Disclosures

No Financial Disclosures
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- McConathy Jonathan, M.D, PhD, Nuclear Medicine
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- Geetika Khanna, M.D, Pediatric Radiology
- Karen Gauvain, M.D, Pediatric Oncology
Select the **BEST** statement regarding the advantages of PET/MR:

1. Lower cumulative dose of ionizing radiation with removal of the CT component
2. Allows for combined metabolic, functional and anatomical imaging
3. Increases the safety profile for vulnerable patients reducing radiation and anesthesia requirements.
4. All of the above
Select the **CORRECT** answer regarding simultaneous PET/MR:

1. MR based PET attenuation correction is not needed for PET/MR
2. There is no correlation between standardized uptake values (SUVs) on PET/CT and PET/MR
3. PET/MR has lower cost and shorter scan times then PET/CT
4. PET/MR provides superior evaluation of the lung parenchyma over PET/CT
5. None of above.
PET/MRI in Pediatric Oncology

Outline:

- **PET/MRI:**
  - Basic Principles
  - FDG
- **Whole Body PET/MRI in Pediatric oncology**
  - *Hematologic malignancies:*
    - Lymphoma/Leukemia
  - *Solid Tumors:*
    - Sarcoma
    - Neurofibromatosis
    - Neuroblastoma
    - Hepatic neoplasm
- **PET/MRI in Pediatric Neuro oncology**
  - FDG PET/MRI in brain and neck tumors
  - Amino acid agents in PET/MR brain tumors
- **Summary**

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Washington University in St. Louis
PET/MRI in Pediatric Oncology

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- **Summary**
PET/MRI in Pediatric Oncology

Basic Principles: Why PET/MRI?

- Reduced radiation exposure
- High soft tissue contrast
- Multimodality imaging review
- Advanced MRI techniques

Images:
- MIP
- PET Fusion
- DWI
- rCBV
- FLAIR
- FDOPA
PET/MRI in Pediatric Oncology

Basic Principles: PET/MRI types

Sequential Scanner

Simultaneous PET/MRI
**PET/MRI in Pediatric Oncology**

Clinical FDG-PET/MR in Adults versus Pediatric

**PET/MRI in Adults**
- Technically feasible
- Comparable to existing technologies (PET/CT, MRI)
- Specific indications that benefit from PET/MRI
- Work in progress: Integration into clinical workflows
- Economic viability of clinical PET/MRI

**PET/MRI in Pediatric**
- Technically feasible but limited experience
- Limited Experience: Can not extrapolate data from adults due to: Physiologic differences in children Tumor biology
- Specific indications that benefit from PET/MRI
- Integration into clinical workflows
- Economic viability of clinical PET/MRI
Malignant transformation of most cell lines is associated with a high glucose utilization rate
- Overexpression of glucose transporters
- Increased hexokinase activity
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FDG-PET/CT Initial Staging

14-year-old girl with classical Hodgkin lymphoma

PET/CT Follow-up

Treatment monitoring during chemotherapy (ABVD).

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Key Points: Role of PET/CT in Pediatric Lymphoma:

FDG-PET/CT is the established *imaging modality* for staging and assessment of treatment response.

FDG-PET/CT has *higher diagnostic imaging accuracy* when compared to conventional anatomic imaging.
PET/MRI in Pediatric Oncology

Hematologic malignancies: Lymphoma

Standard of care whole body FDG-PET/CT

Interval between studies: mean $51 \pm 10$ minutes

Research whole body PET/MRI using residual FDG activity from the PET/CT

Representative images of the PET/MRI protocol in a 15 year-old patient with relapsed Hodgkin

Whole-body Protocol

FDG-PET/CT MIP
FDG-PET/MR MIP
Fused PET/MRI
DWI
T2 HASTE

Correlation plots of PET/CT and PET/MRI from all selected normal organs: A and FDG-avid lesions: B with the corresponding correlation coefficients ($r^2$)
PET/MRI in Pediatric Oncology
18 year old with diffuse large B-cell lymphoma
PET/MRI in Pediatric Oncology

18 year old with diffuse large B-cell lymphoma
PET/MRI in Pediatric Oncology
18 year old with diffuse large B-cell lymphoma
PET/MRI in Pediatric Oncology
18 year old with diffuse large B-cell lymphoma

Teaching Points:
Superior soft-tissue contrast of PET/MRI helped detect a pathological neck lymph node, and the DWI sequence allowed for the assessment of diffusion restriction assisting in the detection and characterization of a FDG-avid renal lesion that was missed on PET/CT due to being obscured by adjacent excreted activity in the renal collecting system.
PET/MRI in Pediatric Oncology

Hematologic malignancies: Lymphoma

Case: Example of PET/MRI artifacts

**Key Points:**
The $\mu$-map as well as the non-attenuation-corrected data should always be inspected in addition to the attenuation corrected data.
Breathing artifact which simulated a lung base nodule on PET/MRI images

**Key Points:**
Errors in attenuation correction within the lung can be caused by respiratory misalignment of PET and MR data due to the difference in duration of two examinations resulting in mismatch of PET emission and MR attenuating data.
**PET/MRI in Pediatric Oncology**

**Hematologic malignancies: Lymphoma**

**Purpose:**
- Feasibility in pediatric patients
- Dosimetry
- Images quality
- Diagnostic performance (Quantitative analysis):
  - $\text{SUV}_{\text{mean}}$ measures on normal organs
  - Mean Standardized Uptake Value ($\text{SUV}_{\text{mean}}$) measured on FDG-avid lesions

**Conclusions:**
- Pediatric FDG-PET/MRI is feasible
- Decreases radiation exposure (39%)
- Good image quality
- High correlation with PET/CT ($r^2=0.88$)
- Very high correlation with PET/CT ($r^2=0.94$)

Whole body Pediatric PET/MRI:
Lymphoma
17-year-old with large B-cell lymphoma with left renal infiltration

Teaching Points:
- Superior soft-tissue contrast and functional imaging capabilities of MRI can aid in lesion detection especially in solid organs with $^{18}$F-FDG-PET/MRI
- PET/MRI is clinically feasible in pediatric population
- PET/MRI has high correlation with PET/CT for both qualitative and quantitative diagnostic performance of response assessment
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FDG-PET/MRI MIP

Whole body axial T2 HASTE FDG-PET/MRI images

PET/MRI in Pediatric Oncology
Neuroblastoma
4-month-old girl who has undergone resection of a right adrenal neuroblastoma
PET/MRI in Pediatric Oncology
Neuroblastoma
4-month-old girl who has undergone resection of a right adrenal neuroblastoma

Dedicated abdominal FDG-PET/MRI

FDG PET  T2 FS  DWI  ADC
PET/MRI in Pediatric Oncology
Neuroblastoma

4-month-old girl who has undergone resection of a right adrenal neuroblastoma

A  Preoperative CT

B  Dedicated abdominal FDG-PET/MRI

T2 FS  DWI  ADC
PET/MRI in Pediatric Oncology

Sarcoma

4-year-old who presented initially with fever, cough, and left flank pain
PET/MRI in Pediatric Oncology

Sarcoma

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PET/MRI in Pediatric Oncology

Sarcoma

3-year old girl with right leg pain
PET/MRI in Pediatric Oncology

Sarcoma

3-year old girl with right leg pain
PET/MRI in Pediatric Oncology

Sarcoma

3-year old girl with right leg pain
PET/MR detection of pulmonary metastasis

PET/MRI in pediatric Oncology
Soft tissue Sarcoma/spindl cell rhabdomyosarcoma
17-year-old male with left hip pain
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PET/MRI in pediatric NeuroOncology

Embryonic rhabdomyosarcoma

10-year-old girl who presented with 4 week of progressive nasal congestion
PET/MRI in pediatric NeuroOncology
Embryonic rhabdomyosarcoma
Status post surgical resection completed chemoradiation
FDG-PET has limited utility in brain tumors
- primarily for distinguishing radiation necrosis from recurrent tumor

Amino acid-PET is well-established in adult neuro-oncology
- Targets system L amino acid transport
- Crosses the intact blood-brain barrier (BBB) therefore visualizes both enhancing and non-enhancing tumors
- Can visualize the entire tumor volume
PET/MRI in Pediatric Oncology

8-year-old with a right thalamic grade IV small cell astrocytoma

A
FDOPA PET/MRI prior to starting bevacizumab therapy

B
FDOPA PET/MRI after 4 weeks of bevacizumab therapy

Karen Gauvain at al. Neuro-Oncology Practice, in press 2017
FDOPA PET/MRI prior to starting bevacizumab therapy

FDOPA PET/MRI after 4 weeks of bevacizumab therapy

Karen Gauvain et al. Neuro-Oncology Practice, in press 2017
Percent MTV change for each tumor in each patient is shown.
\(^{18}\text{F-FDOPA-PET/MRI for monitoring early response to bevacizumab in children with recurrent brain tumors: initial experience}\)

**Results:**
- \(^{18}\text{F-FDOPA PET/MRI was well-tolerated by all patients.}\)
- All tumors were well visualized with \(^{18}\text{F-FDOPA on the initial study with peak tumor uptake occurred approximately 10 min after injection.}\)
- The maximum and mean SUVs were not predictors of response at 3 months.
- Changes in MTVs after therapy ranged from 23\% to 98\% (n=5).
- There is a trend towards the percent MTV change seen on the 4-week scan correlating with progression-free survival.

**Conclusion:**
\(^{18}\text{F-FDOPA PET/MRI was well-tolerated in pediatric patients and merits further investigation as an early predictor of response to therapy.}\)

Karen Gauvain at al. Neuro-Oncology Practice, in press 2017
PET/MRI is expected to have an emerging role in pediatric diagnostic imaging:

- Lower radiation exposure than of PET/CT with similar performance
- Potential reductions in total scan time, repeated examinations, and repeated sedation or anesthesia for certain indications
- Introduction of new tracers may expand the use of PET/MRI
- Simultaneous acquisition of anatomic and functional data, and development of multi-parametric applications will improve diagnostic performance

However, further investigation is needed
PET/MRI in Pediatric Oncology

Maria Rosana Ponisio, M.D.

Thank you