Pediatric PET/CT: Experience at St Jude Children’s Research Hospital, Memphis, USA

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Danny Thomas (1912-1991)

• Founder of St Jude Children’s Research Hospital

• As a struggling young entertainer Danny promised in front a statue of St. Jude Thaddeus, the patron saint of hopeless causes, “show me my way in life and I will build you a shrine”

• Danny become successful and fulfilled his promise by building St Jude Children’s hospital. *(opened in 1962)*

• ‘One of the world’s premier centers for research and treatment of catastrophic diseases in children’

• Hospital is supported by ‘American Lebanese Syrian Associated Charities (ALSAC)’
PET/CT at St Jude

- First PET/CT scanner: 2002
- New Imaging building: 2007
- In-house cyclotron installed: 2007
- Staffing:
  - Nuclear Medicine physician 1
  - Radiologists with Nuclear Medicine privileges
  - Research Fellow 1

- Equipment
  - Discovery Light Speed PET/CT scanner (GE healthcare) 1
  - Radiotracers F$^{18}$ FDG ($C^{11}$ Methionine soon)
  - Gamma Cameras 2
Technical Issues in Pediatric PET/CT

- **Environment**
  (Children friendly)

- **Intravenous Access**
  (challenging & distressing for patients, parents and technologists. Preferably done by experts)

- **Bladder catheterization**
  (mostly considered in patients with pelvic malignancies)

- **Equilibrium phase**
  (60 minutes waiting, dark relatively calm silent cozy place, no movies if brain studies)

- **Immobilization**
  (sheets, sandbags, special holding devices, presence of parents)

- **Sedation and Anesthesia**
  (mentally impaired, young uncooperative, claustrophobic)
  Institutional guidelines

- **CT**:
  for attenuation only
Imaging Protocol

- Fasting: 4+ hours
- Radiopharmaceutical: 18F-FDG
- Dose: 0.15 mCi/kg (5.55 MBq/kg)
- Imaging: 60 minutes post injection
- PET images acquired in 2 sets
  - pelvis-cranially to skull vertex
  - pelvis-caudally to toes
- Attenuation CT without contrast
- Images reconstructed in axial, coronal, sagittal planes
- Standardized Uptake values (SUV)
Physiologic variations of FDG distribution in Children

• Thymus
  – A common finding in children & young adults.
  – Normally appears as an upside-down “V”.
  – Thymus hyperplasia after chemotherapy is a common finding.

• Waldeyer’s ring
  – Prominent FDG uptake often occurs in the naso-/oropharyngeal region: normal symmetrical lymphoid tissue in Waldeyer’s ring.

• Head & Neck
  – Muscles of mastication show FDG uptake in babies who suck pacifiers or are fed within the first 30 min of tracer injection
  – ‘Brown fat’ (Children 15% vs Adults 2%), stimulated by cold temperatures

• Bone and bone marrow
  – Extensive FDG uptake in hematopoietic marrow as compared to adults
  – Symmetrical high FDG uptake in the epiphyseal plates of the long bones

• Developmental changes in cerebral glucose metabolism
Clinical Applications

Oncology
- Lymphoma
- Brain tumors
- Bone tumors
- Wilms’ tumors
- Soft tissue tumors
- Others

Others
- Fever of unknown origins
- Epilepsy
- Cardiac
• 12-year old boy
• Dx: Embryonal sarcoma of the liver

FDG-PET/CT: Thymic uptake on post treatment scan

(H Jadvar, LP. Connolly, FH Fahey, BL Shulkin, PET and PET/CT in Pediatric Oncology Semin Nucl Med 2007; 37:316-331)
Thermogenic Brown Fat

- 15-year-old boy
- Dx: Hodgkin’s disease Stage IIA: off-therapy. On Follow-up

- FDG PET-CT Findings:
  - Sites of hypermetabolic brown fat deposition
  - No evidence of recurrent or residual disease

• Young woman FDG PET/CT images
• Dx: Staging for Hodgkin’s disease
• Short arrows: neck muscles uptake
• Long arrows: Abnormal foci of FDG avid disease

**Granulocyte Colony Stimulating Factor**

- 11-year-old girl
- Dx: Hodgkin’s disease Stage IIB: 8 months post-therapy, mediastinal mass

**FDG PET-CT**
- a-Adenopathy in the superior mediastinum (arrows) indicative of relapsed disease

b-After 6 weeks of therapy
   Diffuse uptake throughout the bone marrow-GCSF.

c-One week later; PET-CT showed marrow avidity—attributed to GCSF effect—nearly normalized

Lymphoma

- 14-year-old boy
- Dx: New nodular sclerosing Hodgkin’s lymphoma

FDG PET-CT
Abnormal FDG uptake in:
- Chest:
  - subcarinal
  - left hilar masses
- Abdomen:
  - Mesenteric, para-aortic,
  - para-caval nodal masses

(Jadvar, LP, Connolly, FH Fahey, BL Shulkin, PET and PET/CT in Pediatric Oncology Semin Nucl Med 2007; 37:316-331)
18-year-old female
Dx: Hodgkin’s Disease.

FDG PET/CT

Pre-chemo: Abnormal uptake: right neck, right supraclavicular fossa, mediastinum

Post-Chemo: Significant resolution with thymic uptake

(SC. Kaste, BL. Shulkin. 18F-FDG PET/CT in Childhood Lymphoma. PET Clin 2006 Vol 1 (3); 265–73)
Infection in Lymphoma Patient

- 12-year-old girl
- Dx: HD stage 4a, off therapy and in complete remission for 1 year.

FDG PET/CT

- Findings: Extensive abnormal FDG uptake in paratracheal, carinal, subcarinal regions
- Biopsy report: *histoplasmosis*, with no evidence of lymphoma

SC. Kaste, BL. Shulkin. 18F-FDG PET/CT in Childhood Lymphoma. PET Clin 2006. 1 (3); 265–73
Glioblastoma Multiforme

- 14 year old girl
- Dx: Brainstem glioblastoma multiforme

Images courtesy Barry Shulkin MD
St Jude's Children's Hospital
Neuroblastoma

- 3-year-old-boy
- Dx: Newly diagnosed neuroblastoma

Images courtesy Barry Shulkin MD St Judes Children’s Hospital
Wilms Tumor

• 8 year old girl
• Dx: Wilms tumor Stage IV

FDG PET/CT

• Pre Rx:
  – Extensive disease in chest and abdomen

• Post Rx:
  – No FDG avid disease in chest and abdomen
  – Posterior neck, supraclavicular uptake: brown fat

Images courtesy Barry Shulkin MD St Jude's Children's Hospital
Recurrent Wilms

- 8 year old female
- Dx: Bilateral Wilms with recurrence: liver metastasis

FDG PET/CT

Pre Rx:
- FDG avid liver lesion
- Adenoidal & laryngeal activity
- Partial nephrectomies

Post Rx:
- Complete response on PET, residual abnormality on CT

Images courtesy Barry Shulkin MD St Jude Children’s Hospital
16-year-old boy
Dx: Ewing’s sarcoma

FDG-PET

A: Primary tumor (arrow), no evidence of metastatic disease.

B: Minimal activity within tumor (arrow)—good response.

(McCarville et al. PET/CT in the Evaluation of Childhood Sarcomas. AJR 2005;184:1293–1304)
Rhabdomyosarcoma

- 16 year old girl
- Dx: Treated alveolar rhabdomyosarcoma
- Being evaluated for bone marrow transplantation

FDG PET-CT
- Clinically unsuspected left breast metastasis (arrows)

(McCarville et al. PET/CT in the Evaluation of Childhood Sarcomas. AJR 2005;184:1293–1304)
Metastatic Ostesarcoma

- 10 year old boy
- Dx: Osteosarcoma, status post pneumonectomy for metastases.

FDG PET/CT

a-Recurrent Rt sided nodule
b-Post radio-frequency ablation

(McCarville et al. PET/CT in the Evaluation of Childhood Sarcomas. AJR 2005;184:1293–1304)
• 4-year-old boy
• Dx: Metastatic hepatoblastoma
• FDG-PET/CT: Left lower lung metastasis, a smaller right lung metastasis

(H Jadvar, LP. Connolly, FH Fahey, BL Shulkin, PET and PET/CT in Pediatric Oncology Semin Nucl Med 2007; 37:316-331)
Liver Mass

- 5 month old girl
- Dx: Liver mass

Primary? Metastases?

FDG PET-CT

- Moderate skeletal uptake
  - marrow activation
- Neck muscle uptake
- Tongue uptake (feeding?)
- Thymus
- Diaphragmatic activity (crying?)
- Enlarged liver:
  - no focal uptake
  - no biopsy spot identified
  - Lack of FDG uptake in liver-FDG unsuitable for localizing metastases

Images courtesy Barry Shulkin MD St Jude’s Children’s Hospital
Non-ossifying Fibromas

13-year-old boy
Dx: 3.2-cm nonossifying fibroma left distal femoral diaphysis, FDG Positive

14-year-old boy
Dx: 2.9-cm nonossifying fibroma left femoral metaphysis, FDG Positive

Indications

- Oncology
  - Diagnosis
  - Staging
  - Restaging
  - Treatment planning
  - Follow up
  - Relapse

- Neurology
- Cardiology
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