Comparison of radiation dose from X-ray, CT, and PET/CT in paediatric patients with neuroblastoma using a dose monitoring program

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Aims and objectives

Children are more radiosensitive than adults, with more than ten times increased risk to develop malignancy in an infant by the same radiation dose (1). The increasing use of diagnostic imaging studies with ionizing radiation in pediatric practice raises an important consideration for radiation exposure (2). Radiation dose from diagnostic CT scanning was reported to have positive relationship with malignancy induction in children (3). In addition, undergoing serial PET/CT scan in children with malignancy also produces a great concern for the hazard by considerable amount of radiation dose. In a 5-year retrospective study with pediatric oncologic patients, the average effective dose of a PET/CT study was 24.8mSv and cumulative radiation dose from PET/CT per patient was 78.9mSv without comparison of tumor type (4).

Neuroblastoma is the most common extracranial solid cancer in childhood (5). There is a report about the median cumulative effective dose from CT scans on 30 neuroblastoma patients as 133.1 mSv with a range of 20.2 to 309.7 mSv (6). However, PET/CT is an emerging important diagnostic tool for neuroblastoma (7,8). Conventional imaging protocols for neuroblastoma include not only CT but also PET/CT before and after treatment, on follow-up, or for recurrence evaluation (9). Therefore, exact calculation and consideration of the radiation dose from imaging studies using ionizing radiation in each neuroblastoma patient is important.

Using the recently developed dose monitoring programs, we are able to calculate, report, and monitor radiation dose more easily than before. Therefore, the purpose of this study was to calculate and compare the radiation dose from imaging studies using radiation including CT and PET/CT in pediatric neuroblastoma patients using a dose monitoring program.
Methods and materials

We retrospectively reviewed the diagnostic imaging studies performed on pediatric patients with pathologically confirmed neuroblastoma at our institution from 2003 to 2014. We reviewed the number of all imaging studies which included the modalities with or without ionizing radiation, such as X-ray, CT, PET/CT, whole body bone scan, $^{123}$I-MIBG scan, ultrasonography, and MRI.

This review included medical chart review for age at the time of diagnosis, gender, and organ of tumor origin. We also reviewed Picture Archiving and Communication System (PACS) for the measurement of the acquisition number in each imaging modality, and dose monitoring program for the calculation of the radiation dose from each modality with ionizing radiation including X-ray, CT, and PET/CT.

Radiation dose data from the dose monitoring program (DoseTrack; GE Healthcare, Waukesha, WI, USA) was available from October 2012 in our hospital. For the studies before October 2012, radiation dose was estimated by applying the mean dose per exam calculated by the data from the program. After estimating the dose per patient, we calculated the relative dose from each modality.
Results

There were 63 patients including 39 boys and 24 girls. The age at the time of diagnosis was 0 to 14 years with the mean of 3 years. Organ of tumor origin was as follows: adrenal gland (n=44), mediastinum (n=10), retroperitoneum (n=7), brain (n=1), and maxillary sinus (n=1). Imaging studies were conducted for the duration of 7 to 3,127 days with a mean duration of 872 days. Total number of examinations was 5,359 of X-ray, 413 of CT, 180 of PET/CT, 213 of whole body bone scan, 18 of $^{123}$I-MIBG scan, 337 of ultrasonography, and 303 of MRI.

Among these patients, 31 patients had available dose data from the DoseTrack program with exams performed after October 2012 (DoseTrack group). The duration of these exams were 1 to 749 days with a mean duration of 355 days. Total number of exams with ionizing radiation in this group was 1,090 of X-ray, 81 of CT, and 17 of PET/CT. Mean radiation dose per exam for this group was 0.08 mSv for X-ray, 1.32 mSv for CT, and 8.16 mSv for PET/CT.

Mean estimated radiation dose per person for total patients (Total group) was 7.06 mSv from X-ray, 8.67 mSv from CT, and 23.30 mSv from PET/CT. Relative radiation dose from each modality was 59.7% for PET/CT, 22.2% for CT, and 18.1% for X-ray.
Fig. 1: The CT scan performed for a 2-year-old boy with adrenal neuroblastoma produced the radiation dose of 1.12 mSv, reported by dose monitoring program.

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**Fig. 2:** The radiation dose from PET/CT scan conducted for a 2-year-old boy with adrenal neuroblastoma was 10.79 mSv, measured by dose monitoring program.

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<table>
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<th>DoseTrack group (n=31)</th>
<th>Total number of exams</th>
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<th>PET/CT</th>
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<tr>
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<td>Total dose (mSv)</td>
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<td>107.13</td>
<td>138.79</td>
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<tr>
<td></td>
<td>Mean dose per exam (mSv)</td>
<td>0.08</td>
<td>1.32</td>
<td>8.16</td>
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</table>

<table>
<thead>
<tr>
<th>Total group (n=63)</th>
<th>Total number of exams</th>
<th>5,359</th>
<th>413</th>
<th>180</th>
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<tr>
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<td>Estimated total dose (mSv)</td>
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<td>Estimated dose per person (mSv)</td>
<td>7.06</td>
<td>8.67</td>
<td>23.30</td>
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<td></td>
<td>Relative dose (%)</td>
<td>18.1</td>
<td>22.2</td>
<td>59.7</td>
</tr>
</tbody>
</table>

**Table 1:** The results of dose monitoring including X-ray, CT and PET/CT exams in paediatric patients with neuroblastoma.
Conclusion

We calculated the radiation dose in pediatric patients with neuroblastoma over last twelve years. The average radiation dose per patient from PET/CT was 23.30 mSv, which was greater than the average dose of 8.67 mSv from CT and attributing about 59.7% of total radiation dose. The relative radiation dose from X-ray was about 18.1% even though the single exam of X-ray had only 0.08 mSv. More concerns are needed to select imaging modality in children with neuroblastoma.

Dose monitoring program was useful in monitoring and analyzing the radiation dose by patient and by imaging modality in these patients. This program may ultimately play an important role in reducing the radiation exposure by planning the imaging studies according to each patient in children with neuroblastoma.
Personal information

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