Assessment of knowledge and perceptions of medical radiation among caregivers and adolescent patients in the paediatric emergency department

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ABSTRACT

**Introduction:** This study aimed to assess the understanding of potential risks associated with medical imaging among caregivers and adolescent patients in a paediatric emergency department (PED) in Singapore.

**Methods:** A prospective convenience sample survey was performed of adolescents and caregivers presenting to our PED from December 2015 to May 2016. The questionnaire examined demographic data, knowledge of imaging procedures and radiation risks, and expectations regarding information provided about medical radiation.

**Results:** 349 questionnaires were returned (caregivers 82.5%, adolescents 17.5%). The mean number of correctly answered questions was 6.2 ± 2.4 (out of 11). Those who had tertiary education fared better than those who did not (36.4% vs. 17.2% scoring above the mean, p = 0.001). Age, gender, history of previous imaging and imaging done during the visit did not affect the score. Two-thirds of the participants did not associate medical radiation with any negative lifetime risk of cancers or know that different scans had differing amounts of radiation. Most were unaware that the radiation dose in medical imaging is adjusted to a child’s size. Among patients who underwent imaging, 90.1% received explanations on the need for scans and 26.5% were told of the risks involved. Almost all participants wished to be informed of imaging indications and risks. More preferred to learn this from physicians (75.6%) or technicians (51.6%) rather than educational pamphlets (34.4%) or Internet resources (22.9%).

**Conclusion:** Medical radiation awareness needs to be improved in our patient population. There is a mismatch between caregiver expectations and the actual procedure of radiation risk disclosure.

*Keywords: computed tomography, medical radiation, parental perception, radiation risk*
INTRODUCTION

Diagnostic imaging is increasingly utilised in paediatric emergency departments (PEDs) for the diagnosis and management of patients, particularly computed tomography (CT) and radiography. In emergency departments (EDs) where CT is frequently utilised in the evaluation of head injury, abdominal pain and polytrauma patients, a fivefold increase in the use of CT has been reported over the course of a decade.\(^{(1-3)}\) This is of special concern because CT involves much higher radiation doses than other diagnostic modalities, and children are more radiosensitive than adults. Hence, the potential malignancy risk to children associated with exposure to ionising radiation may be greater.

In recent years, there has been media interest in potential radiation risks from medical imaging. Despite this, previous studies show that patients underestimate this risk.\(^{(4-6)}\) While the majority of the studies were conducted on adult patients in a non-urgent setting in the radiology department, two of the studies were carried out in PEDs. Both studies highlighted that more than 50% of the surveyed caregivers lacked awareness of the long-term negative effects of medical imaging.\(^{(7,8)}\)

In our own PED experience, we have encountered patients and caregivers who seek out scans when they are not medically indicated. There are also those who have radiation phobia and hesitate or decline diagnostic imaging due to the perceived health risks. Hence, we sought to assess the understanding of the potential risks associated with medical imaging among caregivers and adolescent patients presenting to our PED. We also examined if current physician practice adequately addresses the concerns of our patients and their caregivers regarding medical imaging.

To the best of our knowledge, there has been no study done locally to quantify the understanding of potential malignancy risk associated with medical radiation among caregivers whose children present to the PED. There have also been no previous studies assessing the
perceptions of adolescent patients (aged 12–18 years). As it is important for physicians to accurately and adequately communicate the risks and benefits of medical imaging to patients and their caregivers, knowledge of the current practice of physicians would be useful in determining if improvements are needed.

**METHODS**

This prospective cross-sectional study was carried out from December 2015 to May 2016 at the pediatric emergency department of a tertiary university hospital in Singapore. The PED sees patients up to 18 years of age, with a total of approximately 45,000 visits per year. The study was approved by our local institutional review board. This research did not receive specific grants from funding agencies in the public, commercial or not-for-profit sectors.

A convenience sample of parents/caregivers of non-critically ill children or adolescent patients (aged 12–18 years) who presented to our PED was approached for enrolment into the study. We enrolled one parent/caregiver per child. Informed consent was then obtained from those who were agreeable to participate. Enrolment and study participation occurred after they had completed their consult with the treating physician. We excluded adolescents and caregivers/parents of patients whose Patient Acuity Category Scale score was 1. Participants who were unable to complete the questionnaire were also excluded.

The questionnaire was developed by one of the authors of this study and was based on information from the relevant literature and previous studies done.\(^4\,6\,8\) The survey was pilot-tested on a convenience sample of 25 parents/caregivers and adolescents of varied educational and socioeconomic backgrounds to find out their comprehension level and time required to complete. The questionnaire was modified in accordance to the feedback during the pilot phase.

The final questionnaire (Appendix) comprised of three sections examining (a) patient/caregiver demographic data; (b) their knowledge of radiography/CT and their
associated radiation risks; and (c) their expectations of how they were told about the indications of the required medical imaging and the potential radiation risks involved. In addition, they were also asked if they had ever received prior medical imaging. There were 11 questions that ascertained the participants’ knowledge of medical radiation and effects of ionising radiation. They could answer ‘Yes’, ‘No’ or ‘Don’t know’ to each of these questions. One mark was awarded for the correct answer and zero for the incorrect answer or if the participant did not know the answer. The maximum possible score was 11.

The questionnaire was administered by trained interviewers in English and required about 10–15 minutes to complete. When translation to Mandarin, Malay or Tamil was required, translators were used and efforts were made to ensure that the translated version was semantically close to the original form.

The data was analysed using IBM SPSS Statistics version 23.0 (IBM Corp, Armonk, NY, USA). Descriptive statistics were used to describe patient demographics, knowledge scores and patient/caregivers’ perception of adequate communication of radiation risk. Percentages were used for categorical variables, while mean and standard deviation were calculated for continuous variables. Statistical analyses were performed using chi-square tests. When sample size requirement for chi-square test was not met, Fisher’s exact test was used. The level of significance was set at $p < 0.05$.

**RESULTS**

A total of 349 participants were surveyed. There were 288 (82.5%) parents/caregivers and 61 (17.5%) adolescents. A parent/caregiver was defined as an adult who accompanied the child and was the child’s parent or primary guardian. Adolescent patients referred to those between 12 and 18 years of age. The parents/caregivers had an age range of 22–67 years and a mean age of $37.9 \pm 8.0$ years. Among the adolescent participants, the mean and median ages were $14.8 \pm$
1.5 years. 54.4% of all the participants were male. 42.4% of the participants were Chinese, and the rest were Malay (24.6%), Indian (17.8%) and of other ethnicities (15.2%). The majority of the participants had completed tertiary education (67.6%), while 21.2% and 2.0% had completed secondary and primary education, respectively. 82.3% of the parents/caregivers and 32.4% of the patients reported having previously undergone imaging. Table I summarises and provides additional demographic data on our participants.

Table I. Demographic characteristics of the participants (n = 349).

| Characteristic                  | No. (%)       |
|---------------------------------|---------------|
| Age* (yr)                       | 37.9 ± 8.0    |
| Participant                     |               |
| Adolescent                      | 61 (17.5)     |
| Caregiver/parent                | 288 (82.5)    |
| Gender                          |               |
| Male                            | 190 (54.4)    |
| Female                          | 159 (45.6)    |
| Ethnicity                       |               |
| Chinese                         | 148 (42.4)    |
| Malay                           | 86 (24.6)     |
| Indian                          | 62 (17.8)     |
| Others                          | 53 (15.2)     |
| Education completed             |               |
| Primary                         | 7 (2.0)       |
| Secondary                       | 74 (21.2)     |
| Tertiary                        | 236 (67.6)    |
| Unknown (adolescent)            | 32 (9.2)      |
| Occupation                      |               |
| Self-employed                   | 13 (3.7)      |
| Technician                      | 23 (6.6)      |
| Professional                    | 156 (44.7)    |
| Student†                        | 68 (19.5)     |
| Homemaker                       | 54 (15.5)     |
| Retired                         | 3 (0.9)       |
| Unknown                         | 32 (9.2)      |
| Prior imaging                   |               |
| For patient                     |               |
| Yes                             | 113 (32.4)    |
| No                              | 236 (67.6)    |
| For caregiver (n = 288)         |               |
| Yes                             | 237 (82.3)    |
| No                              | 51 (17.7)     |
Participants were scored on their knowledge of potential malignancy risks associated with radiation exposure. The overall mean and median scores of the 349 survey respondents were 6.2 and 6.0 respectively, with a standard deviation of 2.4. The scores ranged from 0 to 11 with only 6 (1.7%) of the participants achieving a maximum score of 11. When the scores were analysed according to whether the participants were parents/caregivers or adolescents, the results showed that the parent/caregiver group scored better compared to the adolescents (6.4 ± 2.3 vs. 5.2 ± 2.6), although this was not statistically significant (Fig. 1).

Overall, 32.1% (95% confidence interval [CI] 27.2%–37.0%) of the participants were aware that radiography and CT could increase a child’s lifetime risk of developing malignancies (parents/caregivers 30.6% [CI 25.3%–35.9%] vs. adolescents 39.3% [CI 27.0%–51.6%], p = 0.182). Correspondingly, 40.3% (CI 34.6%–46.0%) of the parent/caregiver group was worried about the long-term negative effects of radiation exposure. In contrast, only 9.8% (CI 2.3%–17.3%) of the adolescents expressed concern (p = 0.000).

More parents/caregivers than adolescents were able to report that children were more radiosensitive than adults when exposed to medical radiation (69.8% [CI 64.5%–75.1%] vs. 32.8% [CI 21.0%–44.6%], p = 0.000). Survey scores and the proportion of participants who had knowledge of potential malignancy risks associated with medical radiation exposure were not significantly associated with age, gender, ethnicity and history of previous imaging.

However, there was a positive association between the education level of the participants and the scores as well as the awareness of potential malignancy risks associated with medical radiation exposure (Fig. 2). Of the group that received tertiary education, 36.4% (CI 30.3%–42.5%), as compared to 17.2% (CI 9.0–25.4%) of the participants who received primary and secondary education, achieved a score > 6 (p = 0.001). Regarding awareness of
potential negative effects from medical radiation, 34.3% (CI 28.2%–40.4%) of the group that received tertiary education indicated it correctly, as compared to 14.8% (CI 7.1%–22.5%) of those who did not receive tertiary education (p = 0.001). Expectedly, more participants in the tertiary education group were worried about the long-term effects of medical radiation than those who received primary and secondary education [43.6% (CI 37.3%–50.0%) vs. 23.5% (CI 14.3%–32.7%), p = 0.001].

Some of the questions in the survey were directed at the participants’ understanding of radiography/CT performed in the ED. Over 90% of them correctly stated that these were not painful procedures. In the parent/caregiver group, 64.9% (CI 59.3%–70.2%) were aware that these procedures were performed by the radiographer, as compared to 47.5% (CI 35.5%–59.8%) of the adolescent patients (p = 0.011). More than half of the participants were aware that a child is exposed to background radiation daily, but less than a quarter could correctly estimate the radiation in a single paediatric chest radiograph as compared to background radiation. The majority of the participants also did not know that CT involved greater radiation than radiography. More parents/caregivers than adolescents were aware that scans performed on different parts of the body required different radiation doses [parents/caregivers 53.5% (CI 47.7%–59.3%) vs. adolescents 32.8% (CI 21.0%–44.6%), p = 0.003]. While most were unaware that the radiation dose used in scans is adjusted to the child’s size, more than half of the respondents believed that the hospital had strategies in place to minimise radiation exposure to the child. More in the parent/caregiver group [65.3% (CI 59.8%–70.8%)] felt that such strategies existed compared to 50.8% (CI 38.3%–63.3%) in the adolescent group (p = 0.034). The correct answers to the 11 true/false questions in the questionnaire and how participants performed are shown in Table II.
| Question                                                                 | Answer       | % correct (95% CI)                  | p-value |
|-------------------------------------------------------------------------|--------------|-------------------------------------|---------|
| 1. Undergoing radiography/CT is painful.                                | False        | 93.4 (90.5–96.3)                    | 91.8 (84.9–98.7) | 0.654 |
| 2. Radiography/CT is performed by doctors.                             | False        | 64.9 (59.3–70.2)                    | 47.5 (35.5–59.8) | 0.011 |
| 3. The radiation risks from radiography/CT are more harmful in younger children than adults. | True         | 69.8 (64.5–75.1)                    | 32.8 (21.0–44.6) | 0.000 |
| 4. Radiation from radiography/CT can increase a child’s lifetime risk of developing cancers. | True         | 30.6 (25.3–35.9)                    | 39.3 (27.0–51.6) | 0.182 |
| 5. Radiation from radiography/CT stays in a child’s body and is harmful to those around him/her. | False        | 65.6 (60.0–70.9)                    | 59.0 (46.5–70.5) | 0.327 |
| 6. A child is exposed to background radiation daily.                    | True         | 54.1 (48.3–59.9)                    | 67.2 (55.4–79.0) | 0.062 |
| 7. A child receives more radiation in a single chest radiography than in a year’s worth of background radiation. | False        | 24.7 (20.0–30.0)                    | 16.4 (9.0–27.8)  | 0.165 |
| 8. Radiation used in radiography is greater than in CT.                 | False        | 31.3 (26.2–36.8)                    | 41.0 (29.5–53.5) | 0.142 |
| 9. Radiography/CT performed on different parts of the body requires different radiation doses. | True         | 53.5 (47.7–59.3)                    | 32.8 (21.0–44.6) | 0.003 |
| 10. The radiation dose used in radiography/CT is adjusted to the child’s size. | True         | 44.4 (38.7–50.1)                    | 29.5 (18.1–40.9) | 0.032 |
| 11. The hospital has strategies to minimise radiation exposure to the child. | True         | 65.3 (59.8–70.8)                    | 50.8 (38.3–63.3) | 0.034 |

CI: confidence interval; CT: computed tomography

Based on the questionnaire results, we examined whether the treating physicians had provided adequate information concerning the indication for medical imaging and its potential radiation risks to the patients. Of the 121 patients who required imaging with radiography/CT, 90.1% of them stated that they were informed of the indication for the procedure, but only
26.5% were told of the risks. Among all the participants, 99.4% and 95.7% of them indicated their desire for the indications and risks of the scans, respectively, to be made known to them. In terms of expecting information about indication for the scans, there was no difference between the parent/caregiver and adolescent groups. However, 97.5% of the parent/caregiver group preferred the risks of the scans to be made known, as compared to 86.9% in the adolescent group (p = 0.01). Participants’ expectations of being informed of the indications and risks of medical imaging were not affected by race, gender, ethnicity, education level or history of previous imaging.

The survey also asked where the participants would like to receive information on medical imaging and its radiation risks from. They could indicate multiple answers. Most participants (75.6%) indicated a preference for their treating physicians to explain the information. More respondents preferred to learn it from the radiographer (51.6%) rather than the nurse (28.7%). Some preferred to learn it from educational pamphlets (34.4%) or reliable Internet resources (22.9%).

**DISCUSSION**

The potential association between exposure to medical radiation and cancer risk should be a topic of concern for both the patient and physician. Two recent population studies suggested that a single CT scan increased the risk of cancer in patients.\(^9,10\) At the same time, there is an increase in the utilisation of medical imaging in the ED, in particular CT, which is the largest contributor to diagnostic medical radiation exposure in paediatric emergency medicine.

Our findings revealed that only 30.6% of the parents/caregivers and 39.3% of the adolescent patients in our study were aware of the potential malignancy risk associated with medical radiation. This lack of awareness was more pronounced among respondents with less
formal education. The majority was also unaware that CT involved greater radiation exposure compared to radiography.

Boutis et al\(^{(11)}\) observed a substantial interval increase in public awareness of the potential risk associated with ionising imaging modalities over the past ten years. This was attributed to the increased media coverage and greater communication from healthcare professionals. The two studies performed in the PED setting by Boutis et al\(^{(7)}\) and Hartwig et al\(^{(8)}\) showed that 50% and 40%, respectively, of parents whose children presented to a tertiary care PED were aware of long-term negative effects associated with medical imaging. Comparatively, our respondents displayed greater lack of awareness and knowledge. Even among the respondents who needed imaging, only 37.1% were aware of the risk. This is of concern as the survey was carried out after the physician consultation, and it is assumed that the physician would have discussed the effects of imaging, giving the patient/caregiver a greater understanding of the risks involved. The physician disclosure rate was 26.5% in our study.

Our study also showed that imaging was prevalent in our study population. 82.3% of the parents/caregivers, and 32.4% of the patients (mean age 7.8 ± 5.6 years) had reported having had previous imaging. Despite the prevalence of previous imaging, the radiation risk remains generally underestimated. A possible reason for this lack of awareness is the lack of routine discussion of imaging risks by healthcare professionals. The factors that contribute to this lack of discussion are physicians’ concern about possibly excessive parental anxiety about potential cancer risk and that a needed scan might be denied; unnecessary delays when dealing with a critically ill child; time constraints; litigation; and the lack of easily accessible guidance on how to communicate these risks.\(^{(11)}\) Additional barriers may be patient literacy and the fact that radiation risk is not immediately apparent.

Patients and their parents/caregivers may also underestimate the risks associated with ionising imaging because they incorrectly assume that an investigation that is done so
frequently should not have any safety concerns. Baumann et al\textsuperscript{(4)} reported in their study that ED patients were more confident in their medical care where more testing is performed, specifically when a CT is performed. Such perceptions may result in patients and their caregivers being less receptive to information on the negative effects of ionising imaging.

Compared to the adult respondents in our study, fewer adolescents were worried about the negative effects of medical radiation. Fewer of them also wanted to be informed of the risks of medical radiation. These statistically significant findings are perhaps in keeping with the typical behaviour of adolescents, who may not fully appreciate the long-term and unseen consequences.

Our study also found that the rate of risk disclosure by our physicians did not meet the expectations of our patients and their parents/caregivers. While 95.7\% of all the respondents were eager for information on radiation risks, only 26.5\% of patients who needed imaging in the PED reported receiving this information. Previously published data reported that the physician disclosure rate was 24\%–37\% among general emergency physicians\textsuperscript{(12,13)} and over 60\% among paediatric emergency physicians.\textsuperscript{(14)} While self-reporting surveys among physicians may inflate the results, and patients’ perceptions may not always parallel those of physicians, our study shows that physicians fall short when it comes to counselling our patients regarding the potential long-term risks of radiation. In the current era of medicine in which patient autonomy and shared decision-making are emphasised, physicians have a responsibility to discuss with their patients the benefits of acute diagnostic imaging and the potential long-term risks associated with it. By doing so, we can ensure that patients’ values and preferences are considered and patient-centred care delivered.

As in previous studies, our respondents generally favoured obtaining radiation information from their healthcare provider as compared to written resources such as educational pamphlets and hospital-endorsed Internet sites.\textsuperscript{(6,15)} Their preference is understandable, as a
face-to-face dialogue allows for a more personalised discussion on individual risks instead of population risks. Among healthcare providers, the majority of the respondents preferred to discuss it with their physicians, followed by radiographers. This finding supports a collaborative approach between emergency physicians and radiographers in improving patient-centred communication about imaging.

Multiple studies have consistently reported that patients and their families are eager to be informed of possible radiation risks,\(^{13,15,16}\) and physicians concur that such discussions are needed.\(^{13}\) However, there is also evidence that physicians have insufficient knowledge in this area, particularly non-radiology physicians.\(^{14,17,18}\) To raise patients’ awareness and understanding of radiation risks, a two-pronged approach aimed at both the healthcare providers and patients is required. Equipping healthcare providers with both the necessary knowledge and skills to carry out such dialogues would be useful. Physicians may also be reassured that communicating relevant information to parents/caregivers actually increases their comfort and acceptance of radiation imaging, as seen in the study by Zavras et al.\(^{19}\)

Some of the challenges faced when discussing radiation risks with patients are the limited understanding of the actual risk of cancer currently associated with medical radiation and the many other factors that can alter the risk of developing cancer. In addition, patients may find it challenging to conceptualise risk estimates. To overcome some of these challenges, possible strategies include having imaging decision aids (i.e. clinical decision rules)\(^{20}\) and electronic tools that can present radiation information (i.e. radiation dose and context to risk estimates) simply and concisely.\(^{21}\)

Having a structured format can also facilitate the discussion. One proposal is to discuss the anticipated benefit of the scan, followed by acknowledgement that there may be a small potential future risk. This risk can be compared to other sources of radiation exposure or other
risks in our everyday life. Discussions should also include how the scans are made as safe as possible for patients, including measures such as dose minimisation strategies.\(^{(11)}\)

Information on radiation risks should also be readily available to patients and their families. Apart from educational pamphlets and internet sites, smartphone applications can also be used as alternative modalities. A study by Ukkola et al\(^{(15)}\) found that the majority of their patients preferred symbols to indicate the radiation doses associated with imaging, and verbal or numerical scales to indicate fatal cancer risk. Using simple, clear language and visual charts can aid in their understanding. Lastly, evaluating patient understanding of the discussion is also crucial.

Our study has several limitations. First, it was conducted at a PED of a tertiary university hospital. We only obtained demographic characteristics from those who consented to the survey and hence could not compare our responder and non-responder groups, potentially limiting the generalisability of the study. Second, the nature of a convenience sample survey may have introduced sampling bias. However, the trained recruiters attempted to enrol participants of different ages, genders and ethnicity who presented to the PED on different days of the week and at different times of the day. Third, our results did not reflect the respondents’ baseline knowledge, as the survey was administered after their consult with their physician. However, as their knowledge was generally unsatisfactory even after the encounter with the physician, it would be reasonable to conclude that the findings would be similar even if the survey had been done without ‘physician contamination’. Fourth, although the survey used in our study was not a validated one, the questions were derived from previous studies. Lastly, an intrinsic weakness of a survey format is that respondents may have provided what they perceived to be socially desirable answers instead of their own honest perceptions.

In conclusion, we found that radiation risk awareness among our patients and their parents/caregivers and physician risk disclosure rates are unsatisfactory. Improving our
patients’ knowledge and awareness may be challenging, but we should aim to routinely discuss radiation risks with our patients. With education, training and practical interventions to improve our current practice, shared decision-making can become the standard when imaging is considered in the PED.

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FIGURES

**Fig. 1** Box and whisker plot shows the questionnaire scores of the parents/caregivers and adolescent patients.

**Fig. 2** Box and whisker plot shows the questionnaire scores based on level of formal education.
APPENDIX

Questionnaire on Knowledge and Awareness of Risks Associated with Medical Imaging in the Children's Emergency

A. Patient information
   1. Age ______
   2. Gender Male Female
   3. Why did you come to the Children’s Emergency? __________________________
   4. Have you received medical imaging (X-Rays or CT scans) before? Yes No
   5. Are you receiving any medical imaging (X-rays or CT scans) this visit? Yes No

Parent/guardian information
   1. Age ______
   2. Race Chinese Malay Indian Others
   3. What is your education level? Primary Secondary Tertiary
   4. What is your occupation? Student Homemaker Retired Self-employed Technician Professional Others _______
   5. Have you received medical imaging (X-Rays or CT scans) before? Yes No

B. Understanding the imaging procedure and radiation risks
   1. Has your doctor explained to you why you need this X-ray or CT scan? Yes No
   2. Has your doctor mentioned to you the risks associated with the dose of radiation received from this X-ray or CT scan? Yes No Don’t know
   3. I think the patient will experience pain undergoing the X-ray or CT. Yes No Don’t know
   4. I am worried about the radiation exposure to the patient during the test. Yes No Don’t know
   5. I think the risks from radiation from X-ray/CT are more harmful in younger children than adults. Yes No Don’t know
   6. The radiation from X-ray/CT can increase a child’s lifetime risk of developing cancers. Yes No Don’t know
   7. The radiation from the X-ray/CT stays in a child’s body and is harmful to those around him. Yes No Don’t know
   8. There is background radiation that a child is exposed to daily. Yes No Don’t know
   9. A single Chest X-Ray has more radiation than the background radiation a child receives in a year. Yes No Don’t know
   10. The following radiological imaging uses radiation. X-Ray CT Ultrasound MRI
   11. X-Ray/CT performed on different parts of the body have different radiation risks. Yes No Don’t know
   12. The X-Ray/CT is performed by a Doctor Technician Don’t know
   13. The radiation dose used in X-Ray/CT is adjusted to the child’s size. Yes No Don’t know
   14. The hospital has strategies to minimize the radiation exposure. Yes No Don’t know

C. Expectations
   1. Do you think you should be told why you/your child need an X-Ray/CT? Yes No
   2. Do you think you should be told about the risks associated with the radiation? Yes No
   3. How would you like to receive information regarding radiation risks associated with X-Ray/CT?
      Speaking with a doctor Speaking with a nurse
      Speaking with X-ray/CT staff Education poster/pamphlet
      Internet Others __________