# Automated Assessment of $^{68}$Ga-PSMA PET/CT Images of Metastatic Prostate Cancer Using Quantitative Total Bone Imaging

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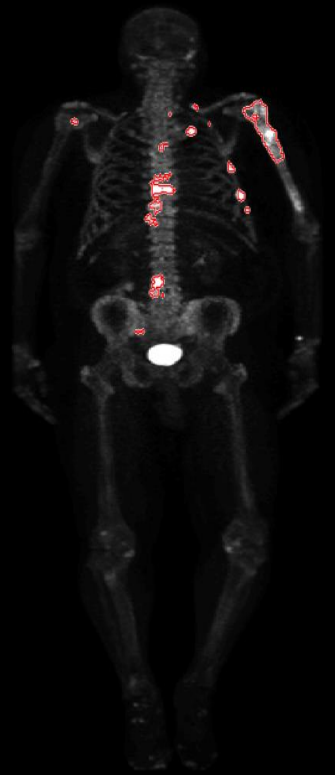
# Background
# Metastatic Prostate Cancer

- Patients with metastatic prostate cancer can have hundreds of lesions with heterogeneous response within a patient (Harmon AAPM 2016)
  - Automation needed to assess these patients

- Several imaging options for assessing bone metastases have associated automated analysis tools
  - $^{99m}$Tc bone scan – Bone Scan Index (Larson JNM 2015)
  - $^{18}$F-NaF PET/CT – Quantitative Total Bone Imaging (QTBI) (Yip et al. PMB 2014, Lin et al. JNM 2016, Harmon et al. JCO 2016, Perk et al. PMB 2018)

Analyzed
NaF PET Image

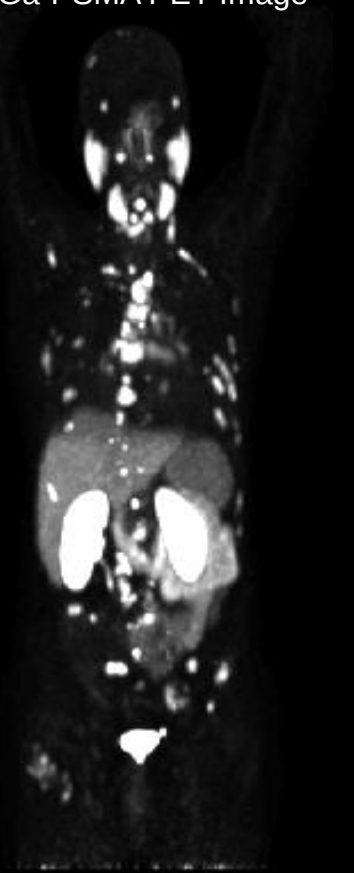


# Background
# Ga-PSMA PET/CT

- Imaging of prostate-specific membrane antigen (PSMA) expression can theoretically identify all prostate cancer metastases
  - Many PET tracers developed
    - $^{68}$Gallium PSMA-11 (Ga-PSMA) PET/CT

- Automation in Ga-PSMA PET/CT not as advanced
  - Thresholds in the image for lesion detection (Hammes et al. JNM 2018, Gafita et al. JNM 2019)
  - No individual lesion response
    - No lesion matching
    - No test-retest limits of agreement established

Ga-PSMA PET Image



# Purpose

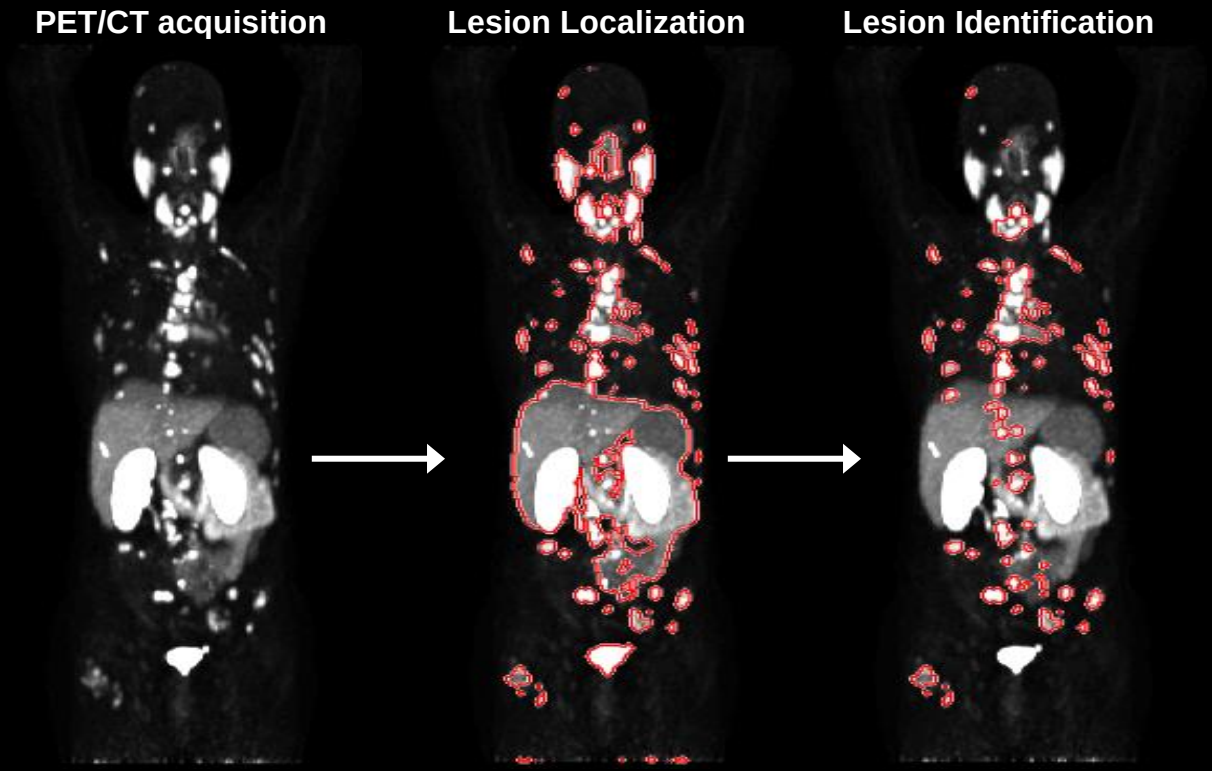
- Extend the Quantitative Total Bone Imaging (QTBI) tool to include soft tissue lesion response quantification using $^{68}$Ga-PSMA-11 PET/CT images
  - Validate QTBI(Ga-PSMA PET/CT) output against physician assessment

# Methods
## Patient Population

- 16 patients from the University of Western Australia included for preliminary QTBI development (McCarthy et al. Int J Radiat Oncol Biol Phys 2019)
  - Patients received baseline and 6 month follow-up Ga-PSMA PET/CT imaging

- Physician assessment performed to label patients based on imaging as:
  - Responder
    - Complete responder (CR)
    - Partial responder (PR)
  - Stable (SD)
  - Progressive disease (PD)
  - Some additional information provided: ex. Lymph nodes and low volume skeletal disease

# Methods
# QTBI(Ga-PSMA PET/CT)




Any part of image with SUV >2.5 g/ml

Manual cleaning

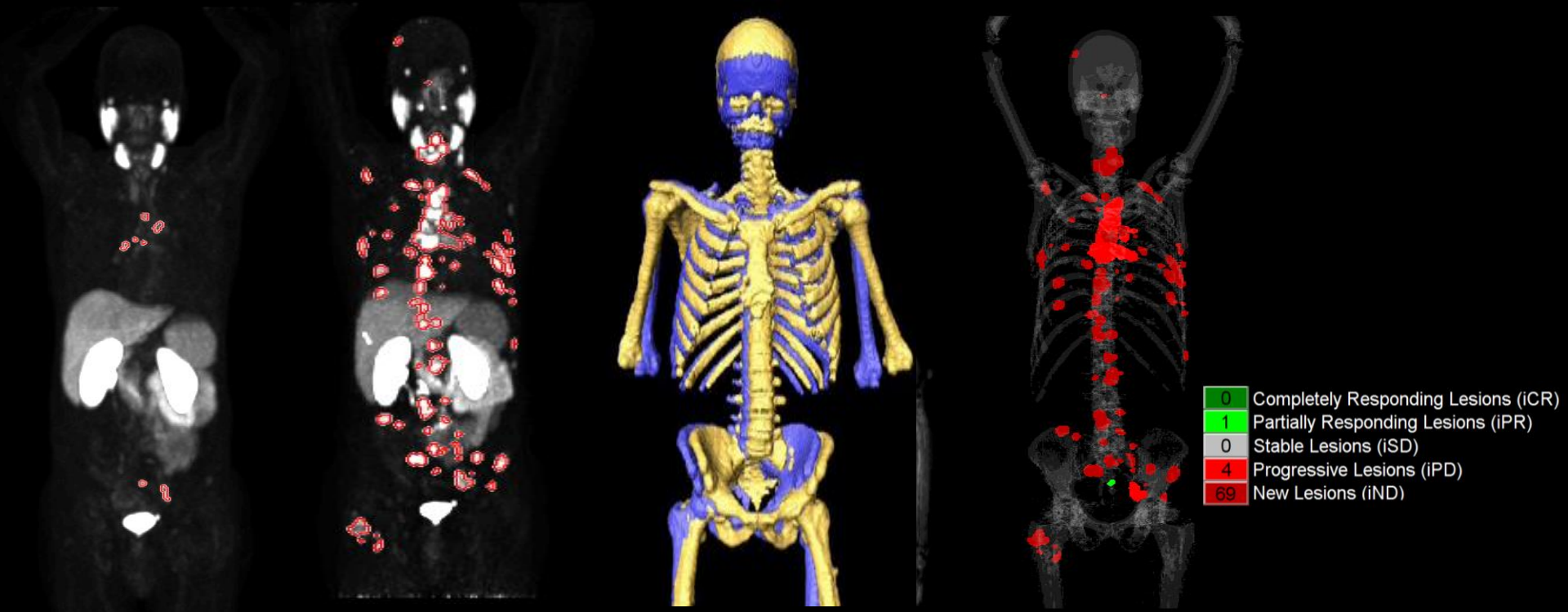
# Methods
# QTBI(Ga-PSMA PET/CT)

Scan 1

Scan 2

Articulated Registration

QTBI Response




Apply registration to soft tissue lesions with nearby bones

±30% used to determine significant change

# Methods
## QTBI Metrics

- QTBI metrics to compare with physician response classification
  - $SUV_{max} = \max_{i \in ROI}(SUV_i)$
  - $SUV_{total}$ (TLG equivalent) = $\sum_{i \in ROI} SUV_i$

- Metrics extracted on different levels
  - Patient-level (ROI = all lesions in a patient)
    - Number of lesions
  - Lesion-level (ROI = single lesions)

# Methods
## QTBI Lesion-level Changes

- Changes in lesion-level metrics used to assess intrapatient response heterogeneity
  - iCR = complete responders (unmatched lesion from baseline scan)
  - iPR = partial responder (change < -30%)
  - iSD = stable disease (-30% < change < +30%)
  - iPD = progressive disease (change > +30%)
  - iND = new disease (unmatched lesion from follow-up scan)

- Response heterogeneity: Patients with one of iCR, iPR and one of iPD and iND

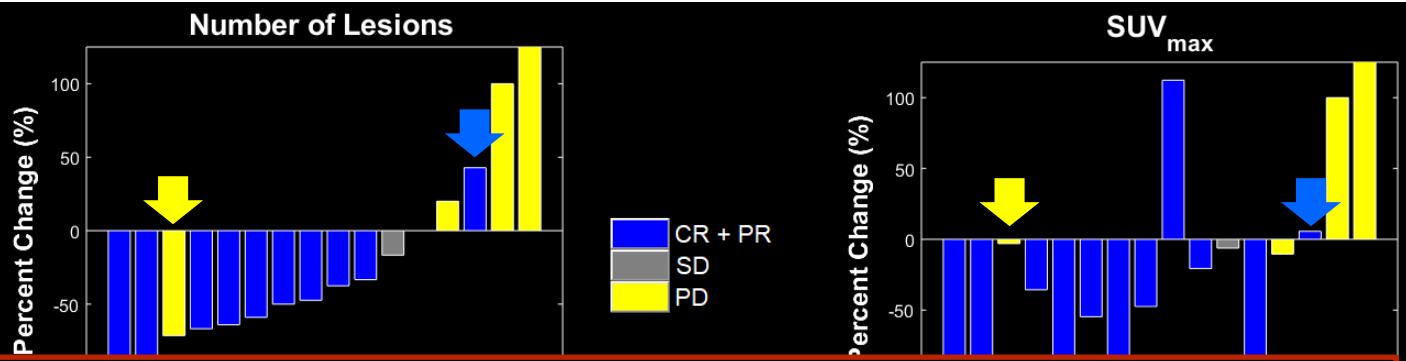
# Results

- Across 16 patients:
  - Responder (complete + partial) – 11 patients
  - Stable – 1 patient
  - Progressive disease – 4 patients

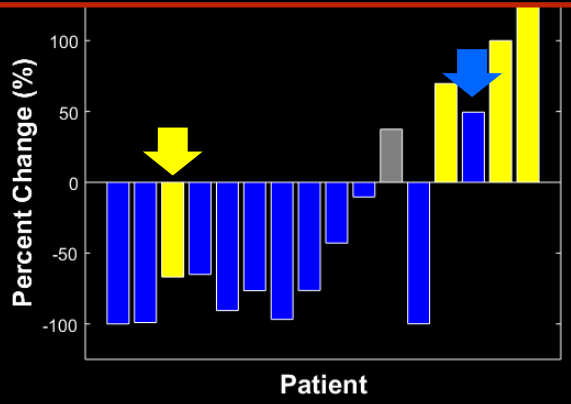
  - 72 bone and 101 soft tissue lesions were identified at baseline
  - 116 bone and 81 soft tissue lesions were identified at follow-up

- 61 lesions automatically matched using articulated registration
  - No manual corrections were required

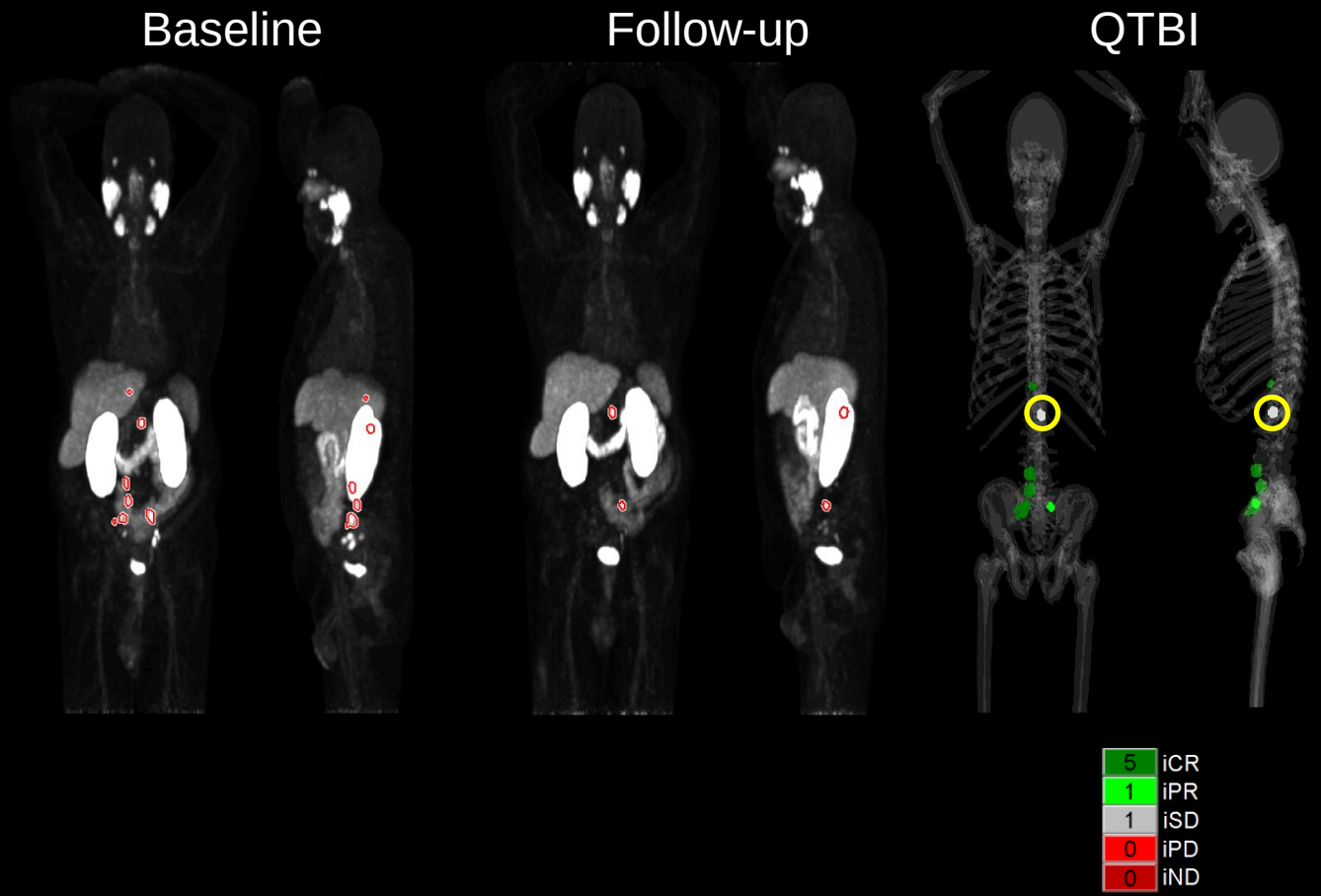
# Results
# Patient-level QTBI Response




In 14/16 patients, patient-level QTBI assessment agrees with physician assessment



# Results
## Patient-level QTBI Responder – Physician Progressive Disease

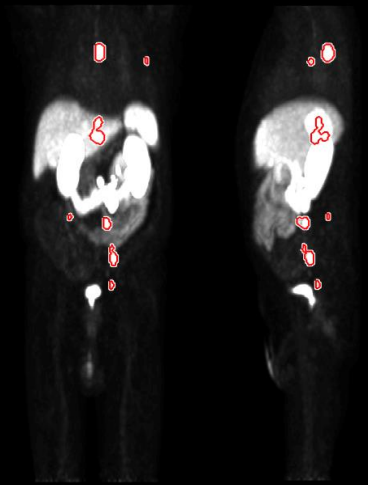



Physician

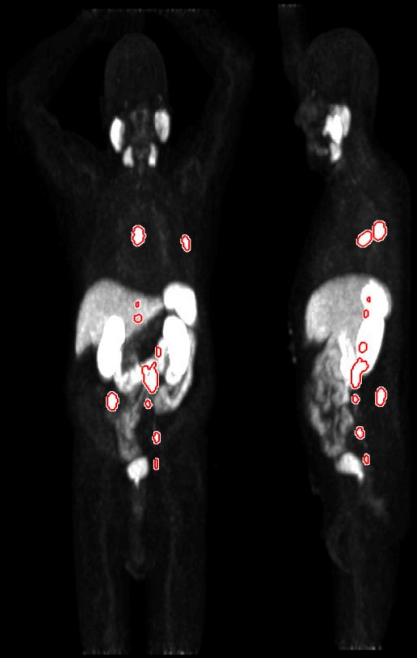
- Progressive disease
- Lymph nodes and low volume skeletal disease
- Minor progression of skeletal lesion

# Results
## Patient-level QTBI Progressive Disease – Physician Responder

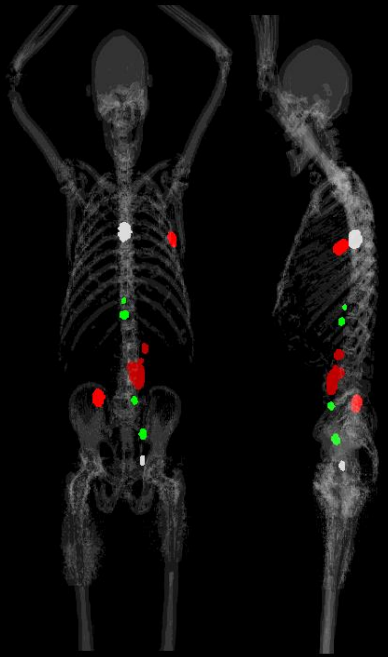
Baseline



Follow-up



QTBI

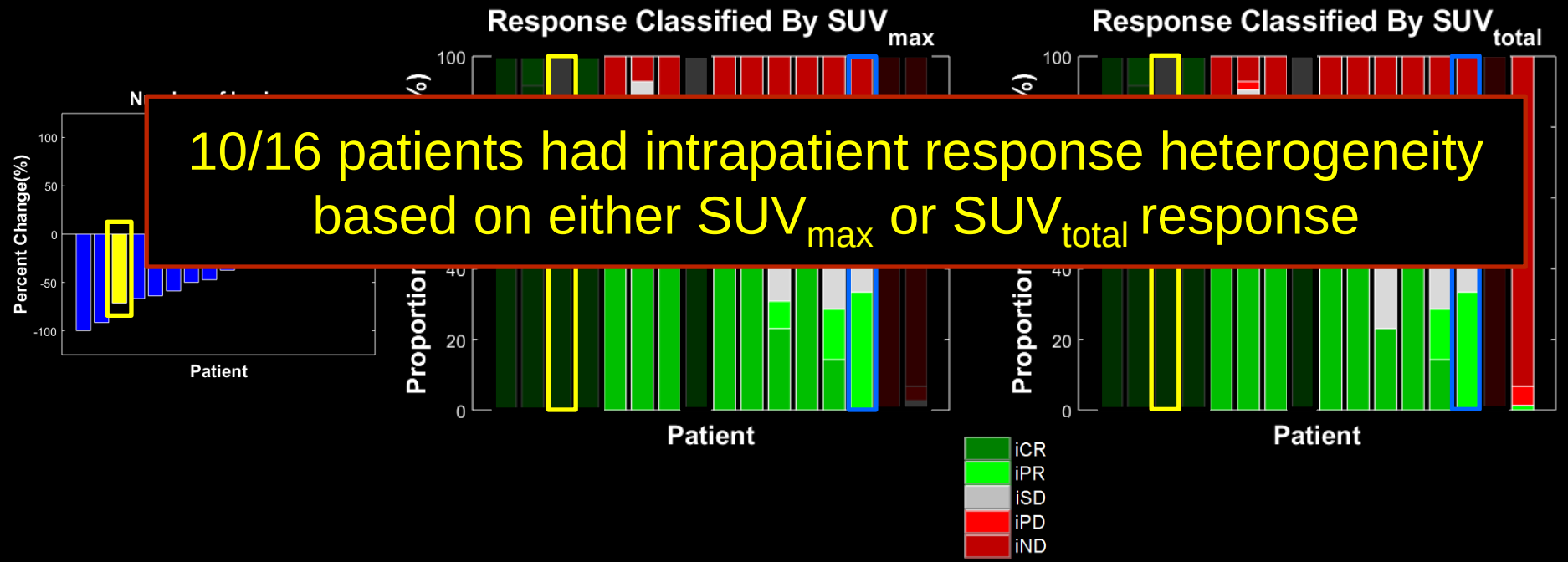



Physician

- Partial responder
- Lymph nodes and skeletal lesions
- Mixed response in skeletal lesions

# Results
## Population Intrapatient Response Heterogeneity

Response heterogeneity: Patients with one of iCR, iPR and one of iPD and iND




10/16 patients had intrapatient response heterogeneity based on either $SUV_{max}$ or $SUV_{total}$ response

# Summary

- Developed prototype of QTBI(Ga-PSMA PET/CT)
  - Patient-level QTBI assessment agreed with physician in 14/16 test cases
  - Intrapatient heterogeneity causes disagreement
    - Identified in 10/16 patients
- QTBI assessment is necessary to fully capture response of these patients
- Future work:
  - Improved lesion detection and normal uptake exclusion
  - Improved lesion matching with matching radii
    - Victor Santoro-Fernandes – WE-FG-304-8: Automated Registration-Based Longitudinal Lesion Matching On PET/CT

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