri, Baltimore, MD (*Abstract Co-Author*) Nothing to Disclose
Jeffrey H. Siewerdsen, PhD, Baltimore, MD (*Abstract Co-Author*) Research Grant, Siemens AG; Consultant, Siemens AG; Research Grant, Carestream Health,Inc; License agreement, Carestream Health,Inc; License agreement, Elekta AB; ; ;
A. Jay Khanna, MD, Bethesda, MD (*Abstract Co-Author*) Nothing to Disclose
Joseph W. Stayman, PhD, Baltimore, MD (*Abstract Co-Author*) Research Grant, Elekta AB; Research Grant, Varian Medical Systems, Inc

PURPOSE

Many imaging scenarios involve known devices in the field-of-view (e.g., intraoperative imaging of metal implants). Known component reconstruction (KCR), which integrates device shape and material information into the reconstruction, has demonstrated great potential to reduce metal artifacts and required x-ray exposures. However, accurate KCR requires spectral characterization of system and components (e.g., through pre-scans of devices in air - greatly reducing the practicality of KCR). In this work, we develop a calibration-free KCR that jointly estimates the patient volume and a spectral transfer function (STF) for homogeneous components from a single diagnostic scan.

METHOD AND MATERIALS

Because KCR decouples patient anatomy and known components, we may target high-fidelity models where they are needed most. Specifically, we adopt a polyenergetic component model while maintaining a simple monoenergetic model for the patient anatomy. We modify KCR to jointly estimate a STF with the reconstruction and component registration using alternating optimizations. We evaluate this new calibration-free KCR in cone-beam CT (CBCT) scans of objects containing metal pedicle screws with unknown material composition. The proposed methodology is compared with filtered-backprojection (FBP) and KCR using calibration scans.

RESULTS

STFs estimated using precalibration and the modified KCR were very similar and provided a good fit to air-scan data. In CBCT studies, FBP exhibited substantial metal artifacts due to beam hardening and photon starvation while KCR methods showed a strong capability for artifact reduction. The calibration-free KCR showed better performance, likely due to its ability to adapt to additional physical effects in the diagnostic scans (e.g. increased beam hardening due to surrounding tissues).

CONCLUSION

Calibration-free KCR has the capability to reduce artifacts through high-fidelity device models, outperforming FBP and a more cumbersome KCR method with precalibration. Improved image quality facilitates assessment of pedicle screw placement (including visualizations of possible complications near the device) as well as potential dose reductions.

CLINICAL RELEVANCE/APPLICATION

Metal artifacts are common in interventional imaging where implant knowledge is available. The proposed approach has potential widespread application in situations where visualization near implant boundaries is critical.

SSK15-07 High Quality Time-resolved C-arm Cone Beam CT Angiography Images for Large Vessel Occlusion Diagnosis

Wednesday, Dec. 2 11:30AM - 11:40AM Location: S403B

Participants
Kai Niu, MS, Madison, WI (*Presenter*) Nothing to Disclose
Pengfei Yang, Shanghai, China (*Abstract Co-Author*) Nothing to Disclose
Yijing Wu, Madison, WI (*Abstract Co-Author*) Nothing to Disclose
Tobias Struffert JR, MD, Erlangen, Germany (*Abstract Co-Author*) Nothing to Disclose
Arnd Dorfler, Erlangen, Germany (*Abstract Co-Author*) Nothing to Disclose
Sebastian Schafer, Madison, WI (*Abstract Co-Author*) Consultant, Siemens AG
Kevin Royalty, PhD,MBA, Hoffman Estates, IL (*Abstract Co-Author*) Employee, Siemens AG
Yu Deuerling-Zheng, MD, Forchheim, Germany (*Abstract Co-Author*) Employee, Siemens AG
Charles M. Strother, MD, Madison, WI (*Abstract Co-Author*) Research Consultant, Siemens AG Research support, Siemens AG License agreement, Siemens AG
Guang-Hong Chen, PhD, Madison, WI (*Abstract Co-Author*) Research funded, General Electric Company; Research funded, Siemens AG

PURPOSE

With the demonstrated feasibility of measuring perfusion parameters, C-arm cone beam CT perfusion (CBCTP) scans performed directly in the interventional suite potentially enable faster patient triaging and improved patient outcomes. In this work, a method for creating time-resolved cone beam CT angiography (4D-CBCTA) images from the CBCTP acquisition and its potential benefits are discussed.

METHOD AND MATERIALS

Under IRB approval, 21 C-arm cone beam CT dynamic perfusion scans of 17 patients with acute ischemic strokes were acquired. For each multi-sweep CBCTP dataset, a 3D isotropic filtered back projection (FBP) image volume of each rotation was reconstructed and co-registered. All image volumes were post processed using Prior Image Constrained Compressed Sensing (PICCS) to reduce noise and TEmporal REsolution and SAmpling Recovery (TERESAR) to enhance temporal resolution and improve the temporal sampling density. The final image volumes were then imported into a research workstation enabling display of time-resolved volumetric renderings of a patient's cerebral vasculature.Two experienced interventional radiologists independently evaluated the image quality and diagnosed each case. Cronbach's alpha coefficients and ROC analysis were used to evaluate the inter-observer agreement and diagnostic value of this novel image presentation.

RESULTS

Post processing greatly reduced the noise contained in each volume and a half-second temporal resolution was achieved. Observers agreed that image quality for large cerebral arteries was very good and ROC curves demonstrated excellent diagnostic value for detecting large vessel occlusions (AUC=0.987 and 1).

CONCLUSION

4D-CBCTA derived from CBCTP datasets provides high quality images that allow accurate diagnosis of large vessel occlusions. With the ability to acquire both CBCTP images and high quality 4D-CBCTA images from a single C-arm acquisition, it may greatly reduce the time needed to transfer acute ischemic stroke patient between CT/MR room and interventional room.

CLINICAL RELEVANCE/APPLICATION

This technique can reduce the time from arrival to endovascular treatment for stroke patients, achieving better patient outcomes.

SSK15-08 Should Dental CBCT Devices be Equipped with Cu-filters? A Monte Carlo Organ Dose Comparison Study

Wednesday, Dec. 2 11:40AM - 11:50AM Location: S403B

Participants
Andreas Stratis, Leuven, Belgium (*Presenter*) Nothing to Disclose
Guozhi Zhang, Leuven, Belgium (*Abstract Co-Author*) Nothing to Disclose
Reinhilde Jacobs, Leuven, Belgium (*Abstract Co-Author*) Nothing to Disclose
Ria Bogaerts, Herestraat 49, Belgium (*Abstract Co-Author*) Nothing to Disclose
Hilde Bosmans, PhD, Leuven, Belgium (*Abstract Co-Author*) Co-founder, Qaelum NV Research Grant, Siemens AG

PURPOSE

To investigate the influence of different x-ray tube filter combinations on organ doses in a dental CBCT exam.

METHOD AND MATERIALS

Promax 3D Max x-ray tube (Planmeca, Finland) is equipped with 0.5mmCu and 2.5mmAl. Its equivalent source model (energy spectrum and filter description) was specified via half value layer (HVL) and air kerma measurements across the detector and by applying the Matlab Spektr tool (Mathworks,Inc). The tube housing (TH) equivalent Al filtration was also determined. Equivalent sources for different filter combinations were designed, employed to the x-ray tube and simulated: from (0 mmCu, 2.5mmAl) to (0.5mmCu, 2.5mmAl) in 0.1mmCu steps and from (0mmCu,2.5mmAl) to (0mmCu,10mmAl) in 2.5mmAl steps. Each spectrum was ray-traced through a 10 cm thick water phantom to determine the attenuation each spectrum undergoes. A spectrum specific scaling factor was calculated as the quotient of the total number of photons in the spectrum to the total number of photons of the lowest HVL spectrum (0 mmCu, 2.5mmAl) which yields the same amount of energy to the detector. Each source model was then used in an EGSnrc based Monte Carlo framework to simulate the jaw protocol (FOV: 130x90 mm2, 96kV, 85.2mAs) for the Zubal head voxel model. Organ doses were calculated for each different filtration such that the detector always receives the same amount of energy.

RESULTS

Increasing the HVL from 6.09mmAl (0mmCu,2.5mmAl,TH) to 9.05mmAl (0.5mmCu, 2.5mmAl,TH) results in dose decrease of 21.3% in skin, 9.4% decrease in cranial bone, 16.3% decrease in muscle, 6.5% decrease in ET and 16.6% decrease in blood doses. On the other hand, there is a 9.7% increase in the dose to brain, 4.5% increase in spinal bone marrow dose, 5.6% increase in eye lens dose and a 3.6 % dose increase to the thyroid. In absolute values these doses remain very low.

CONCLUSION

The beam hardening impact of Cu filtration results in reducing the dose to the skin. On the other hand, the higher mean photon energy results in higher doses outside the primary beam due to more scatter radiation. For the jaw protocol, this is the case for the thyroid and the eye lenses.

CLINICAL RELEVANCE/APPLICATION

To determine whether or not the implementation of Cu filtration has a benefit on organ dose reduction.

SSK15-09 Ultra-High Resolution Quantitative Cone Beam CT of the Extremities with a CMOS X-ray Detector

Wednesday, Dec. 2 11:50AM - 12:00PM Location: S403B

Participants
Wojciech Zbijewski, PhD, Baltimore, MD (*Presenter*) Research Grant, Carestream Health, Inc
Qian Cao, Baltimore, MD (*Abstract Co-Author*) Nothing to Disclose
Joseph W. Stayman, PhD, Baltimore, MD (*Abstract Co-Author*) Research Grant, Elekta AB; Research Grant, Varian Medical Systems, Inc
John Yorkston, PhD, Rochester, NY (*Abstract Co-Author*) Employee, Carestream Health, Inc
Shadpour Demehri, MD, Baltimore, MD (*Abstract Co-Author*) Research support, General Electric Company; Researcher, Carestream Health, Inc; Consultant, Toshiba Corporation
Jeffrey H. Siewerdsen, PhD, Baltimore, MD (*Abstract Co-Author*) Research Grant, Siemens AG; Consultant, Siemens AG; Research Grant, Carestream Health,Inc; License agreement, Carestream Health,Inc; License agreement, Elekta AB; ; ;

PURPOSE

Early detection of pathological alterations in trabecular bone could accelerate treatment and improve prognosis in osteoporosis and osteoarthritis, but is currently challenged by a lack of high resolution imaging modality capable of resolving the trabecular structure (~100 µm) while simultaneously providing diagnostic soft-tissue contrast. We investigate the feasibility of ultra-high resolution in-vivo imaging of trabecular bone by implementation of a CMOS x-ray detector on a previously developed extremities cone-beam CT (CBCT).

METHOD AND MATERIALS

CMOS detectors offer lower electronic noise (~500 electrons/pixel), faster read-out (up to 30 frames/second for 30x30 cm field of view) and higher resolution than aSi flat panel detectors (FPDs) typically used in CBCT. Initial evaluation of CMOS-based extremities CBCT employed a Dalsa Xineos 1515 detector (99 µm pixels, 600 µm CsI scinitillator) and a rotating anode x-ray source (0.3 mm focal spot). Magnification was 1.25 (matching that of extremities CBCT prototype). A contrast phantom, a resolution phantom with a 127 µm Tungsten wire for measurement of Point Spread Function (PSF), and a hand phantom (real skeleton in soft tissue-equivalent plastic) were imaged at 90 kVp, 0.1 - 0.5 mAs/frame and 720 projections (0.5º steps).

RESULTS

Reconstructions of the contrast phantom show satisfactory soft tissue discrimination with adipose-to-water contrast-to-noise ratio ranging from 2.6 at 0.1 mAs/frame to 5.1 at 0.5 mAs/frame. Full-width half maximum of the PSF was 0.26 mm, indicating high spatial resolution. Further improvement of resolution via optimization of CsI thickness is being investigated. Images of the hand phantom show excellent visualization of the cancellous bone, with clearly delineated trabecular architecture down to ~0.2 mm.

CONCLUSION

CMOS-based extremities CBCT provides high spatial resolution and diagnostic soft tissue contrast, establishing a novel platform for in-vivo imaging of bone microarchitecture. When combined with model-based reconstruction with advanced models of detector blur, the system is anticipated to reach ~100 µm detail size, opening applications in quantitative bone morphometrics for early detection of osteoporosis and osteoarthritis.

CLINICAL RELEVANCE/APPLICATION

Major improvement in spatial resolution of extremities CBCT is achieved with a CMOS detector, enabling in-vivo quantitative trabecular morphometry for early detection of osteoporosis and osteoarthritis.