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Doctors knowledge of patient radiation exposure from diagnostic imaging requested in the emergency department

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Abstract

Objective: To assess the knowledge of emergency department doctors regarding the radiation doses of imaging requested as well as describe workplace habits.

Design and setting: Prospective, questionnaire-based observational study conducted at a 570-bed teaching hospital in May 2009.

Participants: All doctors (n=110) in the emergency department, representing all levels of experience.

Main outcome measures: Demographic data and the percentage 'radiation knowledge score' on a 15-item test, and workplace practice for three scenarios on a visual analogue scale (0-100).

Results: 96 doctors (87%) completed the questionnaire. The overall mean knowledge score was 40% (95% CI 37.8-42.8). Senior doctors scored somewhat higher than junior doctors, but not significantly so (41% vs. 39%). Over three quarters (78%) of doctors underestimated the life-time risk of malignancy from a single CT abdomen. The majority of doctors (76%) reported never having any formal training on the risk to patients from radiation exposure. The frequency that doctors intended to inform patients on the risk of radiation varied greatly depending in the clinical scenario (VAS scores between 38 and 90).

Conclusion: Emergency doctors questioned had a varied knowledge of the risks from radiation exposure but overall knowledge was poor. Staff should be targeted for education and the diagnostic imaging request process may need to include information on radiation doses and risks.

Introduction

Medical practice stems around the fundamental teaching *"Primum non nocere"* meaning "*First, not to harm*".[1] With the ever increasing power, accessibility and size of the radiological armoury at our disposal it is important not to forget this old statement. Together with improvements in computed tomography (CT) scanning technology, radiation doses per scan have increased by up to 40%.[2] The now commonplace multi-detector CT scanners have the potential to expose the patient to higher radiation doses than the older single-detector CT scanners.[3]

Alongside increases in the radiation dose per CT scan, the numbers of patients undergoing diagnostic radiology, in particular CT scanning is increasing every year.[4,5] The cancer-causing biological effects of ionizing radiation, including low doses received during medical diagnostic imaging, are well documented.[6,7] All doses, however low, have the potential to cause harm. Estimates regarding cancer risks vary between studies, but varies between overall lifetime attributable risk 1 in 82 in high consumption groups,[8] to between 1 in 143 for a 20 year old women and 1 in 3261 for a 80 year old man as a result of a single CT coronary angiogram (CTCA).[9] It has been estimated that 100-250 deaths occur each year in the United Kingdom alone as a direct result of medical exposure to diagnostic radiation.[10]

A dose of radiation given should be enough to answer the clinical question but as low as reasonably achievable (ALARA) to minimize the risk to the patient.[11,12] Modern imaging equipment allows adjustment for patient size and anatomy to allow closer adherence to the ALARA principle (e.g. using adjusted CT settings in children compared to adults, the amount of radiation is reduced by a factor 6-7).[13] This is important, since the lifetime cancer risk for children exposed to radiation is substantially higher than for adults.[14]

It is important that doctors who request imaging are well trained in deciding whether diagnostic imaging is indicated, but also have an accurate knowledge of the risks associated. This is of particular importance in the emergency department (ED) where many radiological imaging tests are requested each day often in a time-pressured environment by doctors of varying levels of training and experience

Previous overseas studies[10,15-19] indicate that overall knowledge in this area is poor and that doctors often underestimate the actual radiation dose provided by the imaging.[10] Another study reported only 7% of patients who underwent an abdominal CT exam were given information on radiation exposure.[20] One recent Australian study investigated awareness of ionising amongst medical students and interns,[21] but there have been no Australian studies to date specifically looking into this knowledge and working practices of doctors working in an ED.

Given the diversity in experience, background and training of the doctors working in an average Australian ED, the principal objective of this study is to gain insight into the overall understanding and knowledge of emergency doctors regarding patient radiation exposure risks, their training with regards to radiation exposure and their habits with regards to ordering imaging and informing patients about the requested diagnostic imaging.

Methods

This prospective, observational study was conducted in the two emergency departments (Southport and Robina campuses) of the Gold Coast Hospital. The Southport campus is a 570-bed major metropolitan teaching hospital and the Robina campus (located 12km from the main campus) and is an urban district hospital with 200 beds. The study was approved by the health district's ethics committee.

Questionnaire

Data were collected using a three-part questionnaire. The first part asked for demographic data and whether participants had previously received formal education regarding radiation exposure. The second part aimed to investigate how frequently doctors would normally inform their patients on the risk of radiation, using a 100 millimetre visual analogue scale (0-100, 0= never; 100=always), using three common clinical scenarios (Table 2) and two questions on workplace habits. The third part was a 15-item test on knowledge of radiation exposure (summarized in Table 3). Four of the 15 multiple choice questions addressed questions on background radiation in the atmosphere as well as on risks of cancer from diagnostic imaging. For the other 11 questions, the participant had to choose the correct dose of radiation for commonly requested diagnostic imaging such as plain radiographs, CT scans, ultrasound and magnetic resonance imaging (MRI). In answering these 11 questions doctors were asked to consider one chest radiograph (CXR) as one arbitrary unit and to then approximate the number of units of radiation exposure choosing from 5 standard answers provided (see Table 3). The radiation knowledge component of the test was modelled on those used in previous studies (UK,[10,15,17] United States[18,20] and Turkey[19]). Unanswered questions were scored as incorrect. The score out of a possible 15 was converted to a percentage score. The survey was piloted by two Emergency Physicians and staff in the radiology department. After the pilot, small alterations were made prior to survey distribution.

The actual exposure to ionizing radiation from medical imaging varies by country, institution and imaging equipment used. For the purpose of this study, we used data from the National Council on Radiation Protection & Measurements (NCRP) and measurements taken in Queensland Health facilities.[22] This data assumes a natural background radiation of 2.2 mSv/year which is in agreement with other published data.[23] Examples of exposure as outlined in these documents are presented in Box 1.

Study population

The questionnaire was distributed over a 2-week period in May 2009 to all medical staff working in the ED of all levels of experience. The authors and staff involved with piloting the questionnaire were excluded. Questionnaires were distributed during staff meetings, handovers and teaching sessions within work hours. This was done without prior knowledge of doctors, to avoid participants either preparing for or avoiding the questionnaire. Questionnaires were collected immediately after completion. The survey was anonymous.

Statistical Analysis

Data taken from completed surveys were collated using Microsoft Excel spreadsheet software and then coded prior to transfer to the Statistical Package for the Social Sciences (SPSS, version 17.0) for statistical analysis. Before analysis, all variables were reviewed for accuracy of data entry, missing values and outliers using SPSS. For continuous variables we used an independent t-test and analysis of variance (ANOVA) to compare demographic groups. For categorical variables, the chi-square test used to compare differences in proportions. An alpha of 0.05 was deemed statistically significant.

Results

During the study period, questionnaires were distributed to all 110 eligible emergency doctors working at that time and 96 questionnaires were returned (87% response rate). There were less than 3% missing data for any variable.

Radiation knowledge scores

Characteristics of the doctors questioned are summarised in Table 1. There were as many male as female participants, and doctors had between one and 30 years experience. Table 2 shows that the overall mean knowledge score for all doctors studied was 40% (95% CI 37.8-42.8).

There was a trend of gradually increasing overall knowledge scores as the level of employment of the doctor increased. This varied between 36% for interns and 43% for consultants, but this was not statistically significant (ANOVA; p=0.198). Over three-quarters of doctors (78%) underestimated the lifetime risk of fatal carcinoma from a single CT abdomen (1 in 20,000 or less)

Training and workplace habits

Over three-quarters (76%) of doctors questioned had never undergone any formal training on risk of radiation. Seventy percent of participants would have preferred further teaching on the topic of radiation exposure and risks.

Doctors indicated they would often to always discuss the risk of CT scanning with the parents of a six year old with a minor head injury (VAS score: 86) or a pregnant woman considered for a CT abdomen (VAS score: 90), where participants would discuss this risk only sometimes or less (VAS score: 38) with a 76 year old lady with abdominal pain considered for a CT abdomen (Table 2). Doctors with formal training were marginally more inclined to discuss the risks in these three scenarios tested, albeit not statistically significant (VAS scores: 90 vs. 85; 96 vs. 88 and 44 vs. 36, for scenarios 1, 2 and 3, respectively). Senior doctors were more inclined to inform the pregnant patient in scenario 2 compared to their junior counterparts (VAS score: 94 vs. 85, $p<0.05$).

Doctors reported that only in a quarter of cases (23%) they were asked about the effects and risks of radiation from diagnostic imaging by patients. Participants indicated that overall their confidence levels were low to moderate (41%) in counselling patients regarding radiation exposure and answering patient queries concisely and accurately. Senior doctors were more confident in answering questions from patients on the risks of radiation exposure than junior doctors (47% vs. 36%; $p=0.005$).

Knowledge of radiation and imaging modalities

Table 3 shows the estimated radiation dose for several imaging modalities. For lumbar spine, abdominal and pelvic plain films, seven to 41% of doctors provided the correct response with 53% to 90% underestimating the radiation dose. Strikingly, 21% of doctors estimated that a chest radiograph required an equivalent of 1.1-10 CXR, where 60% overestimated the radiation dose from a single CXR (in mSv). For CT based imaging, about half of doctors

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(between 43% and 63%) underestimated the dose of radiation from CT abdomen, CT head, CT pulmonary angiogram (CTPA) and CT chest.

Interestingly, 5% and 21% of participants thought that ultrasound and MRI were associated with ionising radiation. Men were better at quantifying the radiation dose associated with MRI than women (88% vs. 70%, p=0.039).

Discussion

This study found that doctors' knowledge of radiation exposure from medical imaging is poor and that they underestimate radiation exposure of frequently used diagnostic imaging and the risks associated. Underestimation of these doses and risks may lead to doctors requesting more diagnostic imaging than they would with accurate knowledge. Interestingly, despite general underestimation of exposure for imaging, the actual estimated dose in mSv for a single CXR was overestimated, indicating that doctors are unfamiliar with units of radiation.

On the other side of the spectrum, it is concerning that a small but relevant proportion of doctors, considered that ultrasound and MRI expose patients to a dose of radiation (5% and 21%, respectively). This likely reflects a deficit of knowledge regarding basic scientific principles. It may be explained by the fact that MRI is a test that is infrequently requested from the emergency department, often difficult to access and more likely requested by the more senior members of staff. Although a smaller proportion (5%) of doctors associated ultrasound imaging with radiation, this potentially clinically more relevant, due to the numbers of ultrasounds requested. These results are consistent with previous studies which reported that 4-11% of participants associated ultrasound scanning with radiation as did 8-28% for MRI.[10,15,19,21] Interestingly, a similar proportion of doctors (21%) indicated a CXR would require radiation than the equivalent needed for *one* CXR. An explanation may be that on requesting a chest radiograph, two films are often taken (posterio-anterior and lateral), leading to this overestimation.

It is unclear what the reasons are for the poor scores achieved in this study. It may be related to the education provided during undergraduate level. This is supported by the fact that the majority of doctors (76%) reported to never having undergone formal teaching on this topic. However, there was no difference in knowledge scores for those who had received formal education compared to those who had not (40% vs. 40%). The same finding was reported in another study, with no difference in knowledge of radiation between doctors who attended radiation safety courses and those who did not.[24]

Interestingly, it was shown that males were better at quantifying the exposure to radiation from MRI compared to females. In our study 12% of men and 30% of women thought MRI was associated with radiation, which is consistent with previous studies.[19, 21] This maybe explained by the fact that men in general may be more interested in the technical aspects of imaging and radiation.

Whether doctors would inform their patients regarding the risks of radiation exposure varied with the clinical scenario posed (average VAS-scores varied between 38 and 90). This large variability may be dependent on the risk to the patient as perceived by the doctor, for example the lifelong risk to a small child (or fetus) from radiation is higher than that in an elderly person. This difference may also be due to the clinical picture itself. It could be argued that a doctor may have a more paternalistic approach in certain cases where the need for imaging is clear (such as a multi-trauma patient with serious injuries), and only discuss the risks of imaging where the justification for the test in their mind is borderline or questionable.

Our study has a number of limitations. The newly constructed questionnaire was not validated, although it was constructed from previously used questionnaires. We chose equal weighting for all 15 items of the knowledge score, which may limit interpretation of this score, since some items may be more important than others. Also, we only measured the self-reported intention to inform patients in three scenarios, but not the detail or content of this information. We cannot exclude that selection bias has taken place, however we surveyed all eligible ED doctors with a high response rate (87%), making it likely that the sample was representative. This study is also limited by the fact that it was carried out at a single institution, however over two sites. This may limit the ability to extrapolate results to different settings, especially non-tertiary hospitals.

There was a large proportion of junior doctors and especially interns in the study group, possibly leading to poorer results, however this is a true representative of the actual levels of doctors employed in our ED and most public hospital EDs. At present, junior doctors (Interns and Resident Medical Officers) need to discuss the need for CT imaging with a senior doctor (registrar or ED consultant) before ordering the imaging.

Conclusion

This study demonstrated that overall knowledge of radiation exposure from medical imaging and its risks amongst emergency department doctors is poor. Although this is likely multifactorial, improved education is necessary for better knowledge and possibly a change in awareness, leading to change in behaviour, especially in view of minimizing the seemingly unavoidable increase in malignancies in the future.

Recommendations

To address this lack of knowledge, we recommend education and ongoing assessment during the intern year to improve understanding and knowledge of radiation exposure. There is also a role for continued collaboration between radiologists and emergency physicians to create (local) protocols. It has been previously suggested to provide radiation dose and associated risks on imaging requests. This will allow the requesting doctor to consider this information and discuss the risks with the patient.[15] This may increase general awareness under doctors and have a more lasting effect on overall knowledge and behaviour. The patient's personal (total accumulated) dose of radiation could also be included on the formal imaging report, as occurs in a number UK hospitals.[25]

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Box 1. Examples of exposure as outlined in NCRP documents and measurements taken in Queensland Health facilities.[22]

Diagnostic imaging	Exposure examples
One CXR	0.02 mSv = 3 days background radiation = 4 hours flying (39,000 ft) = risk (LAR) of fatal cancer 1:1,000,000
One CT abdomen	10 mSv = 4.5 years background radiation = 2000 hours flying (39,000 ft) = risk (LAR) of fatal cancer 1:2000

NRCP: National Council on Radiation Protection & Measurements, CXR: Chest radiograph, mSv: milliSievert, LAR: Lifetime attributable risk

Table 1. Demographic characteristics of the study population (N=96)

	Frequency (N)	Percentage of Total (%)
Gender		
Male	48	50
Female	48	50
Experience level		
<= 3 years	41	42.7
> 3 years	55	57.3
Country of Medical Degree		
Australia	46	47.9
NZ	3	3.1
UK	23	24
India	4	4.2
Other	20	20.8
Type of Degree		
Undergraduate	58	61.1
Post-graduate	38	38.9
Current Employment Level		
Junior	*48*	*50.0*
Intern	15	15.6
JHO	12	12.5
SHO	21	21.9
Senior	*48*	*50.0*
Registrar/PHO	30	31.3
SMO	3	3.1
Consultant	15	15.6

Table 2. Mean percentage radiation knowledge scores and scores on 100mm Visual Analogue Score (95% CI), representing how frequently participants thought they would discuss the risks of radiation exposure with patients/relatives in three clinical scenarios.

	Mean Radiation Knowledge Score (95% CI)	***Scenario 1:*** *Six year old boy with a closed head injury with GCS 15. The parents are convinced that he needs a CT brain.*	***Scenario 2:*** *A 23 year old pregnant woman with abdominal pain after a low speed road traffic accident for a CT abdomen.*	***Scenario 3:*** *A 76 year old lady with acute abdominal pain for a CT abdomen*
Total Group *(N)*	40 (38-43)	86 (81-91)	90 (85-95)	38 (32-44)
Gender				
Male *(48)*	41 (37-44)	83 (75-91)	86 (79-94)	37 (39-45)
Female *(48)*	40 (36-44)	89 (84-94)	94 (89-99)	38 (30-46)
Experience Level				
<= 3 years *(41)*	39 (35-43)	85 (78-92)	90 (84-96)	29 (22-35)**
> 3 years *(55)*	41 (38-44)	87 (80-94)	90 (84-96)	45 (37-53)
Country of Medical Degree				
Australia (46)	38 (34-41)*	84 (77-91)	89 (84-94)	30 (23-37)
NZ *(3)*	31 (20-43)	88 (70-100)	99 (96-100)	20 (8-32)
UK *(23)*	47 (42-52)	93 (86-100)	97 (93-100)	44 (32-56)
India *(4)*	38 (29-48)	94 (81-100)	76 (21-100)	59 (29-89)
Other *(20)*	40 (35-45)	80 (66-94)	86 (72-100)	47 (35-59)
Type of Degree				
Undergraduate *(58)*	42 (38-45)	89 (83-95)	93 (89-97)	40 (33-47)
Post-graduate *(38)*	38 (35-42)	81 (73-89)	84 (75-93)	33 (25-41)
Current Employment Level				
Junior (48)	*39 (35-42)*	*82 (75-89)*	*85 (77-93)****	*33 (26-40)*
Intern *(15)*	36 (29-43)	84 (73-95)	89 (76-100)*	32 (23-42)
JHO *(12)*	37 (31-43)	71 (55-87)	81 (65-97)	33 (21-45)
SHO *(21)*	42 (36-48)	87 (76-98)	86 (73-99)	32 (22-42)
Senior (48)	*42 (39-46)*	*90 (84-96)*	*94 (91-98)*	*43 (31-51)*
Registrar *(30)*	42 (38-45)	89 (80-98)	95 (91-99)	52 (42-62)
SMO *(3)*	40 (25-55)	70 (36-100)	83 (50-100)	10 (3-17)
Consultant *(15)*	43 (35-52)	97 (93-100)	96 (91-100)	32 (20-44)

* P<0.05 (ANOVA) comparing the three junior doctor levels, ** P<0.05 (t-test), *** p<0.05, comparing senior vs. junior. VAS: Visual Analogue scale 0-100 mm, with 0 = would never discuss, 100 = would always discuss. 95% CI: 95% confidence interval. GCS: Glasgow Coma Scale (15 = maximum score and equates with normal level of consciousness)

Table 3. The 15 item radiation knowledge component of the questionnaire. For the first 11 items, participants estimated the radiation exposure for each modality (in number of CXRs).

Modality *(Correct answer)*	**Underestimated** **%**	**Correct** **%**	**Overestimated** **%**
Limb x-ray *(0-1 CXRs)*	0	50.5	49.5
Lumbar Spine x-ray *(50-100 CXRs)*	89.5	7.4	3.2
Chest x-ray *(0-1 CXRs)*	0	78.9	21.1
Abdominal x-ray *(10-50 CXRs)*	66.3	28.4	5.3
Pelvic x-ray *(10-50 CXRs)*	52.6	41.1	6.3
CT abdomen *(100-500 CXRs)*	46.3	44.2	9.5
Ultrasound abdomen *(0-1 CXRs)*	0	94.7	5.3
CT Head *(50-100 CXRs)*	43.2	34.7	22.1
MRI head *(0-1 CXRs)*	0	78.9	21.1
CTPA *(100-500 CXRs)*	53.7	29.5	16.8
CT chest *(100-500 CXRs)*	63.2	30.5	6.3
Lifetime risk of cancer from CT abdomen? *(1:2000)*	78.1	19.8	2.1
Number of days of background radiation equals 1 CXR? *(3 days)*	83.3	13.5	3.1
Flying from Brisbane to London equates to how many CXR? *(5 CXRs)*	62.5	19.8	17.7
How many mSv for one CXR? *(0.02 mSv)*	7.3	33.3	59.4

CXR: Chest radiograph, mSv: milliSievert. The multiple choice answer options for the first 11 items were: 0-1 CXR, 1.1-10 CXR, 10-50 CXR, 50-100 CXR and 100-500 CXR.