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Investigating Physics-Based Standardization of Radiomics from Normal and Fibrotic Lung Regions across CT Reconstruction Kernels and Radiation Doses

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INTRODUCTION

- Diffuse lung disease (DLD) is a group of pulmonary diseases that can cause irreversible pulmonary fibrosis (scarring).
- CT can provide **objective, quantitative measurements via radiomic features** that capture tissue phenotypic properties, but clinical adoption is limited because of lack of reproducibility across CT acquisition parameters[1].
- Radiomics standardization based on mathematical characterizations of intrinsic physics-based image properties (spatial resolution and noise) have been shown to reduce radiomics variability in phantoms[2].
  - **The purpose of this work is to investigate whether physics-based radiomics standardization can increase agreement in radiomic features across different kernels and doses in patients with DLD.**

METHODS AND MATERIALS

- Raw CT projection data of 3 patients receiving a thoracic CT exam for DLD was collected from a Siemens Somatom Force scanner.
- Raw data reconstructed with 5 kernels and 4 doses:
  - Kernels
    1. Br32d (smooth)
    2. Br40d (medium smooth)
    3. Br49d (medium)
    4. Br59d (medium sharp)
    5. Br69d (sharp)
  - Doses
    1. 100% (of original scan)
    2. 75%
    3. 50%
    4. 25%
- All raw projection data reconstructed with Siemens ReconCT v14.
- 16 reconstruction conditions were made in total (each kernel except Br49d crossed with each dose).
  - The Br49d-100% condition was selected as a reference condition for comparison. **Note:** only the reference condition is reconstructed with B49d.
- 2 board certified thoracic radiologists annotated regions of classic normal and classic fibrosis in this reference condition (Fig. 1).
- Each non-reference condition was standardized using the physics-based standardization method from Gang *et. al*[2]; summarized as:
  1. Deconvolve blur of non-reference kernel from an image and reconvolve with blur from reference kernel (Br49d).
  2. Deconvolve noise from radiomic distributions (histogram and GLCM).
- Within annotations, 12x12 pixel patches were sampled for standardization and radiomic features were measured before and after standardization.
- 39 total radiomic features were extracted; 18 histogram and 21 GLCM.

Analysis

- Features from non-reference conditions before/after standardization were compared to values from the reference condition (Br49d-100%) using:
  - Ratio of number of patches with values ≤ 5%, ≤ 10%, and ≤ 20% different from the reference value;
  - Concordance correlation coefficient (CCC).

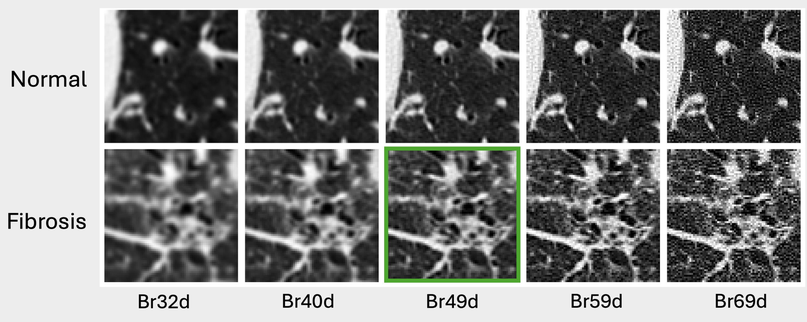

Figure 1. Normal and fibrosis tissue in an image reconstructed with each of the kernels ranging from smoothest to sharpest from left to right. The Br49d kernel is boxed in green and indicates the kernel used as reference.

Results

- Before standardization, no condition for either tissue achieved > 50% of features withing 5% of reference (Fig. 2, top row of each before block).
- **After standardization, 10/16 (62.5%) and 9/16 (56.3%) conditions for normal and fibrotic regions achieved > 50% of features withing 5% of reference (Fig. 2, top row of each after block).**
- Before standardization, percent of features with CCC > 0.9 relative to reference ranged from 7-59% across reconstruction conditions for normal and 31-62% for fibrosis (Fig. 3a and 3c).
  - Kernel has a greater impact of radiomic feature value than dose dose.
- **After standardization, percent of features with CCC > 0.9 relative to reference ranged from 58-93% across reconstruction conditions for normal, and 44-93% for fibrosis (Fig. 3b and 3d).**
  - Normal tissue demonstrated higher consistent agreement with reference values than fibrosis after standardization.
  - Kernels closer to reference (i.e., Br40d and Br59d) achieved better agreement (Fig. 4b and 4d) regardless of dose.

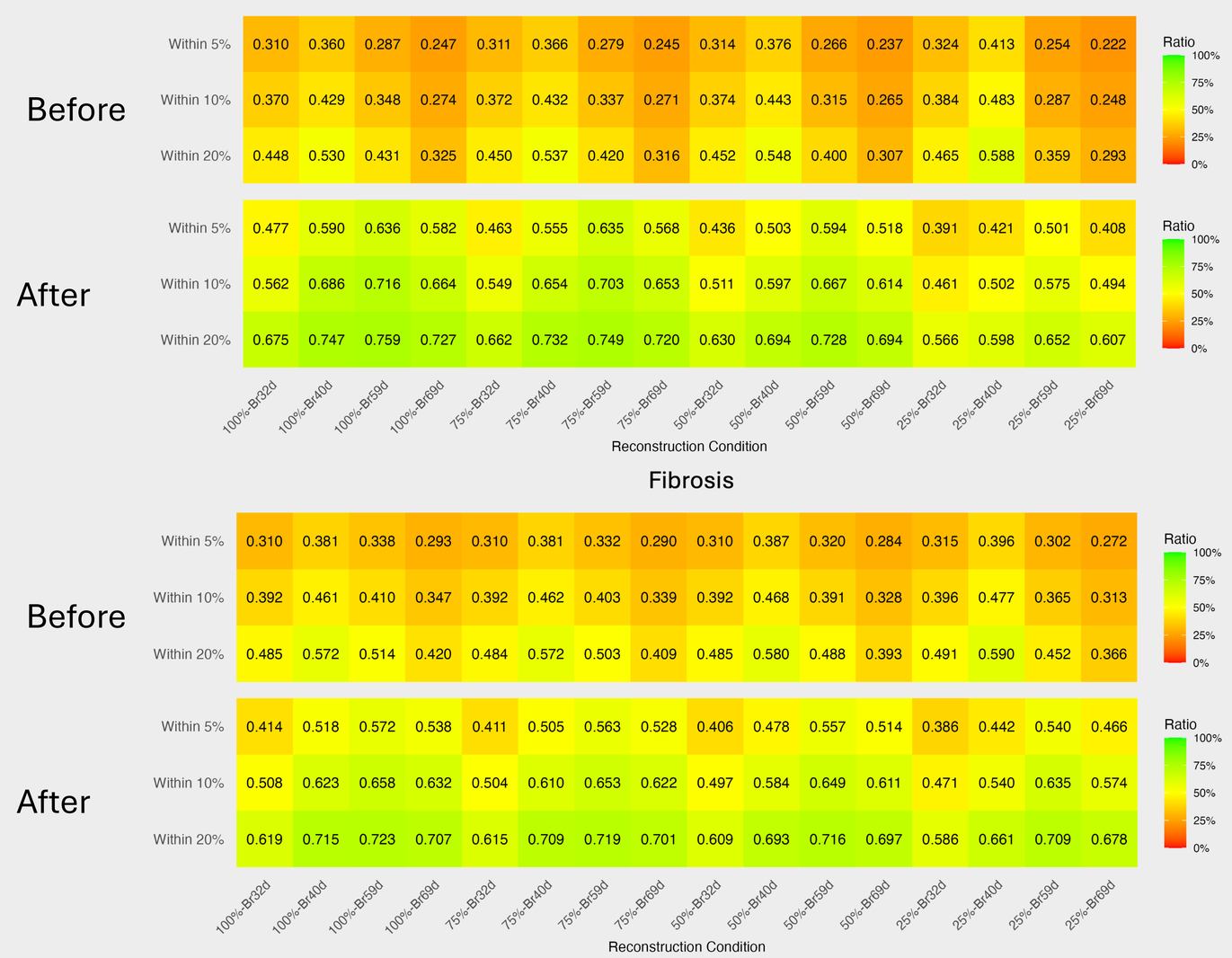

Figure 2. Heatmaps of ratios of total radiomic features extracted from 12x12 patches of normal (top) or fibrotic regions (bottom) in images reconstructed with non-reference conditions within 5%, 10%, and 20% of the value from the reference condition before and after standardization. For every non-reference reconstruction, standardization increases the ratio of features within each percent difference range in both tissue types. Standardization appears to have a greater benefit on features from kernels sharper than the reference (Br49d). The smoothest kernel (Br32d) appears to benefit the least from standardization relative to the chosen reference condition.

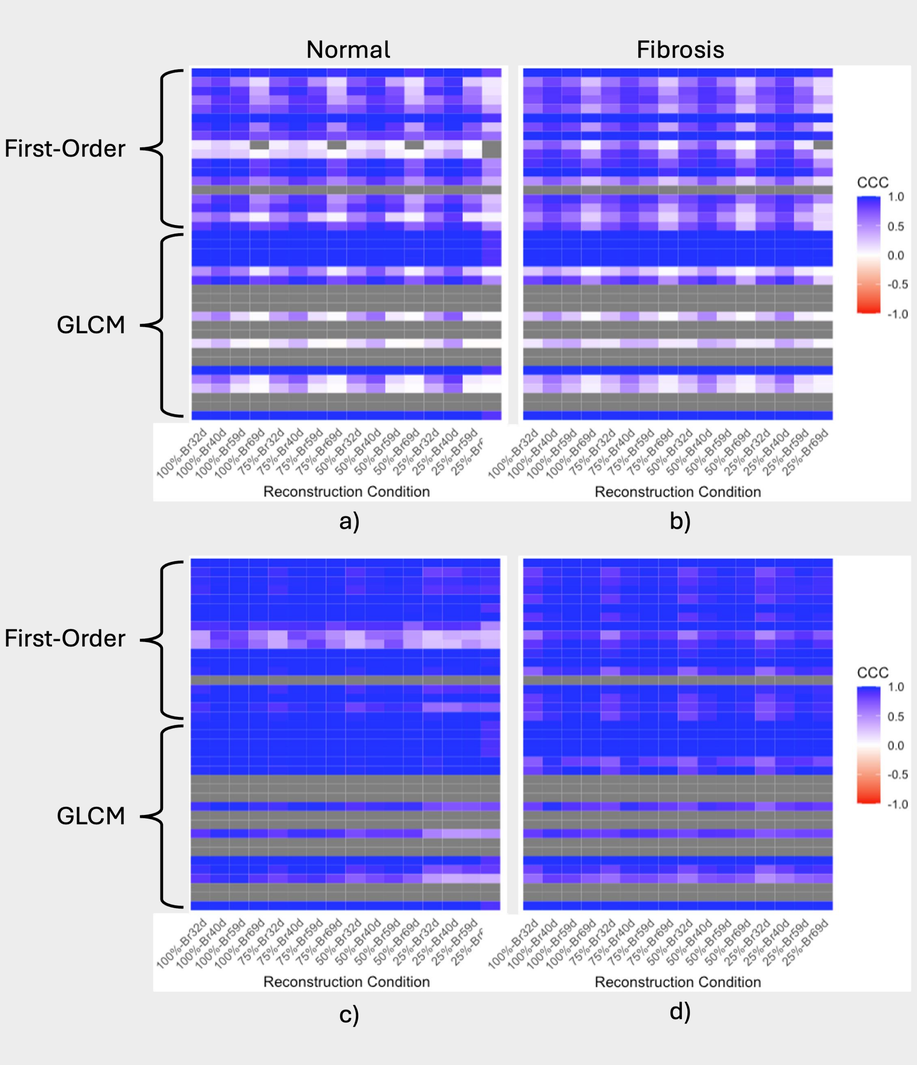

Figure 3. Heatmaps of average CCC between feature values extracted from non-reference reconstructions and the reference condition (Br49d-100%) in normal regions before (a) and after (c) standardization and fibrotic regions before (b) and after (d). Gray tiles represent cases of zero divisions in the CCC calculation. Few features from either class agreed well with the reference value before standardization in both tissue types regardless of reconstruction condition. After standardization, CCC increased for many features in both feature classes and tissue types. The sharp kernel (Br69d) reconstructions increased CCC the most in both tissues, and in fibrotic regions, the Br32d reconstructions benefited less from standardization (periodic light purple bands in d)).

Conclusions

- Physics-based radiomics standardization can increase agreement with radiomics extracted from normal and fibrotic lung regions across a range of CT reconstruction kernels and doses.
- Limitations:
  - Only 3 patients were included;
  - Br49d (reference kernel) at lower doses was not investigated.
- Future work will expand the cohort size, examine additional dose reduction levels, and include ground glass tissue to further investigate the ability of physics-based standardization to improve agreement.

References

1. R. Berenguer, *et. al.* Radiomics of CT Features May Be Nonreproducible and Redundant: Influence of CT Acquisition Parameters. *Radiology*, 288(2):407-415, August 2018.
2. G. Gang, *et. al.* Standardization of Histogram- and Gray-Level Co-Occurrence Matrices-Based Radiomics in the Presence of Blur and Noise. *Phys. Med. Biol.*, 66(7):074004, April 2021.