Use of Optimized Post-Contrast Enhanced PET/CT to Improve Diagnostic Accuracy, Staging, and Follow-Up of Children with Cancer

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INTRODUCTION

- Use of positron emission tomography/computed tomography (PET/CT) at BC Children's Hospital **began in 2005**.
- Even today, technique and protocols for pediatric PET/CT imaging are **not fully standardized** between institutions.[1]
- Many sites do not administer intravenous (IV) contrast for PET/CT imaging and the area of scan coverage can vary depending on institution and disease.[1]
- True whole-body (**vertex-to-toes**) scans are preferred in children, since pediatric cancers are more likely to have **distant metastases** than adult cancers.[2-5]
- BC Children's Hospital obtains **vertex-to-toes, low-dose, IV-contrast enhanced PET/CT** for almost all patients.

Figure 1. PET, CT, and PET/CT scans performed on a pediatric patient with lymphoma. Areas of malignancy are indicated by a circle or red arrow.

OBJECTIVES

- To **analyze PET/CT use** at BC Children's Hospital through a comprehensive, retrospective review.
- To determine the **effectiveness** of optimized post-contrast enhanced PET/CT in diagnosing, staging, and assessing response to therapy in children with solid tumors.

METHODOLOGY

- Retrospective review of **1,758 PET/CT scans** performed between July 1, 2005 and June 30, 2017.
- Pediatric patients (<18 years of age) with solid tumors were identified.
- PET/CT scanner is sited at **BC Cancer Agency**.
- **Data collected**:
  - Demographic information
  - PET/CT imaging findings and pathology
  - Type and number of imaging modalities used 2 weeks before and after the PET/CT
  - Use of intravenously-injected (IV) contrast
  - Area of scan coverage (vertex-to-toes, brain-only, eyes-to-thighs, etc.)
  - Volume CT dose index ($CTDI_{vol}$) and dose-length product (DLP)
- **Questionnaires** were given to the referring pediatric oncologists for scans performed between 2007 and 2015 to determine how often scan findings **changed patient management** or overall **improved decision-making**.
- **Statistical analysis** was performed using SAS Statistical Software v9.4 (SAS Institute, Cary, NC).
  - Descriptive statistics were generated.
  - Frequency tables were generated for all categorical data.
  - Group differences were assessed using either a Chi-square or Fisher's Exact test.
  - Univariate analyses were used for all continuous data. Median and interquartile range (IQR) were reported.

Figure 2. PET/CT scanner at the BC Cancer Agency.

RESULTS

IMAGING REVIEW

- Nearly all scans were performed as **true whole-body vertex-to-toes (96%)**.
  - Remaining scans: brain only (1%), eyes-to-thighs (1%), or vertex-to-thighs (2%)
- **CT Technique**: 80 kVp, 40-60 mAs with dose modulation; **83% IV-contrast enhanced**
- All CT scans performed in conjunction with PET were non-breath-hold studies.
- **Demographics**:
  - 58% Males vs. 42% Females
  - Median age of 14 (IQR: 9 – 16)
- **Brown fat** was observed in 20% of cases, but did not impede scan interpretation.
- **Pediatric patients** were assessed on 1,655 PET/CT scans.

Table 1. Median volume CT dose index ($CTDI_{vol}$) measured in milligrays (mGy), median dose-length product (DLP) measured in milligray-centimeters (mGy*cm), and interquartile range (IQR) of these radiation doses.

	Initial Scans	Follow-up Scans
Median $CTDI_{vol}$ (mGy)	1.1 (IQR: 0.6 – 2.0)	0.8 (IQR: 0.6 – 1.4)
Median DLP (mGy*cm)	185 (IQR: 94 – 319)	125 (IQR: 86 – 238)

REFERRING PHYSICIAN SURVEYS

- Of the 759 completed surveys (response rate of 67%), PET/CT scan findings were reported to:
  - **Change management** in 68% of cases, and
  - **Improve decision-making** in 92% of cases.
- Changes in patient management included alterations in plans for **systemic therapy** (38%), **surgery or biopsy** (28%), **radiotherapy** (21%), and/or **intention to treat** (21%) (N = 759).
- In **sarcoma** cases, follow-up scan findings were **significantly more likely** to change management than initial scans (p = 0.02).
- Initial and follow-up scans were **equally likely** to change management in **other tumor types**.

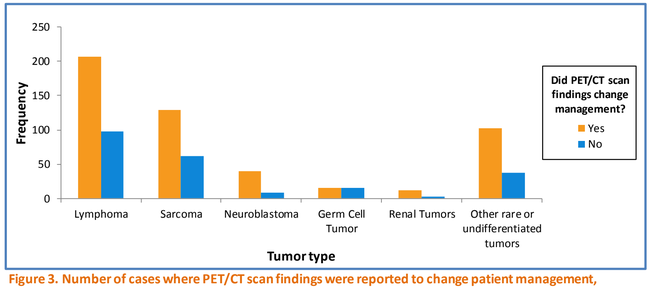

Figure 3. Number of cases where PET/CT scan findings were reported to change patient management, separated by tumor type.

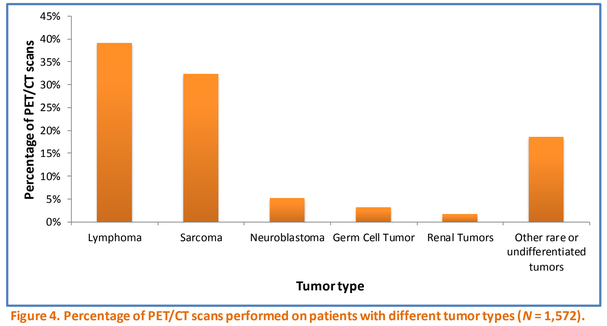

Figure 4. Percentage of PET/CT scans performed on patients with different tumor types (N = 1,572).

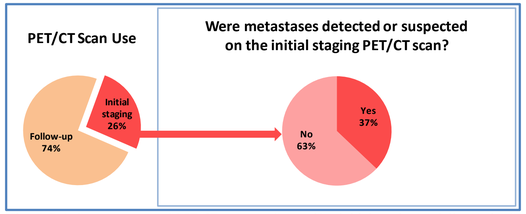

Figure 5. *Left*: percentage of PET/CT scans performed for initial staging and diagnosis of disease vs. for follow-up to assess response to therapy (N = 1,572). *Right*: percentage of initial staging PET/CT scans that detected or suspected metastases (N = 411).

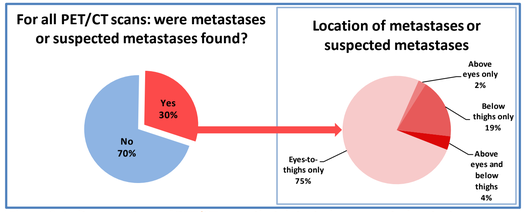

Figure 6. *Left*: percentage of PET/CT scans that detected or suspected metastases vs. those that did not (N = 1,572). *Right*: percentage of PET/CT scans with detected or suspected metastases located above eyes only, below thighs only, above eyes and below thighs, or from eyes-to-thighs only (N = 469).

DISCUSSION AND CONCLUSIONS

- Our study is the **largest single-institutional review and analysis of PET/CT** performed using this methodology.[5,6]
- PET/CT was a useful imaging modality in **all solid tumors** for diagnosing, staging, and assessing response to treatment.
- Optimized post-contrast enhanced, low-dose PET/CT with attenuation correction can **suffice without an additional attenuation scan**.
  - Reduced number of scans needed per patient, and
  - Decreased radiation exposure.
- **Unexpected metastases** were detected at diagnosis, interim, and end-of-treatment time points.
- PET/CT findings were helpful to clinicians for **decision-making** at all of these different time points.

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