6-2022

MRI-Based Synthetic CT Images Generated Using 3D Conditional GAN for IMPT Treatment Planning

Shupeng Chen
Beaumont Health

An Qin
Beaumont Health

Rohan Deraniyagala
Beaumont Health

Xuanfeng Ding
Beaumont Health

Y Peng

See next page for additional authors

Recommended Citation

Chen S, Qin A, Deraniyagala R, Ding X, Peng Y, Liu Y, et al MRI-based synthetic CT images generated using 3D conditional GAN for IMPT treatment planning. Med Phys. 2022 Jun 1;49(6): E700-E701.

Authors
Shupeng Chen, An Qin, Rohan Deraniyagala, Xuanfeng Ding, Y Peng, Y Liu, C Zhao, and X Deng

and optimizing use of patient time and staff resources**. Methods:** We performed a retrospective IRB-approved single-institution review of 2471 patients, who were treated with PBT between 2017 and 2021. For each anatomic site, QACT and re-planning patterns were analyzed to identify the optimal frequency for QACTs for different anatomical sites, while maintaining the same quality of care as before. **Results:** Weekly QACTs are recommended for head-and-neck (HN) patients treated twice per day. Every-other-week QACTs are required for lung and HN treatments treated once per day, whereas first-week and half-way-through-treatment QACTs are necessary for abdomen, pelvis, bladder, rectum, and anus treatments. QACTs for gynecologic, spines, and prostate with seminal vesicles (SVs) and pelvic lymph nodes (LNs) with sequential treatments require QACTs in the first week and a week before the boost plan starts. Liver, pancreas, kidney, stomach, prostate, and prostate with SVs require QACTs in the first week of treatment. Brain treatments need QACTs on the second week of treatment, and Breast patients require QACTs half-way through treatment. No QACTs are required for craniospinal irradiation and extremity tumors. Following these new guidelines, a total of 7023 QACTs could be effectively reduced by 2750 QACTs (~39% reduction) over 5 years. **Conclusion:** The above newly proposed QACT patterns for all anatomic sites are optimal and maintain treatment quality. Following this analysis, we have adopted a new clinical paradigm for decreased routine QACTs.

PO-GePV-M-82, The Pearson Correlation Coefficient of Target and the Beam Path Length Using Cone-Beam CT Images as Adaptive Planning Indicators of Head and Neck Patients Undergoing Proton Therapy: D Han[1]*, N Biswal[2], B Zhang[3], M Witek[4], B Yi[5],(1) University of Maryland, Baltimore, MD, (2) Unversity of Maryland, School of Medicine, Bel Air, MD, (3) University of Maryland School of Medicine, Baltimore, MD, (4) University Of Maryland School Of Medicine, , , (5) University of Maryland School of Medicine, Baltimore, MD

Purpose: This study tested the Pearson correlation coefficient (PCC) and the change in beam path length (BPL) on daily cone beam (CBCT) images as adaptive planning indicators in proton beam therapy (PBT) for head-and-neck (HN) tumors. PCC gives information about tumor morphological changes, whereas BPL change gives information about changes in tissue. **Methods:** We retrospectively analyzed CBCT images of 247 HN patients for the measurements of BPL change and analyzed (BPL group). Each beam was ray traced from the isocenter to the skin surface along the central axis using the daily CBCT images. 148 CBCT images of 20 HN patients who were adaptively replanned during the course of treatment for PCC (PCC group). The target volumes were mapped on the CBCT images and the PCC values were obtained between first and the successive CBCT images. **Results:** Total 91 patients among BPL group were replanned. 87% of them demonstrated the change of BPL > 3 mm. The sensitivity of the BPL threshold 3mm is 90%. The average and the median PCC values for PCC group were 0.45 and 0.50, respectively, on the day when a QACT was triggered. The PCC threshold for replan is determined to be 0.5 so that half of the replanning group belongs to this criterion. Among the PCC group, 16 demonstrated the BPL change >3mm, which suggest replan per the BPL threshold and 4 showed less. Two of 4 cases showed PCC less than 0.5. By combining both of the BPL and the PCC thresholds over all sensitivity is 95%**. Conclusion:** The Pearson correlation coefficient (PCC) of tumor morphology and/or beam path length (BPL) change from isocenter to the skin surface along beam central axis on CBCT images can be used as an adaptive plan indicator for proton beam therapy (PBT) HN patients with 95 % sensitivity.

PO-GePV-M-83, MRI-Based Synthetic CT Images Generated Using 3D Conditional GAN for IMPT Treatment Planning: S Chen*, A Qin, R Deraniyagala, X Ding, William Beaumont Hospital, Royal Oak, MI Y Peng, Y Liu, C Zhao, X Deng, Sun Yat-sen University, Guangzhou, Guangdong, China

Purpose: To develop an advanced deep convolutional neural network architecture to generate synthetic CT (SCT) images from MR images for intensity-modulated proton therapy (IMPT) treatment planning of head and neck cancer patients**. Methods:** T1-weighted MR images and paired CT (PCT) images were obtained from 189 nasopharyngeal cancer (NPC) patients under radiotherapy immobilization. Deformable image registration was performed between MR and PCT images for each patient to create an MR-CT image pair. Thirteen pairs were randomly chosen as independent test sets and the remaining 176 pairs (14 for validation and 162 for training) were used to build two conditional generative adversarial networks (GAN)s: 1) GAN3D using a 3-dimensional Unet enhanced with residual connection and attentional mechanism as the generator and 2) GAN2D using a standard 23-layer 2-dimensional Unet as the generator. For each test patient, SCTs were generated using the generators with the MR image as input and were compared with respect to the corresponding PCT. A 4-beam IMPT treatment plan was created and optimized on the PCT, and then the dose matrix was recalculated on the SCTs. The dosimetric accuracy was evaluated using gamma index**. Results:** The mean absolute error (MAE) between the PCT and SCT images, within the whole body, was (65.31±5.16)HU and (66.12±4.51)HU for GAN3D and GAN2D models, respectively. The MAE, within the bony structure (HU>150) were (172.01±16.71)HU and (175.7±18.54)HU for GAN3D and GAN2D models, respectively. The (2m/2% and 3m/3%) gamma passing rates were (98.2±1.7)% and (99.4±0.8)% for the GAN3D model and (97.7±1.9)% and (99.3±0.8)% for the GAN2D model. **Conclusion:** SCT image generated using the conditional GAN achieved

clinical acceptable dosimetric accuracy for IMPT plan of NPC patients. Using advanced network architecture design, such as residual connection and attention mechanism for the generator, SCT image can be further improved and resulted in a small improvement of dosimetric accuracy.

PO-GePV-M-84, Feasibility Study of Proton Scanning System with Perpendicular Magnetic Field by Open MRI: H Ueda[1]*, Y Fujii[2, 3], T Takayanagi[3], K Nishioka[4], T Hashimoto[4], H Aoyama[4], K Umegaki[1], T Matsuura[1],(1) Faculty of engineering, Hokkaido University, Japan, (2) Graduate School of Engineering, Hokkaido University, Japan, (3) Hitachi Ltd., Japan, (4) Department of Radiation Oncology, Faculty and Graduate School of Medicine, Hokkaido University, Japan

Purpose: To achieve both large field-size (FS) of protons and large field-of-view (FOV) in MRI-integrated proton therapy (MRiPT) system, an open MRI design has been proposed, where a hole is made in the center of the yoke through which the proton beam travels to patient. This study identified the offset rotation angle of the MR scanner around the beam's central axis to ensure the large FOV and explored the feasibility of a prostate plan with the proposed MRiPT assembly**. Methods:** Proton scanning nozzle with its design slightly modified from the existing system and the magnetic field map modeled for 0.3-T MRiPT system were used in the Geant4 simulation. The yoke hole is open over 20 degrees in a direction vertical to the magnetic field. 70 and 220-MeV pencil beams were delivered to a water phantom with the Bragg peaks positioned at the isocenter depth, laterally shifted by ±20 cm from the isocenter. The offset rotation angle of the MR scanner was determined so that the yoke hole ensures an unobstructed proton beam path. Then, by assuming the assembly, prostate plans were made using the Geant4-based inverse optimization tool, and the impact of the beam deflection by the magnetic field was assessed by comparing the DVH parameters of CTV and OARs (rectum and bladder). **Results:** The irradiation field of 40 × 30 cm² was successfully scanned with 3 degrees of scanner's rotation. The differences in DVH parameters of both CTV and OARs were all less than 2.5%, therefore, the impact of the magnetic field on the dose distribution was considered to be small**. Conclusion:** Large FS of proton beam was realized with a small rotation of the open MRI scanner. The treatment planning for prostate cancer was shown to be feasible with the proposed MRiPT assembly.

Yusuke Fujii and Taisuke Takayanagi are paid by Hitachi Ltd.

PO-GePV-M-86, Determining the Feasibility of Integrating Laser Plasma Accelerated Proton Beams and Thermoacoustic Dose Imaging Into a Small Animal Image-Guided Therapy Platform: M Vieceli*, A Almalki, K Stantz, Purdue University, West Lafayette, IN

Purpose: To determine the feasibility of using thermoacoustic imaging to measure the 3D dose distribution from protons generated from laser plasma acceleration (LPA)**. Methods:** The Monte Carlo (MC) program FLUKA was used to simulate a proton beam with LPA characteristics based on literature (50 MeV, 30% FWHM energy spread, 2 degrees angular divergence, 10^7 protons/pulse). Thermoacoustic waves were simulated on a voxel-wise basis of the MC generated dose and sampled using 2π and sub-2π transducer arrays based on in-house detectors. A 3D filtered backprojection algorithm was used to reconstruct volumetric images of the dose. An iterative reconstruction algorithm was implemented to achieve 4π sampling of projection space. The dose sensitivity of the detectors was determined by adding different noise levels to the signals**. Results:** By shifting the water level within the sub-2π detector, the increased angular sampling of the dose distribution in projection space improved the overall image accuracy and reduced artifacts, although with off-isocenter blurring. The iterative reconstruction algorithm was able to significantly improve the image accuracy, with its application to the initial 2π detector image achieving convergence toward the MC dose in magnitude and spatial distribution**. Conclusion:** This work demonstrates the feasibility of measuring LPA proton beams with thermoacoustic imaging. The implementation of an iterative reconstruction algorithm enables high accuracy images to be obtained without requiring 4π transducer array angular coverage. Ongoing experiments are being performed to determine the dose sensitivity of our detectors using high frequency transducers and low frequency hydrophones. Future work will correct for off-isocenter blurring to improve dose accuracy and precision when implementing a sub-2π transducer array.

This work was prepared under an educational institution award from the U.S. Nuclear Regulatory Commission. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the view of the institution or the U.S. Nuclear Regulatory Commission.

PO-GePV-M-87, Intensity and Range Modulated Proton Radiography Using High Energy Therapeutic Proton Scanning Pencil Beams: C Pelas[1]*, N Alsbou[2], S Ahmad[1], I Ali[1],(1) , Oklahoma City, Ok, OK, (2) Department of Engineering and Physics, University of Central Oklahoma, Edmond, OK

Purpose: To investigate the visibility of intensity- and range-modulated proton radiography proton with pencil beam

