A Longitudinally-Aware Segmentation Network for Automatic Interim PET Analysis in Pediatric Hodgkin Lymphoma Patients

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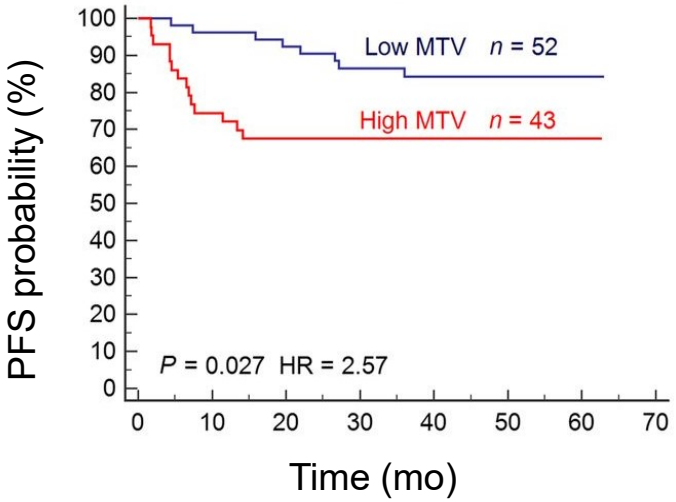
Disclosures

No disclosures

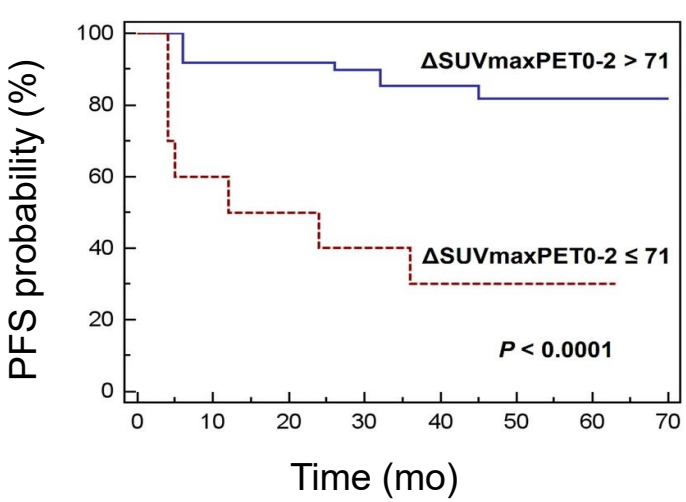
Background

Quantitative PET biomarkers in guiding **lymphoma** treatment strategies

TMTV



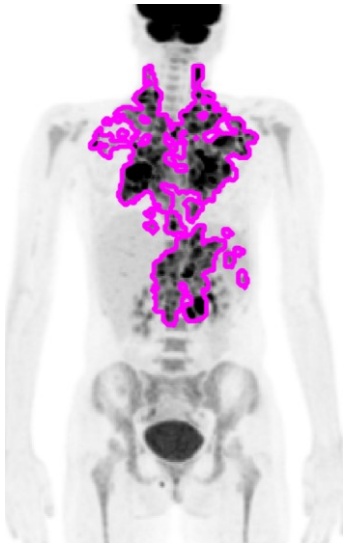
ΔSUVmax



1. Cottereau AS, et al. *J Nucl Med*. 2020; 61(1):40-45.
2. Rossi C, et al. *J Nucl Med*. 2014; 55(4):569-573.

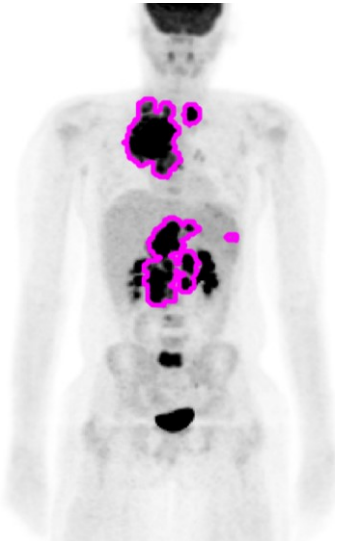
Background

- **Deep learning** (DL) for automatic PET analysis
  - Segment lymphoma
  - Quantify **baseline** tumor burden



Baseline PET

TMTV	878.6 ml
TLG	3664 g
SUVmax	17.8 g/ml
…	…

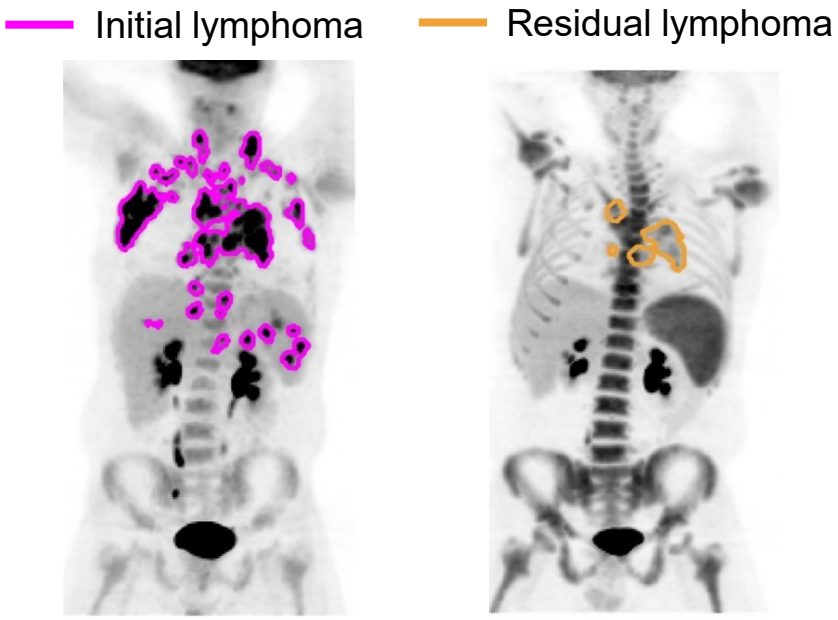


Baseline PET

TMTV	499.0 ml
TLG	3061 g
SUVmax	10.8 g/ml
…	…

Background

- **Interim** PET analysis
  - Response assessments
  - Guide treatment
  - ***Few*** *attempts !*



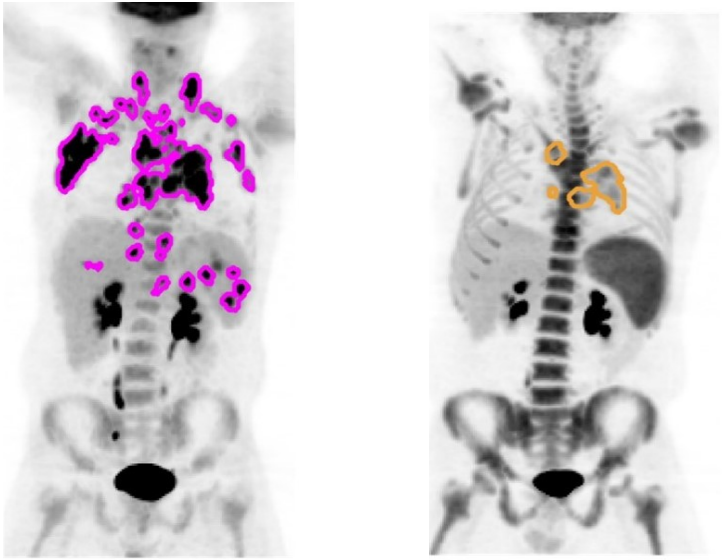
Baseline PET

Interim PET

Background

Deauville scores

Initial lymphoma Residual lymphoma



Baseline PET **Interim** PET

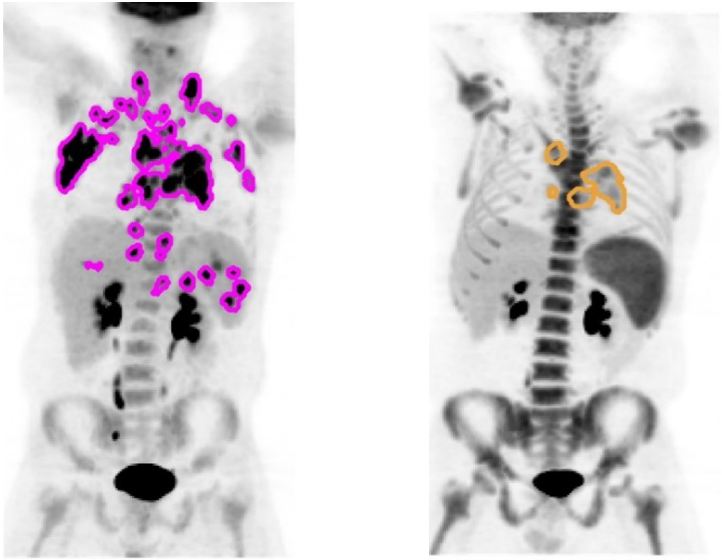
Deauville score: ***4***

Background

Deauville scores

Quantitative biomarkers

Initial lymphoma Residual lymphoma



Baseline PET

Interim PET

ΔSUVmax: ***63.6%***

qPET: ***2.19***

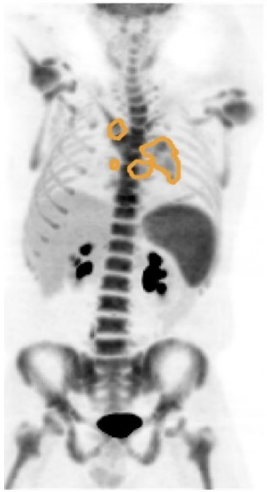
Background

Challenges of Interim PET analysis

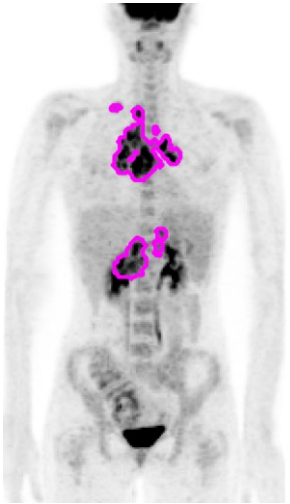
- Subtle tumor uptake
- Difficult to differentiate from inflammatory activity

Initial lymphoma Residual lymphoma

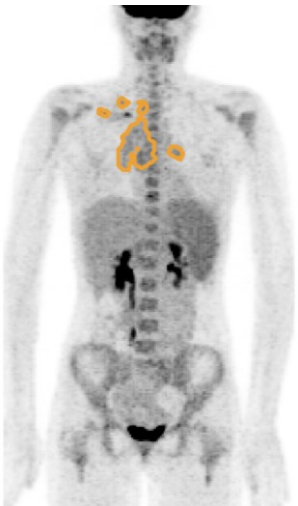
Baseline PET



Interim PET



Baseline PET

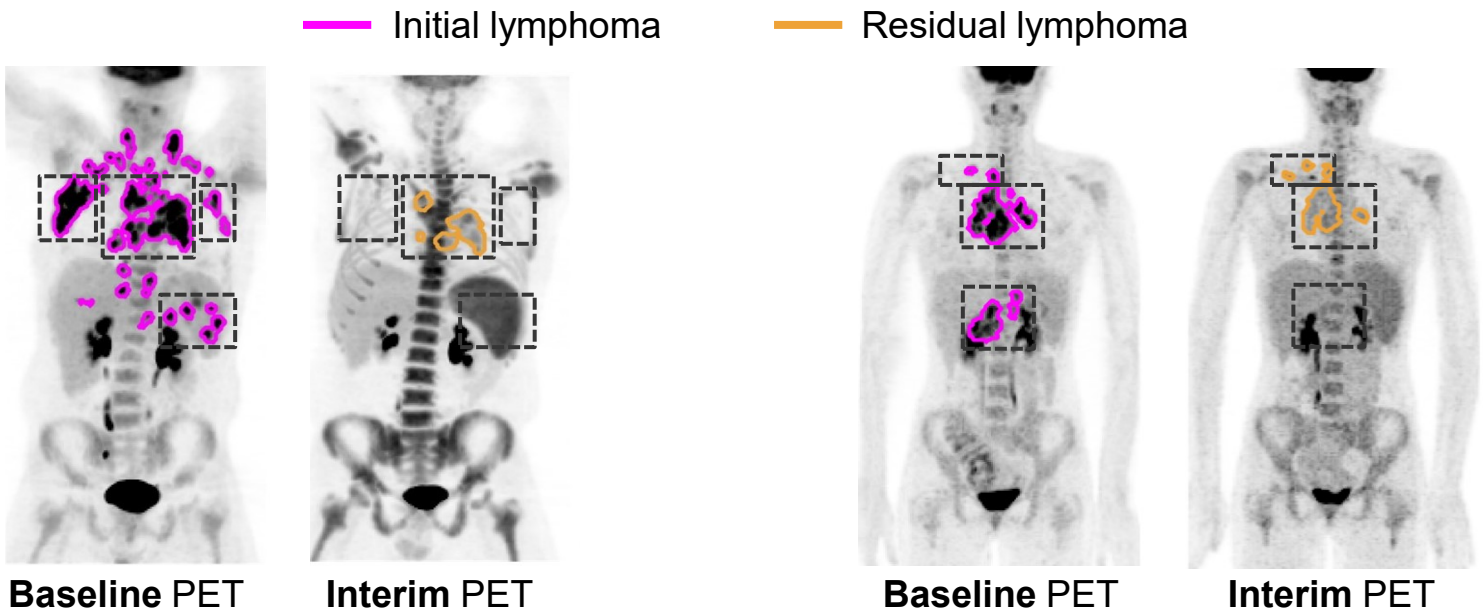


Interim PET

Background

Physicians rely on **cross comparison** with baseline PET

- Methods for incorporating prior images are underexplored



Purpose

To develop a novel longitudinally-aware segmentation network that can detect residual disease on interim PET scans utilizing baseline PET data

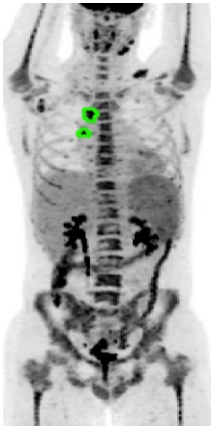
Dataset

- Two Children's Oncology Group (COG) clinical trials
  - Phase 3 trials
  - Pediatric patients diagnosed with high-risk Hodgkin lymphoma

- COG AHOD1331 (2015-2019)
  - 200 labeled cases
  - Internal cohort

- COG AHOD0831 (2009-2012)
  - 97 labeled cases
  - External cohort

Labeled Baseline PET



Labeled Interim PET

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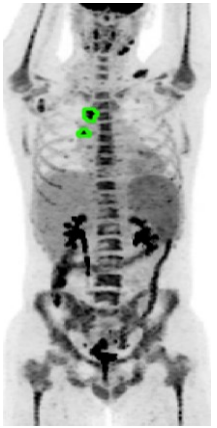
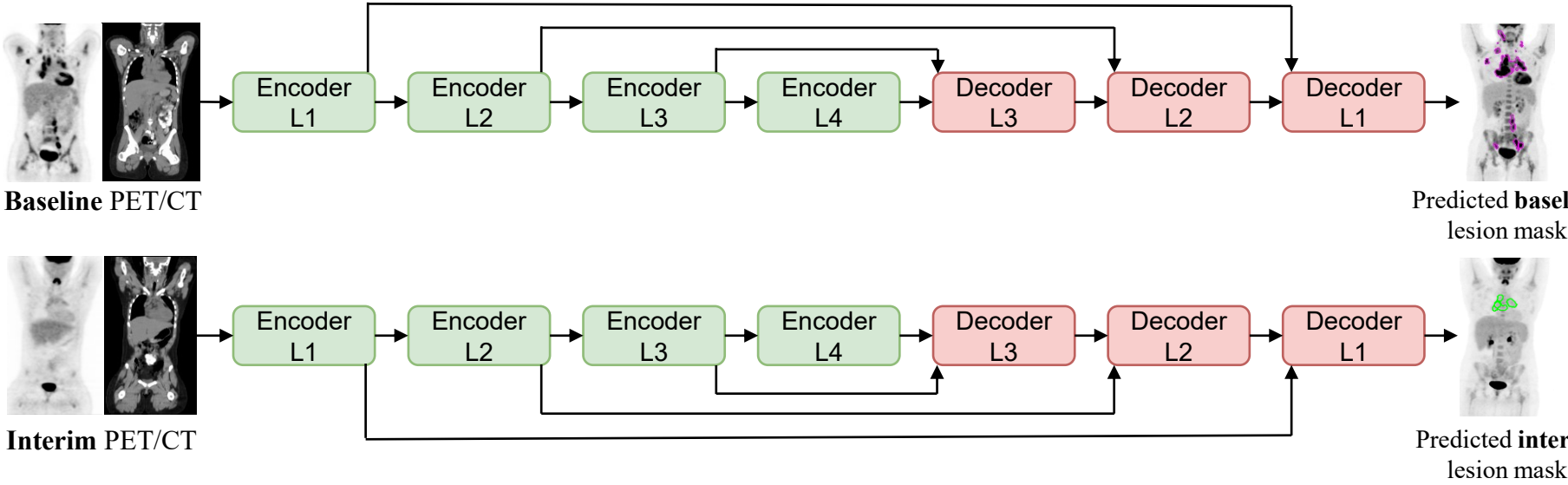


Labeled Interim PET

Methods

- Longitudinal-aware segmentation network (LAS-Net)
  - 3D SwinUNETR



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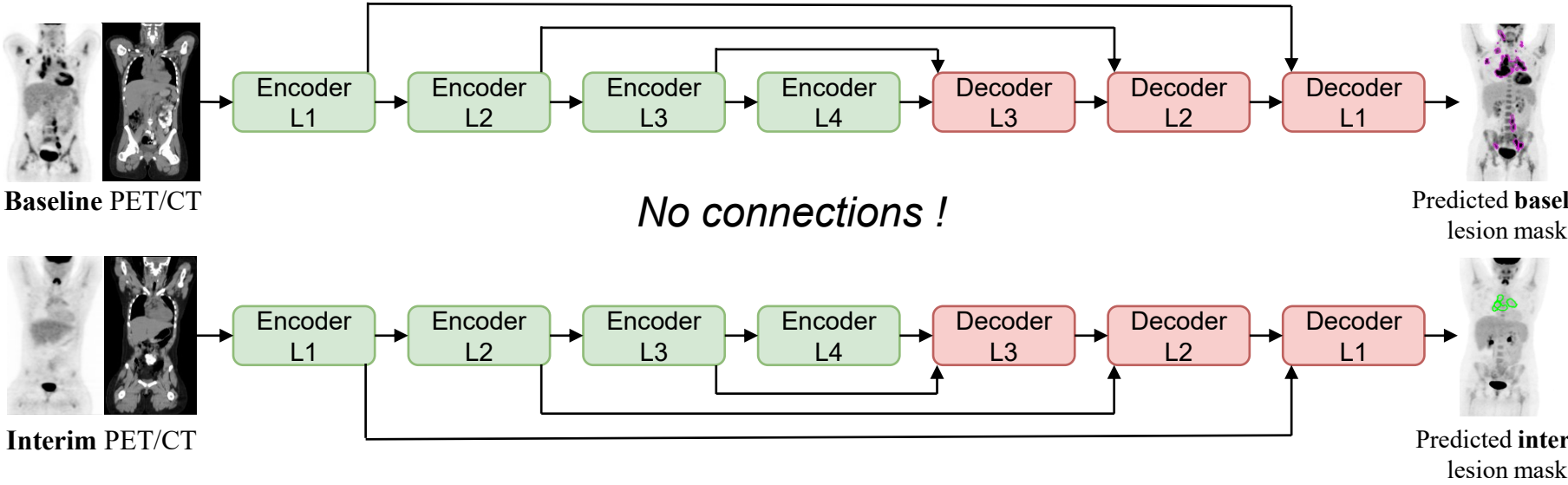

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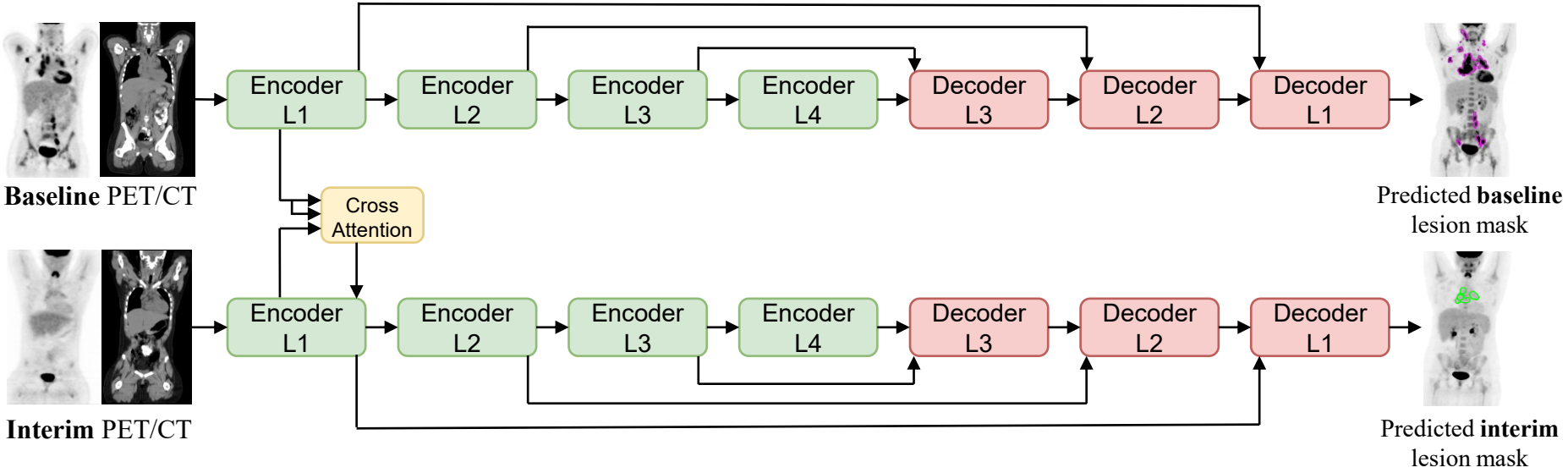
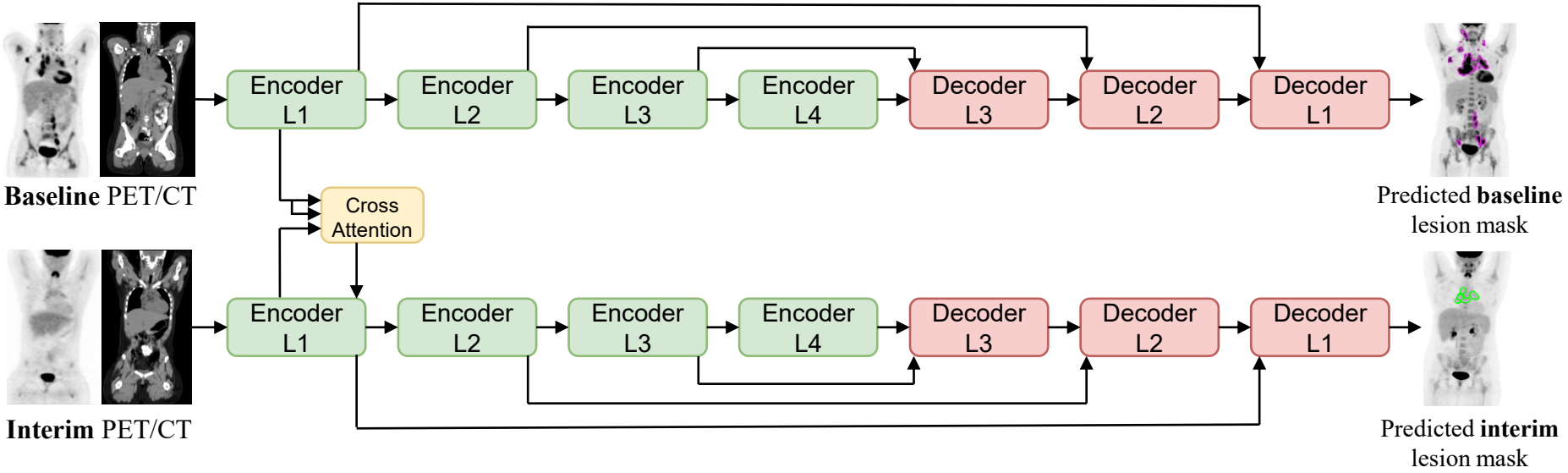
  - Dual-branch with longitudinal cross-attention



Methods

- Longitudinal-aware segmentation network (LAS-Net)
  - 3D SwinUNETR
  - Dual-branch with longitudinal cross-attention
  - One-way information flow



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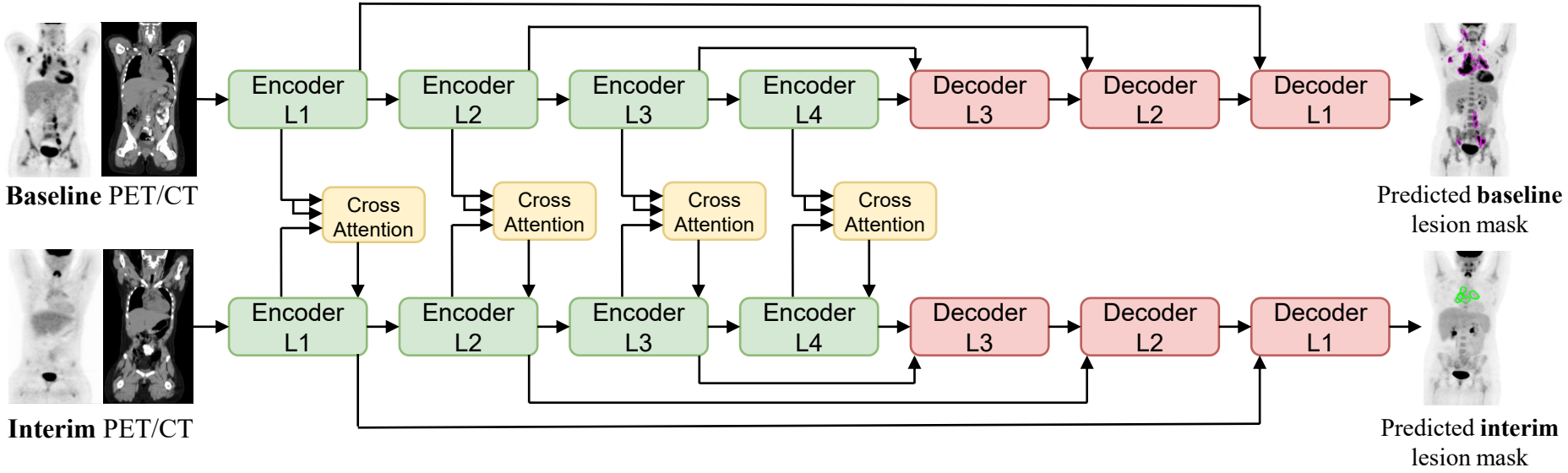
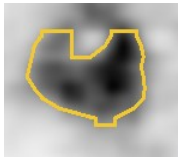
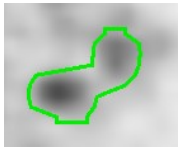


Training and Evaluation

- Joint optimization for baseline and interim PET segmentation
  - Cross-entropy and Dice loss
  - Patch inputs (112×112×112) from co-registered PET scans
- Evaluation metrics
  - Detection **F1 scores** for interim PET



*SUVmax: **8.28** g/ml*
*SUVpeak: **7.12** g/ml*



*SUVmax: **5.86** g/ml*
*SUVpeak: **4.75** g/ml*

Training and Evaluation

- Joint optimization for baseline and interim PET segmentation
  - Cross-entropy and Dice loss
  - Patch inputs (112×112×112) from co-registered PET scans

- Evaluation metrics
  - Detection **F1 scores** for interim PET
  - Interim **PET biomarkers**: SUVmax, ΔSUVmax, qPET
  - Spearman's **ρ** correlations

Training and Evaluation

- Joint optimization for baseline and interim PET segmentation
  - Cross-entropy and Dice loss
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- Evaluation metrics
  - Detection **F1 scores** for interim PET
  - Interim **PET biomarkers**: SUVmax, ΔSUVmax, qPET
  - Spearman's **ρ** correlations
- Model Comparison
  - DynUNet, SegResNet, SwinUNETR
  - **No** longitudinal cross-attention

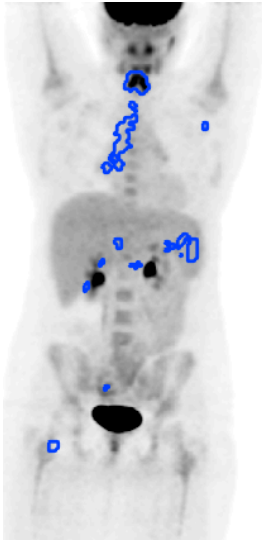
How about Deformable Registration?

Mask Propagation through Deformable Registration (MPDR)

Predicted baseline
lesion mask

Baseline PET

Predicted Interim
lesion mask



Interim PET

1. Weisman AJ, et al. *J Nucl Med (supplement 1)*. 2020; 1434

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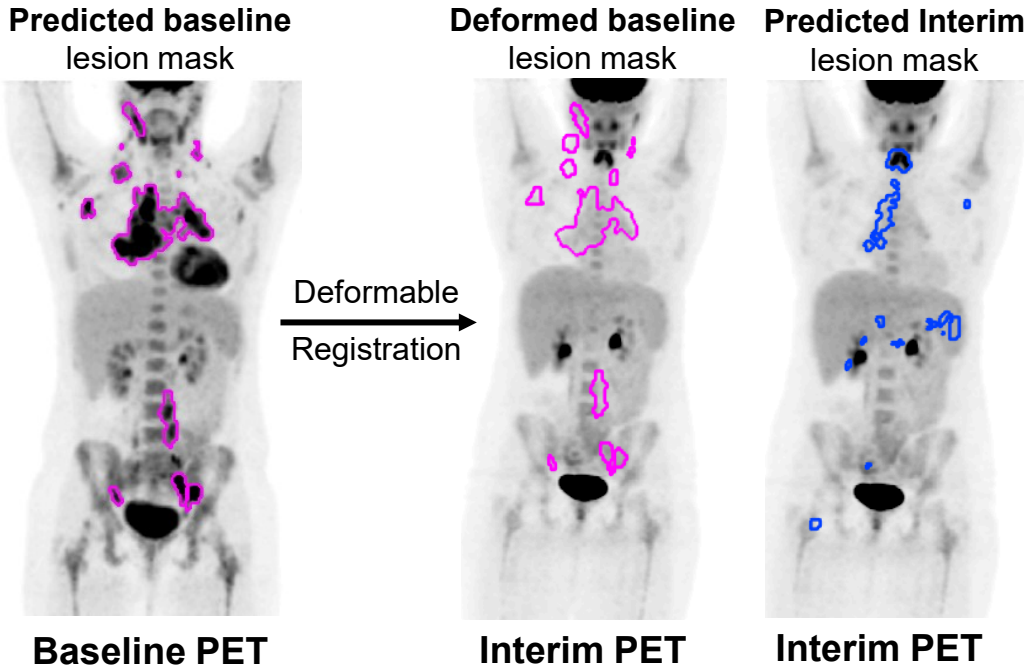

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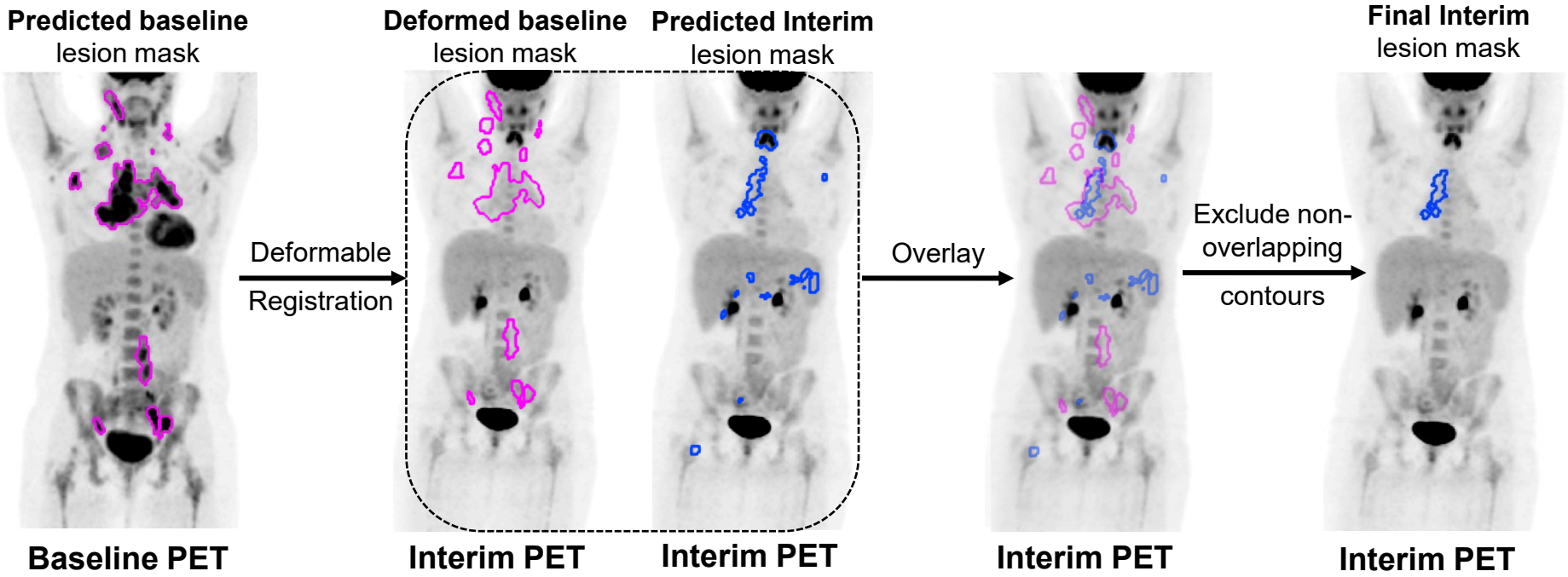

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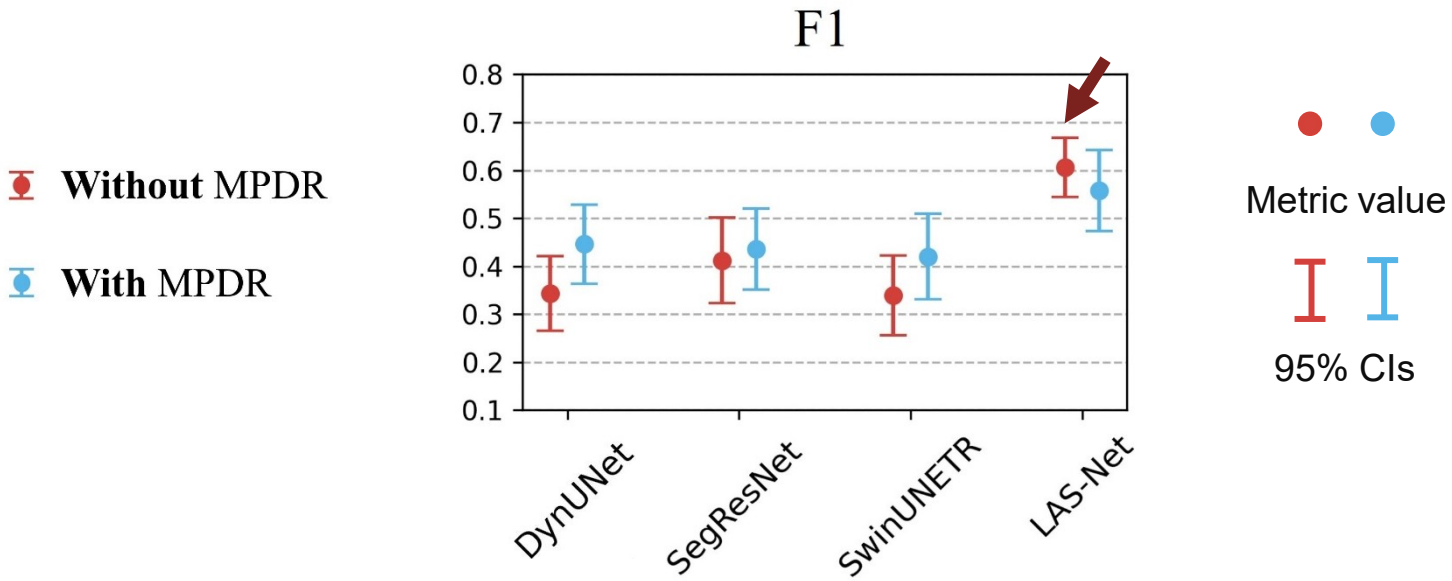
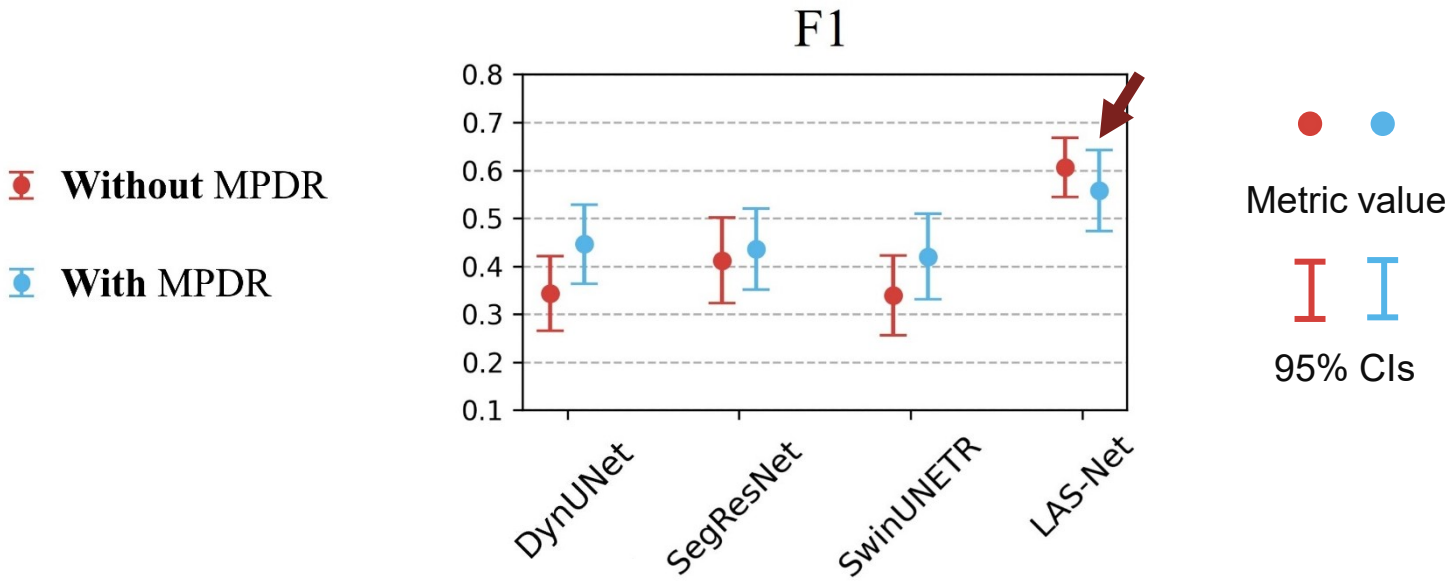
Results – Detection Performance

- Without MPDR, the detection **F1 score** was **0.61**



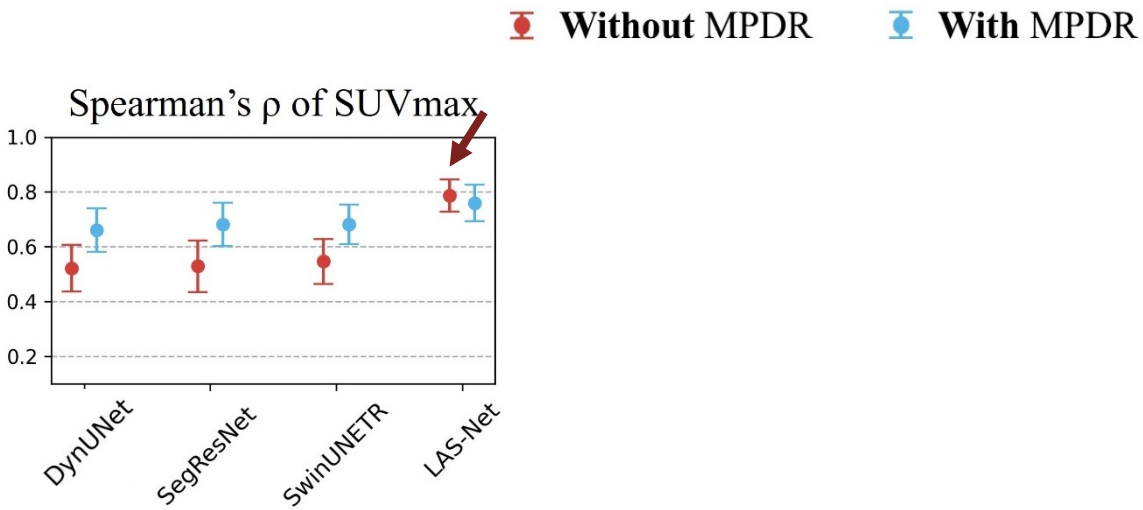
Results – Detection Performance

- Without MPDR, the detection **F1 score** was **0.61**
- With MPDR, no increase in the F1 score



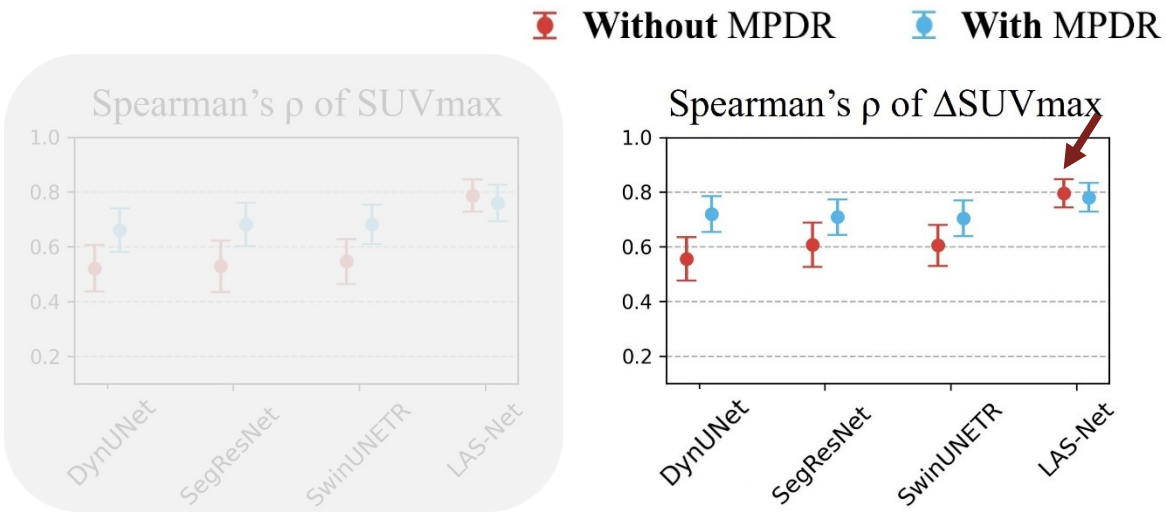
Results – Quantitative PET biomarkers

- Agreement with physician measurements
  - **SUVmax**: ρ=0.79



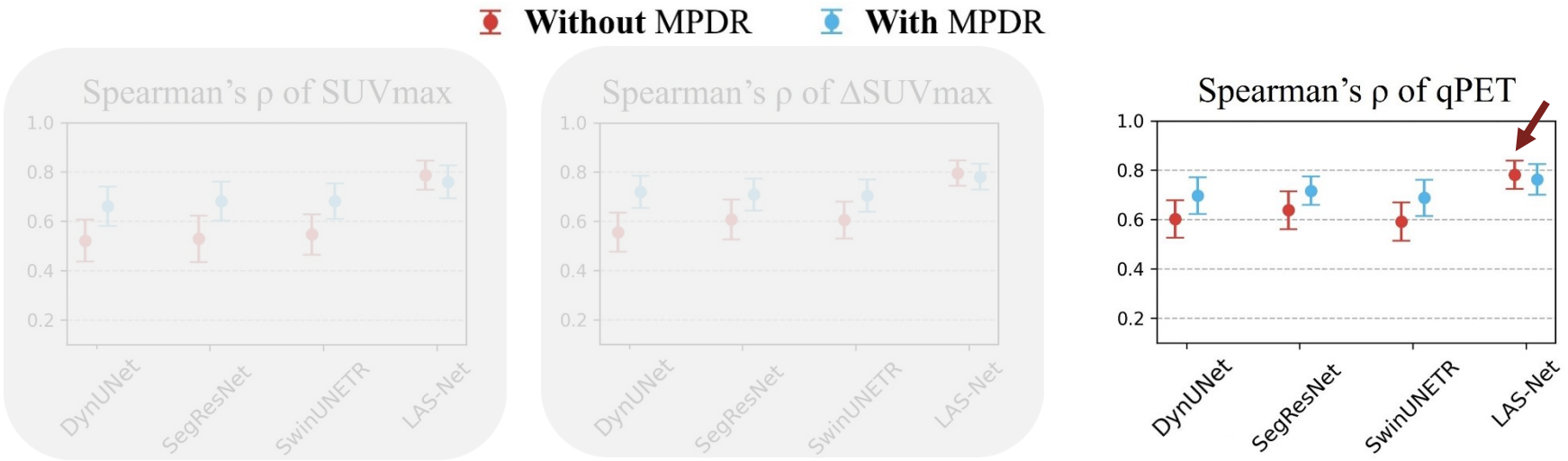
Results – Quantitative PET biomarkers

- Agreement with physician measurements
  - **SUVmax**: ρ=0.79
  - **ΔSUVmax**: ρ=0.80



Results – Quantitative PET biomarkers

- Agreement with physician measurements
  - **SUVmax**: ρ=0.79
  - **ΔSUVmax**: ρ=0.80
  - **qPET**: ρ=0.78



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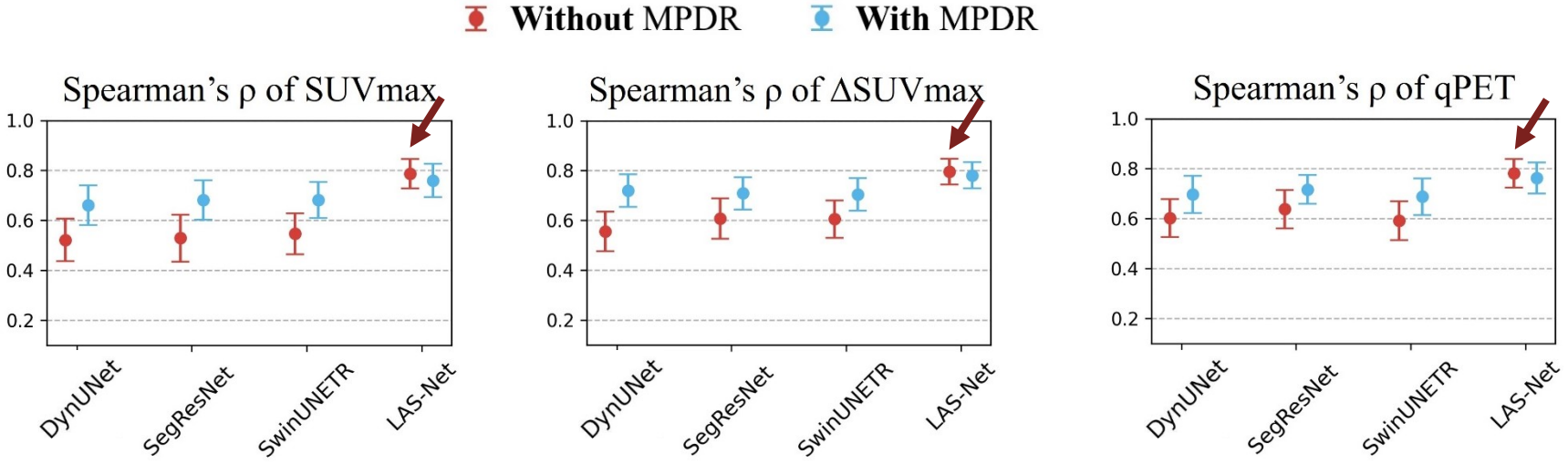
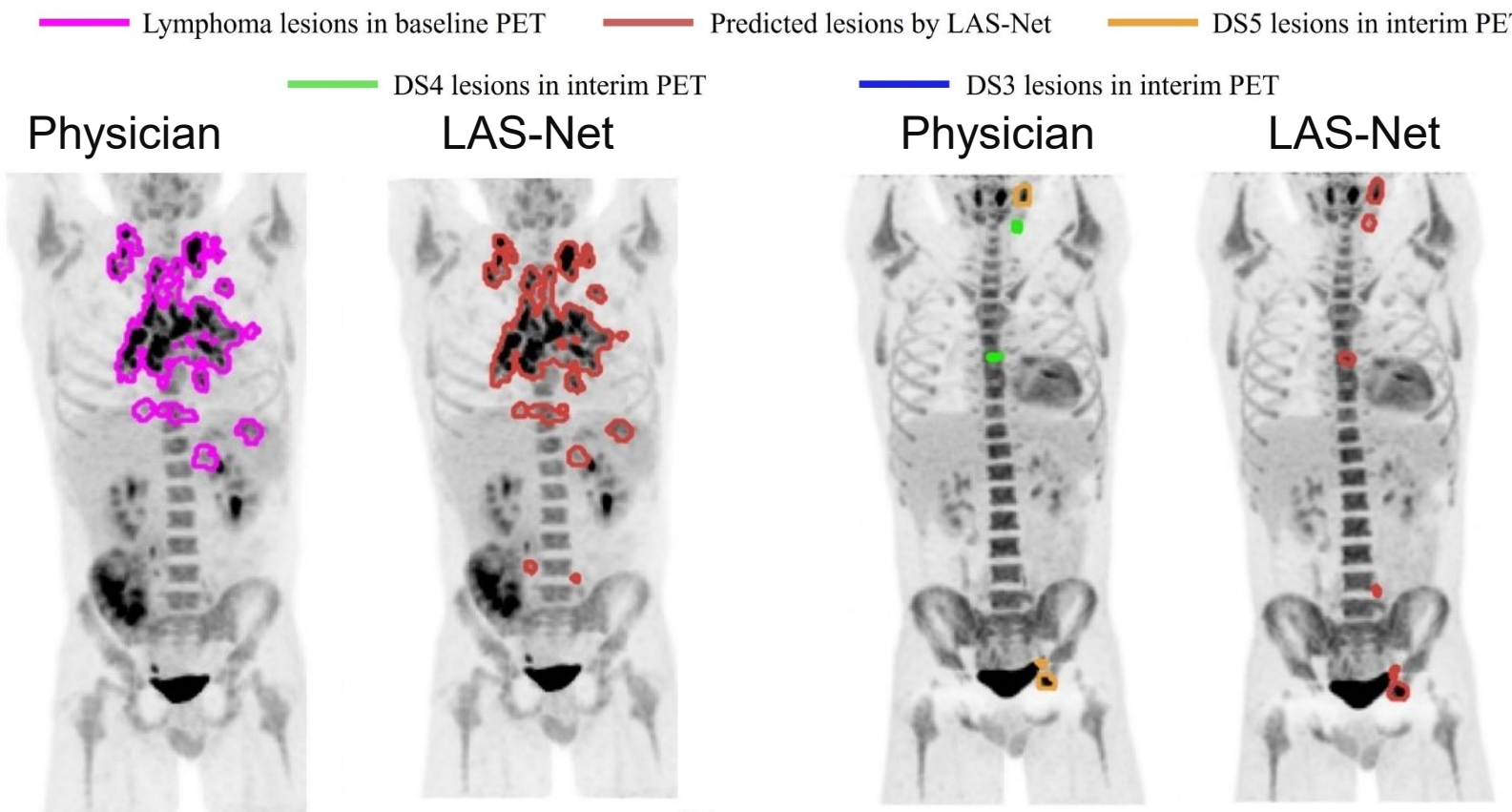


Results – Sample Case



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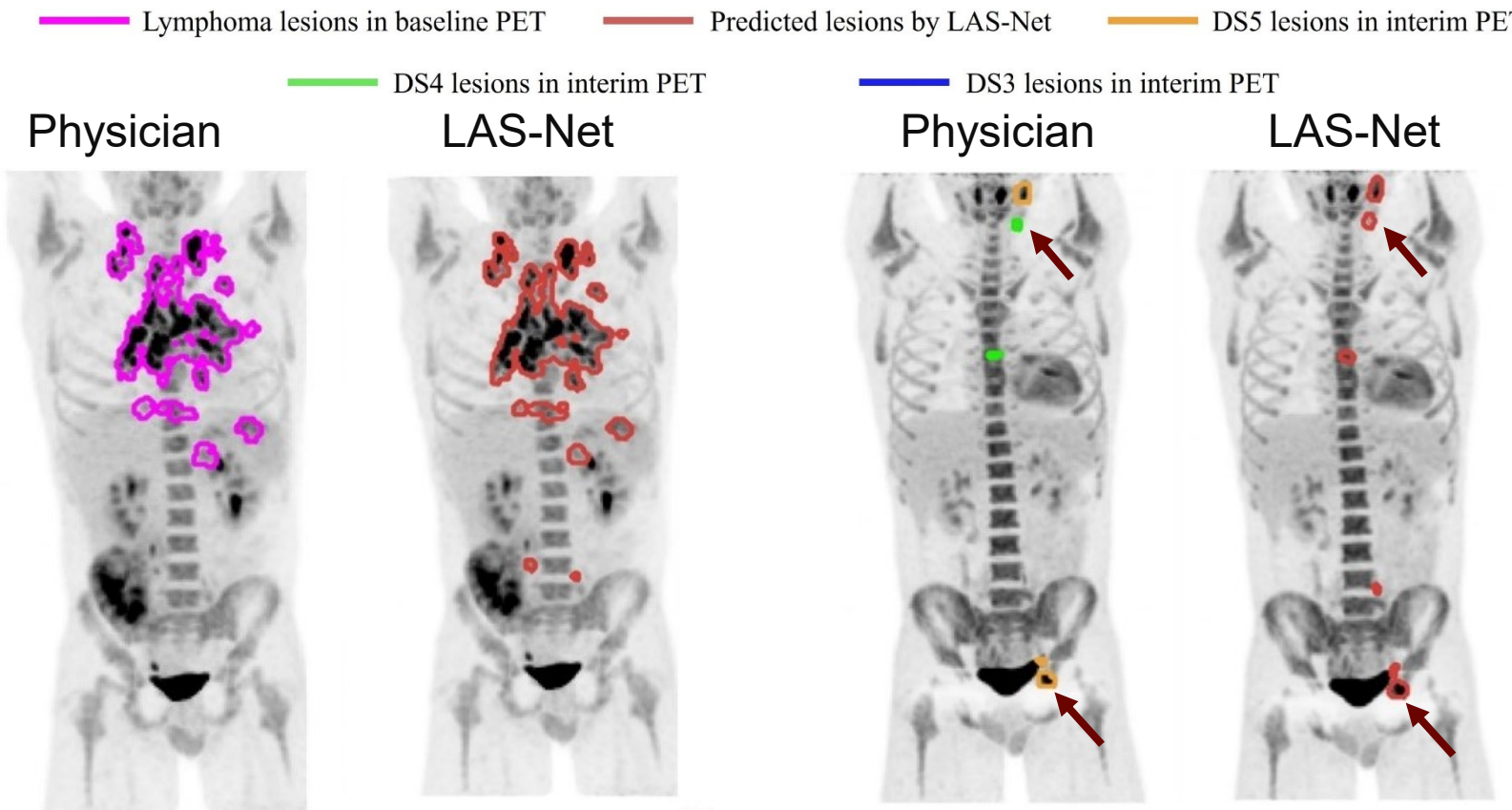

Results – External Validation on AHOD0831

- The detection **F1 score** on interim PET was **0.52**

- Spearman's **ρ** correlations of interim PET biomarkers
  - **0.70** for **ΔSUVmax**
  - **0.69** for **qPET**

Results – External Validation on AHOD0831

- The detection **F1 score** on interim PET was **0.52**
- Spearman's **ρ** correlations of interim PET biomarkers
  - **0.70** for **ΔSUVmax**
  - **0.69** for **qPET**
- Potential reasons for the performance drop
  - Generations of PET/CT **scanners**
  - **Annotation** approaches

Conclusions

- Our study introduced a novel method for detecting and segmenting residual lesions on **interim PET** scans
  - multi-institutional clinical trial
  - pediatric Hodgkin lymphoma
  - **Improved detection performance and higher agreements of interim PET biomarkers**

- **Longitudinal awareness** in analyzing multi-time-point imaging datasets

Thank you

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arXiv

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