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JOINT AAPM | COMP MEETING

Predicting Achievable Cardiac Dose Reduction with Deep Inspiration Breath-Hold Using Free-Breathing CT and Deep Learning

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INTRODUCTION

1. Left-Sided Breast Cancer Radiotherapy

- Adjuvant radiotherapy for left-sided breast cancer reduces recurrence and, in selected patients, mortality [1]
- **Each 1-Gy increase in mean heart dose (MHD)** is associated with a **7.4% increase in major coronary events** [2]
- Reducing MHD is clinically important

2. DIBH for Cardiac Dose Reduction

- Deep-inspiration breath-hold (DIBH) is widely used worldwide to reduce cardiac dose
- Its benefit varies among patients, but evaluation typically requires both free-breathing and DIBH CT simulation and treatment planning

3. Deep Learning-Based Pre-selection for DIBH

- Deep Learning (DL)-based DIBH pre-selection has been reported
- To our knowledge, no study has quantitatively predicted patient-specific MHD reduction from routine free-breathing (FB) CT alone

4. Aim

- **Predict patient-specific MHD reduction achievable with DIBH using FBCT alone**
- Two-stage DL framework: **generate synthetic DIBH-CT (sDIBH-CT)**, then **predict the DIBH dose distribution**

METHODS AND MATERIALS

1. Patient Cohort and Data Preparation

Patient Cohort

- **132 left-sided breast cancer patients** simulated in both FB and DIBH
- Collected per patient: FB-CT and DIBH-CT images, structure sets, and clinical dose distributions

Data Preparation

- Split into **training / validation / test (92 : 19 : 21)**
- CT images and dose distributions resampled to a common spatial resolution
- **Cropped to 64 x 192 x 192**, centered on the heart and breast region
- CT intensities **clipped to -200 to 300 HU** and normalized

2. Two-Stage Deep Learning Framework

Stage 1: Synthetic DIBH-CT Generation

- **3D Pix2Pix GAN** trained to generate **sDIBH-CT from FB-CT**
- **External, left-lung, and heart masks** auto-generated with **TotalSegmentator**

Stage 2: Dose Prediction

- **3D U-Net** trained on **clinical DIBH-CT + anatomical mask channels (External, L-Lung) to predict the DIBH dose distribution** (Heart mask used for evaluation only)
- At inference: applied to both the original FB-CT and the generated sDIBH-CT
- **Predicted reduction**

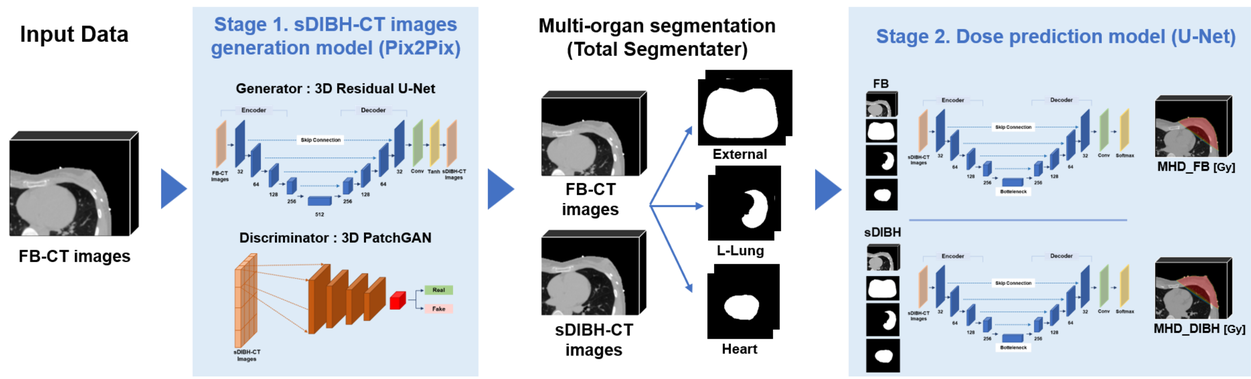
$$\Delta MHD\_prediction = MHD\_FB\_prediction - MHD\_sDIBH\_prediction$$

3. Evaluation

- **Reference reduction (clinical plans)**

$$\Delta MHD\_reference = MHD\_FB\_plan - MHD\_DIBH\_plan$$

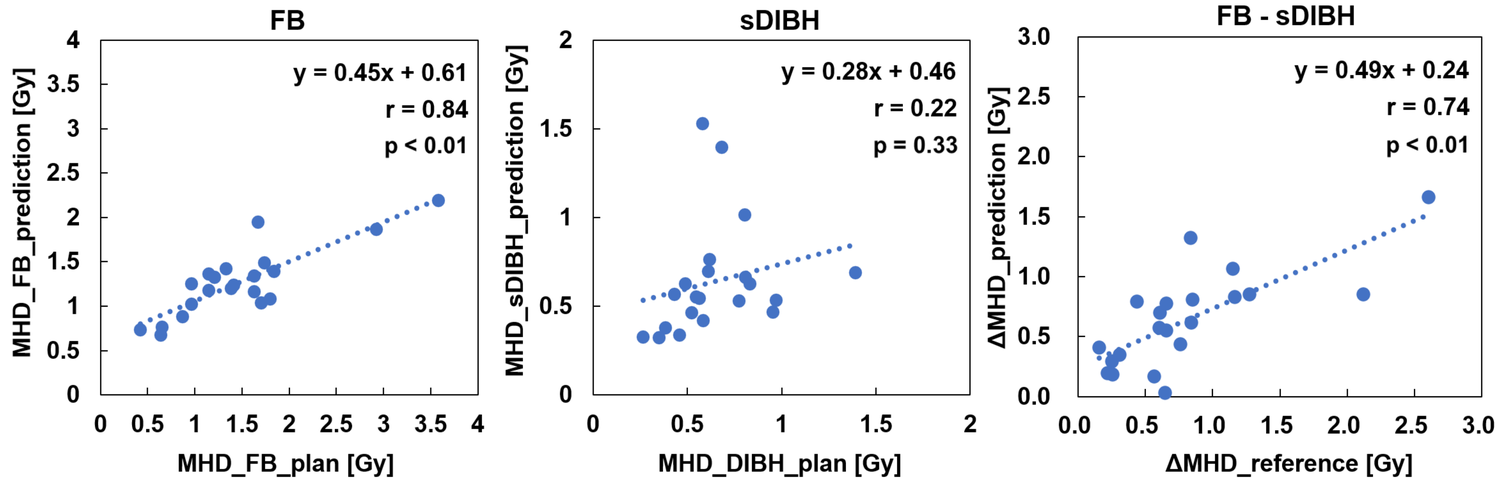
- Evaluated on the held-out test set: predicted vs. reference ΔMHD
- Metrics: mean abusolute error **(MAE),** median absolute error **(MedAE)**, **Pearson's correlation coefficient (r)**



The proposed deep learning–based workflow

RESULTS

Predicted vs. Reference MHD and ΔMHD

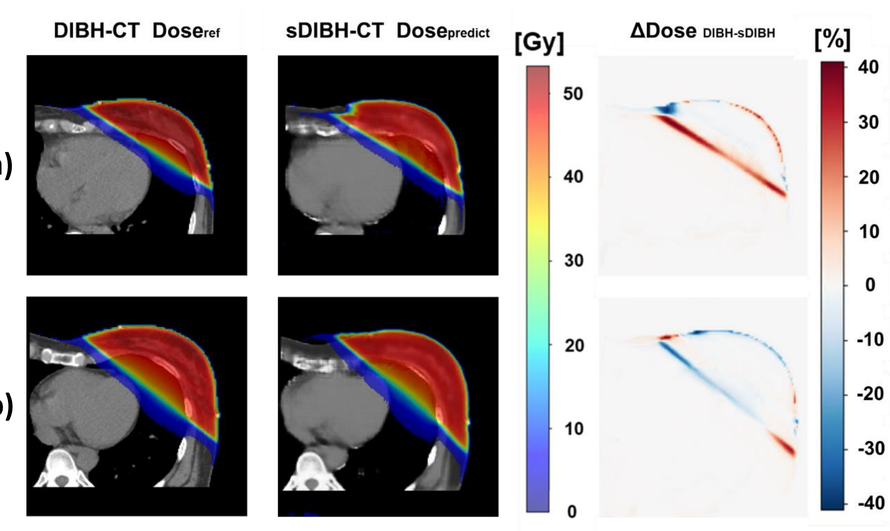


Prediction performance

Metrics	MHD_FB	MHD_DIBH	ΔMHD
MAE	0.34	0.24	**0.25**
95%CI	0.21-0.50	0.14-0.36	**0.14-0.38**
MedAE	0.25	0.14	**0.11**
IQR	0.11-0.44	0.06-0.25	**0.04-0.34**

All values in Gy. 95% CI, 95% confidence interval; IQR, interquartile range.

Dose Comparison in Representative Cases



(a). High error case ΔMHD=0.62 Gy, (b). Low error case ΔMHD=0.03 Gy

DISCUSSION

1. Clinical Utility

This approach may help identify patients likely to benefit from DIBH, reducing unnecessary respiratory coaching, additional CT scans, and planning workload.

2. Framework Advantage

The framework models DIBH-related anatomical changes and dosimetric effects. Synthetic DIBH-CT and predicted dose distributions may also support visual evaluation and error analysis.

3. Study Limitation

This was a single-institution study and requires external validation. In addition, TotalSegmentator-based segmentation was affected by inaccuracies in the synthetic DIBH-CT.

CONCLUSIONS

We developed a two-stage deep learning framework using FB-CT alone to predict patient-specific MHD reduction achievable with DIBH, suggesting the potential for individualized prediction of DIBH-associated cardiac dose reduction.

REFERENCES

1. EBCTCG et al. Lancet. 2014;383:2127–2135.
2. Darby SC et al. N Engl J Med. 2013;368:987–998.

IRB・COI

- This study was IRB approved. [IRB approval number: 25 - 38]
- No conflicts of interest to disclose.

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