auto-segmentation performance for adaptive prostate radiotherapy, by leveraging the daily image-guidance fan-beam CT images of the specific patient available in the current IGRT workflow.

Materials/Methods: Our institution has set up a newly developed biology-guided radiotherapy (BgRT) system enabling high-quality fan-beam CT imaging for daily treatments. The data of the first prostate patient treated with this system including 26 daily fan-beam CT scans were utilized in this study. A population network was first trained for the auto-segmentation of the prostate and seven pelvic OARs, based on a population dataset containing 56 different patient cases treated on the regular Linac. The pre-trained population network was intentionally fine-tuned to adapt to this specific patient with a transfer learning method. The selected OARs of this patient were contoured by two radiation oncologists on the initial treatment planning and all sets of daily fan-beam CT images as the ground truth for the patient-specific learning. Three different fine-tuning methods, i.e., fine-tuning the last convolution layer, the last convolution block and the whole network were analyzed. A longitudinal study was conducted by exploring the relationship between the auto-segmentation performance and the number of the sequential prior data used for learning. The performance of the patient-specific network was compared with the population network as well as the clinical rigid registration method to highlight its efficiency in radiotherapy practice.

Results: The Dice similarity coefficient (DSC) results of the proposed patient-specific network were 0.882, 0.934, 0.864, 0.827, 0.952, 0.954, 0.921 and 0.904 for the prostate, bladder, rectum, seminal vesicle, left and right femoral head, bowel and lymph nodes, respectively, outperforming the population network (mean DSC of 0.627) and the clinical registration method (mean DSC of 0.716). The whole network fine-tuning method outperformed the other two fine-tuning methods, showing it is more effective in this study. The contouring accuracy of the patient-specific network gradually increased with the increment of longitudinal training cases and approached saturation with more than four training cases.

Conclusion: This study proposes an accurate auto-segmentation method based on the patient-specific deep learning for adaptive prostate radiotherapy. By utilizing the image and contour similarity between the treatment fractions, the patient-specific auto-segmentation could outperform the common population network and the clinical registration method by a large margin, and thus is promising to facilitate more precise radiotherapy based on the new BgRT system.

Author Disclosure: Y. Chen: None. S. Butler: None. L. Xing: Research Grant; Varian Medical Systems. Honoraria; Varian Medical Systems. Stock Options; Zap Surgical Inc, Huiyihuiying Med Co., Luca Medical Systems, More Health Inc. Royalty; Varian Medical Systems, Standard Imaging Inc. Scientific Advisory; Huiyihuiying Medical Co, Luca Medical Systems, More Health Inc. Consultant and Advisory; Zap S. B. Han: None. H.P. Bagshaw: None.

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Automatic Contour Refinement of Inaccurate Auto-Segmentation Using an Active Contour Model for MR-Guided Adaptive Radiotherapy

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Purpose/Objective(s): One of the bottleneck problems of MR-guided adaptive radiotherapy (MRgART) is the impractically long time required to segment the patient's anatomy of the day. Deep learning auto-segmentation (DLAS) has a limited success for complex structures such as those in abdomen. We have previously proposed an active contour model (ACM) to automatically refine the inaccurate contours from DLAS. This study aims to improve the performance of the ACM method by further optimizing the method and testing it using large and diversified abdominal MRI datasets.

Materials/Methods: An improved ACM method that does not require any manual parameter adjustment was implemented. The ACM utilizes the probability maps generated from DLAS models to establish 2D parameter maps and to initialize contour evolution. The performance of the ACM method was tested on the inaccurate DLAS contours of abdominal organs from 91 MRI sets (76 sets of T2-HASTE sequence from a 3T MR-simulator and 15 sets of BTFE sequence from a 1.5T MR-Linac). Bowels were divided into multiple subregions with each including a bowel loop. Levels of contour inaccuracies were divided into two groups: (1) major error group with Dice similarity coefficient (DSC) <0.5 or mean distance to agreement (MDA) >8 mm, and (2) minor error group with remaining contours of 0.5≤ DSC<0.8 or 3 mm<MDA≤8 mm. The performance of the ACM was evaluated based on various metrics, e.g., DSC, MDA, and the added path length (APL, a metric that is correlated with contour editing time). Manually delineated contours were used as ground truth.

Results: As shown in the table below, the average DSC, MDA and APL values for all the contours were improved after the ACM correction. By applying this ACM, approximately half of the contours in major error group were improved to minor error group, and 12-40% of the contours became practically acceptable per TG-132 recommendation (DSC>0.8 and MDA<3 mm). The largest improvement was seen in the major error group of pancreases, where APL reduced by one third, indicating substantial reductions in the subsequent contour editing effort. The execution time of this method to correct one contour was around 1 second.

Conclusion: The ACM method was successfully implemented to automictically and quickly correct for inaccurate contours from MRI-based DL auto-segmentation for complex anatomy, e.g., bowels and pancreas, in abdomen. The ACM method may be used to reduce the manual contour editing workload and accelerate the segmentation process for MRgART.

Abstract 3241 — Table 1

Organs	Initial auto-segmentation error group	Contours improved to minor error	Contours improved to acceptable	Mean DSC change	Mean MDA (mm) change	Mean APL (mm) change
Bowels	Major	54% (527/979)	12% (114/979)	0.34 → 0.60	6.89 → 5.12	94.12 → 74.24
	Minor	n/a	40% (1300/3281)	0.72 → 0.79	3.27 → 3.20	97.76 → 91.18
Pancreas	Major	49% (117/237)	14% (33/237)	0.31 → 0.56	6.71 → 4.58	73.06 → 48.20
	Minor	n/a	29% (252/863)	0.70 → 0.73	3.51 → 3.49	63.74 → 49.03

Author Disclosure: J. Ding: None. Y. Zhang: None. A. Amjad: None. J. Xu: None. D. Thill: None. A. Li: Research Grant; Elekta AB, Siemens Healthineers, Manteia Med. Honoraria; Accuray Inc.

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Organs-at-Risk Segmentation on T_2-Weighted Magnetic Resonance Imaging Using a Transformer-Based Model

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Purpose/Objective(s): The scarcity of high-quality, annotated MRI data for MR-only radiotherapy (RT) treatment planning remains a limitation for training automatic segmentation algorithms. In this study, we develop a framework first to synthesize T_2-weighted MRI from CT using unpaired input images, and subsequently train a volumetric transformer-based segmentation model with propagated CT contours to perform segmentation on acquired T_2-weighted MRI.

Materials/Methods: A retrospective database including 46 patients with locally advanced was identified. For synthesis, a 3D patch-based CycleGAN model (patch size of 96 × 96 × 96) was trained and validated on 13 and 5 patients respectively. Then, a transformer-based segmentation algorithm was trained and validated on synthetic MR images from 32 and 7 patients respectively to segment the femoral heads, bladder, rectum, bowel and sigmoid (binary cross entropy loss + Dice loss).

Results: The results from automatic contouring of OARs on synthetic images revealed that our framework delineated the femoral heads and the bladder with average Dice scores and Hausdorff distance of >0.9 and

<10mm respectively. However, the segmented contours were less accurate in bowel and rectum due to their variable geometry and difficulty in segregating from adjacent soft tissues. The predictions of these organs on acquired T_2-weighted MR images also showed acceptable accuracy with visual inspection.

Conclusion: Our framework showed the feasibility of transferring anatomical knowledge from a pre-existing labelled CT data for RT to synthetic T_2-weighted MR images, particularly in the femoral heads and bladder. This approach provides significant clinical value as it uses an unsupervised approach for data augmentation and/or domain adaptation Future studies will quantitatively evaluate our framework's performance on larger acquired MRI cohorts and explore weakly-supervised techniques to assess performance improvements on more challenging soft tissues (e.g., bowel, rectum) with inclusion of several labelled MRI input datasets.

Abstract 3242 − Table 1: Mean and standard deviations of Dice and 95% percentile Hausdorff distance based on synthetic T2-weighted MR images from

Metric	R Femoral Head	L Femoral Head	Bladder	Bowel	Rectum
Dice	0.903±0.033	0.909±0.026	0.912±0.073	0.778±0.0681	0.603±0.163
95% Hausdorff Distance (HD) (mm)	5.032±2.452	4.654±1.476	9.974±14.632	19.793±10.061	29.641±9.934

Author Disclosure: R. Kalantar: None. J.M. Winfield: Honorary contract; The Institute of Cancer Research. employee/employer; The Royal Marsden NHS Foundation Trust. C. Messiou: None. S. Lalondrelle: Elekta. MSD, GSK. D. Koh: None. M. Blackledge: Stock; CeleScan.

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Accuracy of Prostate Segmentation on Synthetic MR Images Generated from CT Scans Using a Novel Generative Adversarial Network for High-Dose-Rate Prostate Brachytherapy

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Purpose/Objective(s): For patients undergoing prostate HDR brachytherapy at our institution, both CT and MRI scans are acquired to identify catheters and delineate the prostate, respectively. However, acquiring both scans increases the time and hospital resources needed for treatment. We hypothesized that a synthetic MRI (sMRI) could be generated with sufficiently high soft-tissue contrast from the planning CT using a novel Generative Adversarial Network (GAN) framework with the goal to use sMRI to delineate the prostate without requiring the MRI.

Materials/Methods: Our newly developed PixCycleGAN, a hybrid of Pix2Pix and CycleGAN to maximize the advantage of Pix2Pix and to add the strength of CycleGAN training with paired CT-MRI datasets acquired on the same day for previously treated HDR prostate patients. PixCycleGAN is composed of two Residual Network generators and four discriminators with two transformation cycles. To train PixCycleGAN, 58 paired CT and T2-weighted MRI datasets without metal or motion artifacts were selected. Using 10 independent datasets, the image quality of sMRI was evaluated using metrics including the mean absolute error (MAE), mean squared error (MSE), Peak Signal-to-Noise Ratio (PSNR), and Structural Similarity Index (SSIM). The accuracy of prostate segmentation was evaluated by having radiation oncologists manually delineate the prostate on real MRI (rMRI) and sMRI images. All rMRI and sMRI images were presented in a random order to reduce potential bias in segmentation. The dice similarity coefficient (DSC) and Hausdorff distance (HD) were evaluated for the prostate contours delineated on sMRI vs. rMRI. To estimate interobserver variability (IOV), DSC and HD of prostate contours independently delineated on rMRI by two radiation oncologists were calculated.

Results: Qualitatively, sMRI images showed enhanced soft-tissue contrast on the boundary of the prostate and rectum compared to the CT scans. In addition, sMRI contained features from both MRI and CT showing clear visualization of the boundary of the prostate and the catheters. Image quality metrics were: MAE=0.13±0.03, MSE=0.03±0.01, PSNR=69.2±1.42 (dB), SSIM=0.78±0.07. The DSC of the prostate contour was 0.85±0.05 for sMRI vs. rMRI and 0.84±0.07 for IOV (p=0.13). However, the HD for sMRI vs. rMRI (7.77±1.83 mm) was smaller than the HD for IOV (9.53± 2.74 mm).

Conclusion: We developed a novel PixCycleGAN framework to generate a sMRI from the planning CT which depicted enhanced soft-tissue contrast at the boundaries of the prostate. The agreement between DSC of the prostate on sMRI vs. rMRI and DSC of IOV shows that the accuracy of prostate segmentation on sMRI is within the segmentation variation on rMRI between two radiation oncologists. In the future, we will evaluate dosimetric impact of using sMRI in prostate segmentation for HDR treatment planning.

Author Disclosure: H. Kang: None. B.P. Venkatesulu: None. A. Podgorsak: None. M. Abuhamad: None. M.M. Harkenrider: Advisory Board; AstraZeneca. Section editor of journal; Brachytherapy Journal. Secretary and treasurer for the board of directors; Chicago Radiological Society. A.A. Solanki: None. J.C. Roeske: None.

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^{68}Ga-DOTATATE PET vs. MRI-Based Treatment Planning for Post-Operative and Intact Meningioma: A Dosimetric Analysis

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Purpose/Objective(s): The current standard for radiation treatment planning involves MRI-based image guidance to define intact disease and residual tumor. Because nearly all meningiomas express somatostatin receptor 1/2 (SSTR1/SSTR2), SSTR ligands such as ^{68}Ga-DOTATATE are being explored for meningioma radiotherapy treatment planning. Incorporation of ^{68}Ga-DOTATATE PET can assist with radiation target volume delineation and reduce the dose to organs-at-risk (OARs). We hypothesize that ^{68}Ga-DOTATATE PET-based treatment plans will reduce dose to OARs when compared to MRI-based plans.

Materials/Methods: For each patient, 7 blinded physician contours were retrospectively performed on MRI and PET. A representative MRI and PET physician contour was chosen. All treatment plans were rendered on computed tomography (CT) planning datasets, using VMAT and 6MV photon energy. Each arrangement consisted of 3 independent partial arcs. Two arcs were positioned on the coplanar axis with alternated collimator settings of 0 and 90 degrees to promote MLC sparing with a third unique vertex arc chosen independently to spare normal brain tissue and associated organs at risk (OAR). For MRI structures, a 1 cm expansion from the gross tumor volume (GTV) was used to create a clinical treatment volume (CTV) 60. A 2 cm expansion was used to create a CTV 54. For PET