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

Gerben B Keijzers and Charles J Britton


## ABSTRACT

**Objective:** To assess emergency department (ED) doctors' knowledge of radiation doses associated with diagnostic imaging and to describe their practice with regard to informing patients of risk.

**Design, participants and setting:** Prospective, questionnaire-based observational study in May 2009 among all 110 doctors in the EDs of a 570-bed teaching hospital and a 200-bed district hospital.

**Main outcome measures:** Percentage knowledge score; and frequency of discussing radiation risk with patients, based on responses to three scenarios rated on a visual analogue scale (VAS), where a score of 100 indicates doctors would always discuss it.

**Results:** 96 doctors (87%) completed the questionnaire. The overall mean knowledge score was 40% (95% CI, 38%–43%). Senior doctors scored somewhat higher than junior doctors, but not significantly (42% v 39%; $P = 0.75$). Over three-quarters of doctors (78%) underestimated the lifetime risk of fatal cancer attributable to a single computed tomography scan of the abdomen. Most doctors (76%) reported never having had any formal training on risks to patients from radiation exposure. The frequency at which doctors would inform patients of the risk of radiation varied greatly depending on the clinical scenario (mean VAS scores, between 38 and 90).

**Conclusion:** Emergency doctors in our sample had a varied knowledge of the risks from radiation exposure, but overall knowledge was poor. Staff should receive education, and the diagnostic imaging request process may need to include information on radiation doses and risks.


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The number of patients undergoing diagnostic radiology, in particular computed tomography (CT) scanning, is increasing every year.[1,2] Together with improvements in CT scanning technology, radiation doses per scan have increased by up to 40%.[3] Now commonplace, multidetector CT scanners have the potential to expose patients to higher radiation doses than older single-detector CT scanners.[4]

The cancer-causing biological effects of ionising radiation, including low doses received during medical diagnostic imaging, are well documented.[5,6] All doses, however low, have the potential to cause harm. Studies have shown an overall lifetime attributable risk of cancer of 1 in 82 in high-use groups,[7] and between 1 in 143 for a 20-year-old woman and 1 in 3261 for an 80-year-old man as a result of a single CT coronary angiogram.[8] It has been estimated that 100 to 250 deaths occur each year in the United Kingdom as a direct result of medical exposure to diagnostic radiation.[9]

The dose of radiation given in any diagnostic procedure should be enough to answer the relevant clinical question but as low as reasonably achievable to minimise the risk to the patient.[10,11] Modern imaging equipment allows adjustment for patient size and anatomy.[12] This is important, as the lifetime attributable risk of fatal cancer for children exposed to radiation is substantially higher than for adults.[13]

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 associated risks. This is particularly important in the emergency department (ED), where many radiological imaging tests are requested each day, often in a time-pressured environment. There have been no Australian studies of ED doctors' knowledge of this area and their related work practices. Given the diversity in experience, background and training of doctors who work in Australian EDs, we aimed to gain insight into emergency doctors' overall understanding of risks to patients from radiation exposure, their training in this regard, and their practices of requesting diagnostic imaging and informing patients of risks.

## METHODS

This prospective, observational study was conducted in the two EDs of the Gold Coast Health Service, Queensland, located at Southport and Robina. Gold Coast Hospital, Southport, is a 570-bed major metropolitan teaching hospital and Robina Hospital is an urban district hospital with 200 beds. The study was approved by the Gold Coast Health Service District Human Research Ethics Committee.

A pilot survey was tested by two emergency physicians and staff in the radiology department. Small alterations were made as a result. The questionnaire was distributed to all doctors working in the ED over a 2-week period in May 2009 during staff meetings, handovers and teaching sessions within working hours. This was done without the prior knowledge of the doctors so they could not prepare and were less likely to avoid participating. Questionnaires were collected immediately after completion and were anonymous. We excluded ourselves and the staff who had been involved in testing the pilot questionnaire.

### Questionnaire

The questionnaire covered three main areas. The first requested demographic data and included questions about formal education in radiation exposure risks. The second part aimed to investigate how frequently doctors would inform their patients about the risks of radiation. Using three common clinical scenarios, and marking their response on a 100 mm visual analogue scale (VAS; 0 = never, 100 = always), doctors were asked "In the following scenarios please indicate how often you would discuss any risk due to radiation exposure with patients/relatives prior to them undergoing imaging requested from the ED". Respondents were also asked how often patients or their relatives enquired about potential risks of radiation exposure and how confident they would be of providing concise and accurate information on the specific future risks. Thirdly, respondents' knowledge of radiation exposure levels was tested in a 15-item multiple-choice section that included the concepts of lifetime risk, background environmental radiation and effective dose.

Respondents were asked to choose the correct dose of radiation for commonly requested diagnostic imaging modes — plain radiographs, CT scans, ultrasound and magnetic resonance imaging (MRI). They were instructed to consider one chest x-ray as one arbitrary unit (CXR) and to approximate the equivalent number of units of radiation exposure for 11 specific types of imaging, choosing from five standard answers. The knowledge component of the test was modelled on previous studies in the UK,[9,14,15] United States[16,17] and Turkey.[18] Unanswered questions were scored as incorrect. The score out of a possible 15 was converted to a percentage.

Levels of exposure to ionising radiation from medical imaging vary by country, institution and the imaging equipment used. In formulating our questionnaire, we used data from the US National Council on Radiation Protection and Measurements and measurements taken in Queensland Health facilities.[19] These data assume a natural background radiation of 2.2 mSv/year, which agrees with other published data.[20] Examples of exposure levels as outlined in these documents are presented in Box 1.

### Statistical analysis

Data from completed surveys were collated and coded using Excel (Microsoft, Redmond, Wash, USA) before transfer to SPSS, version 17.0 (SPSS Inc, Chicago, Ill, USA) 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 to compare demographic groups. The $\chi^2$ test was used to compare differences in proportions for categorical variables (with $\alpha = 0.05$).

## RESULTS

Questionnaires were distributed to the 110 eligible ED doctors working during the study period, and 96 were returned (87% response rate). No more than 3% of data were missing for any variable.

### Respondent characteristics and education

Respondents had between 1 and 30 years' experience and there were as many men as women (Box 2). Most doctors (76%) reported never having undergone any formal training on radiation risk. Seventy per cent would have preferred to have received more teaching on the topic of radiation exposure and risks at medical school.

**1 Examples of radiation exposure levels from diagnostic imaging***

| Imaging | Exposure equivalent |
|---|---|
| Chest x-ray | 0.02 mSv |
| | 3 days' background radiation |
| | 4 hours' flying at 12 000 m |
| | 1 in 1 000 000 LAR of fatal cancer |
| CT scan of abdomen | 10 mSv |
| | 4.5 years' background radiation |
| | 2000 hours' flying at 12 000 m |
| | 1 in 2000 LAR of fatal cancer |

LAR = lifetime attributable risk. CT = computed tomography. * As outlined in US National Council on Radiation Protection and Measurements documents and measurements taken in Queensland Health facilities.[19] ◆

**2 Demographic characteristics of participants (*n* = 96)**

| | Number |
|---|---|
| Sex | |
| Men | 48 |
| Women | 48 |
| Experience level | |
| ≤ 3 years | 41 |
| > 3 years | 55 |
| Country of medical degree | |
| Australia | 46 |
| New Zealand | 3 |
| United Kingdom | 23 |
| India | 4 |
| Other | 20 |
| Type of degree | |
| Undergraduate | 58 |
| Postgraduate | 38 |
| Current employment level | |
| Junior | 48 |
| Intern | 15 |
| Junior house officer | 12 |
| Senior house officer | 21 |
| Senior | 48 |
| Registrar/principal house officer | 30 |
| Senior medical officer | 3 |
| Consultant | 15 |

### Workplace practice

Respondents indicated that they would often to always discuss the risk of CT scanning with the parents of a 6-year-old with a minor head injury (Scenario 1; mean VAS score, 86) or a pregnant woman considered for a CT scan of the abdomen (Scenario 2; mean VAS score, 90), whereas they would discuss this risk only sometimes or less often with a 76-year-old woman with abdominal pain considered for a CT scan of the abdomen (Scenario 3; mean VAS score, 38) (Box 3). Doctors with formal training were marginally more likely to discuss the risks in the three scenarios tested, although the differences were not statistically significant (mean VAS scores, 90 v 85, 96 v 88, and 44 v 36, for Scenarios 1, 2 and 3, respectively). Senior doctors were more likely than their junior counterparts to inform the pregnant patient in Scenario 2 of her risk (mean VAS score, 94 v 85; $P < 0.05$).

Doctors reported that they were hardly ever asked about the potential risks of radiation from diagnostic imaging by patients (mean VAS score, 23). Respondents indicated that they would have only moderate confidence in counselling patients regarding radiation exposure levels and answering patients' queries concisely and accurately (mean VAS score, 41). Senior doctors were more confident about answering questions from patients on the risks of radiation exposure than were junior doctors (mean VAS score, 47 v 36; $P \leqslant 0.01$).

### Knowledge of radiation and imaging

The mean knowledge score for all respondents was 40% (95% CI, 38%–43%) (Box 3). Those who had received formal education scored the same as those who had not (40%). There was a trend of gradually increasing knowledge scores with seniority. Overall, mean scores were 42% for senior doctors and 39% for junior doctors, but this was not a statistically significant difference ($P = 0.75$).

Over three-quarters of doctors (78%) underestimated the lifetime attributable risk of fatal cancer from a single CT scan of the abdomen (Box 4). Correct estimates of the radiation dose were given for lumbar spine, abdominal and pelvic x-rays by 7% to 41% of doctors, while 53% to 90% underestimated the radiation dose. The radiation dose in mSv from a single chest x-ray was overestimated by 60% of respondents, and 21% estimated that a chest x-ray required an equivalent of 1.1–10 CXR. Between 43% and 63% of respondents underestimated the dose of radiation from CT scans of the abdomen, head, and chest, and from a CT pulmonary angiogram.

Some respondents wrongly associated ultrasound and MRI with ionising radiation (5% and 21%, respectively). The radiation dose associated with MRI was correctly quantified by 88% of men and 70% of women ($P$=0.04).

**3 Radiation knowledge scores, and VAS scores representing how frequently respondents would discuss with patients and their relatives any risks of radiation exposure from requested imaging, according to three clinical scenarios**

| | | Clinical scenario mean VAS score (95% CI) | | |
|---|---|---|---|---|
| Characteristic | Radiation knowledge score, mean (95% CI) | 1* | 2† | 3‡ |
| Total group (*n* = 96) | 40% (38%–43%) | 86 (81–91) | 90 (85–95) | 38 (32–44) |
| Sex | | | | |
| Men (*n* = 48) | 41% (37%–44%) | 83 (75–91) | 86 (79–94) | 37 (29–45) |
| Women (*n* = 48) | 40% (36%–44%) | 89 (84–94) | 94 (89–99) | 38 (30–46) |
| Experience level | | | | |
| ⩽ 3 years (*n* = 41) | 39% (35%–43%) | 85 (78–92) | 90 (84–96) | 29 (22–35)§ |
| > 3 years (*n* = 55) | 41% (38%–44%) | 87 (80–94) | 90 (84–96) | 45 (37–53) |
| Country of medical degree | | | | |
| Australia (*n* = 46) | 38% (34%–41%)¶ | 84 (77–91) | 89 (84–94) | 30 (23–37) |
| New Zealand (*n* = 3) | 31% (20%–43%) | 88 (70–100) | 99 (96–100) | 20 (8–32) |
| United Kingdom (*n* = 23) | 47% (42%–52%) | 93 (86–100) | 97 (93–100) | 44 (32–56) |
| India (*n* = 4) | 38% (29%–48%) | 94 (81–100) | 76 (21–100) | 59 (29–89) |
| Other (*n* = 20) | 40% (35%–45%) | 80 (66–94) | 86 (72–100) | 47 (35–59) |
| Type of degree | | | | |
| Undergraduate (*n* = 58) | 42% (38%–45%) | 89 (83–95) | 93 (89–97) | 40 (33–47) |
| Postgraduate (*n* = 38) | 38% (35%–42%) | 81 (73–89) | 84 (75–93) | 33 (25–41) |
| Current employment level | | | | |
| Junior (*n* = 48) | 39% (35%–42%) | 82 (75–89) | 85 (77–93)** | 33 (26–40) |
| Intern (*n* = 15) | 36% (29%–43%) | 84 (73–95) | 89 (76–100)†† | 32 (23–42) |
| JHO (*n* = 12) | 37% (31%–43%) | 71 (55–87) | 81 (65–97) | 33 (21–45) |
| SHO (*n* = 21) | 42% (36%–48%) | 87 (76–98) | 86 (73–99) | 32 (22–42) |
| Senior (*n* = 48) | 42% (39%–46%) | 90 (84–96) | 94 (91–98) | 43 (31–51) |
| Registrar/PHO (*n* = 30) | 42% (38%–45%) | 89 (80–98) | 95 (91–99) | 52 (42–62) |
| SMO (*n* = 3) | 40% (25%–55%) | 70 (36–100) | 83 (50–100) | 10 (3–17) |
| Consultant (*n* = 15) | 43% (35%–52%) | 97 (93–100) | 96 (91–100) | 32 (20–44) |

VAS = visual analogue scale (0–100 mm, with 0 = would never discuss, 100 = would always discuss). JHO = junior house officer. SHO = senior house officer. PHO = principal house officer. SMO = senior medical officer. CT = computed tomography. ANOVA = analysis of variance. * *"A six year old boy has a closed head injury and a Glasgow Coma Score of 15 where the child's parents are convinced that he needs a head CT scan."* † *"A 23 year old pregnant lady with abdominal pain after a low-speed road traffic accident for a CT abdomen."* ‡ *"A 76 year old lady with acute abdominal pain for a CT abdomen."* § $P < 0.05$ (*t* test). ¶ $P < 0.05$ (ANOVA). ** $P < 0.05$, comparing senior with junior. †† $P < 0.05$ (ANOVA) comparing the three junior doctor levels. ◆

## DISCUSSION

Our study found that emergency doctors' knowledge of radiation exposure from medical imaging is poor, and that whether they would inform their patients of the risks of radiation exposure varied with the clinical scenario. Overall, these doctors underestimated radiation exposure of frequently used diagnostic imaging and the associated risks. Underestimation of doses and risks may lead to doctors requesting more diagnostic imaging than they would if they had accurate knowledge.

It is likely that many factors contributed to the poor knowledge scores achieved in this study. It might be assumed that they reflect the education provided at undergraduate level, since about three-quarters of doctors reported never having undergone formal training on this topic. However, there was no difference in knowledge scores between those who had received formal education and those who had not. The same finding has been reported in another study, with no difference in knowledge of radiation between doctors who attended radiation safety courses and those who did not.[21]

Overseas studies[9,14-16,18,22] also indicate that overall knowledge of this area is poor and that doctors often underestimate the radiation dose.[9] In one study, only 7% of patients who underwent an abdominal CT scan were given information on radiation exposure.[17] It is concerning that a small proportion of doctors considered that ultrasound and MRI expose patients to a dose of radiation. This seems to reflect a deficit of knowledge of basic scientific principles. It may be explained by the fact that MRI is infrequently requested from EDs, is often difficult to access and is more likely to be requested by the senior members of staff. Although a smaller proportion of doctors associated ultrasound imaging with radiation exposure, this potentially has more clinical relevance because of the numbers of ultrasounds requested. These results are consistent with previous studies which reported that ultrasound scanning and MRI were associated with radiation by 4%–11% and 8%–28% of respondents, respectively.[9,14,18,23] Significantly more men than women recognised that MRI does not expose patients to ionising radiation, consistent with previous studies.[18,23]

Interestingly, despite general underestimation of exposure for imaging, the actual estimated dose in mSv for a single chest x-ray was overestimated by nearly two-thirds of doctors, perhaps indicating unfamiliarity with units of radiation. Surprisingly, about one-fifth of doctors indicated that a chest x-ray was equivalent to more than one CXR. It is possible that these doctors were taking into consideration that two films are often requested with chest radiography (posterio-anterior and lateral).

The large variability in doctors' practice of informing patients of risk may be dependent on the degree of risk to the patient as perceived by the doctor; for example, the lifelong risk to a small child (or fetus) is higher than that to an elderly person from the same level of radiation. 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 in a multitrauma patient with serious injuries), and only discuss the risks of imaging where the justification for the test is borderline or questionable.

Our study had 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, as some items may be more important than others. Also, we measured the self-reported intention to inform patients in three scenarios, but not the detail or content of this information. We cannot exclude selection bias; however, we surveyed all eligible ED doctors, with a high response rate, making it likely that the sample was representative. This study was also limited by being carried out at a single institution, although over two

**4 Overall results of participants' responses to the 15-item radiation knowledge component of the questionnaire**

| Type of imaging or situation (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 scan of the abdomen (100–500 CXRs)* | 46.3% | 44.2% | 9.5% |
| Ultrasound of the abdomen (0–1 CXRs)* | 0 | 94.7% | 5.3% |
| CT scan of the head (50–100 CXRs)* | 43.2% | 34.7% | 22.1% |
| MRI of the head (0–1 CXRs)* | 0 | 78.9% | 21.1% |
| CT pulmonary angiogram (100–500 CXRs)* | 53.7% | 29.5% | 16.8% |
| CT scan of the chest (100–500 CXRs)* | 63.2% | 30.5% | 6.3% |
| Lifetime risk of fatal cancer from a single CT scan of the abdomen (1 in 2000) | 78.1% | 19.8% | 2.1% |
| Days of background environmental radiation equivalent to one chest x-ray (3) | 83.3% | 13.5% | 3.1% |
| No. of chest x-rays equating to exposure on a 20-h flight from Brisbane to London (5) | 62.5% | 19.8% | 17.7% |
| Radiation absorbed during a single chest x-ray, in mSv (0.02 mSv) | 7.3% | 33.3% | 59.4% |

CXR = one arbitrary unit equal to the radiation exposure from one chest x-ray. CT = computed tomography. MRI = magnetic resonance imaging. * Participants were instructed to estimate the radiation exposure for each modality in the equivalent number of CXRs. The multiple-choice answer options were: 0–1; 1.1–10; 10–50; 50–100; and 100–500. ◆

sites. This may limit extrapolation of the results to different settings, especially non-tertiary hospitals.

The study group comprised a large proportion of junior doctors, and especially interns, possibly leading to the poorer knowledge scores. However, this is a true representation of the actual composition of the staff employed in our ED and most public hospital EDs. At present, junior doctors need to discuss the need for CT imaging with a senior doctor before ordering a scan.

We recommend education and ongoing assessment during the intern year to improve understanding of radiation exposure. There is also a need for continued collaboration between radiologists and emergency physicians in creating local protocols. It has been previously suggested that radiation doses and associated risks should be provided on imaging request forms. This would allow the requesting doctor to consider this information and discuss the risks with the patient.[14] This may increase doctors' general awareness 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 already occurs in a number of UK hospitals.[24]

Education to improve awareness is needed to bring about a change in behaviour, especially in view of minimising the seemingly unavoidable increase in malignancies in the future.


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## COMPETING INTERESTS

None identified.


## AUTHOR DETAILS

**Gerben B Keijzers,** MB BS, MSc(Epid), FACEM, Emergency Physician,[1] Assistant Professor and Clinical Lead in Emergency Medicine[2]
**Charles J Britton,** MB ChB, Advanced Trainee and Emergency Registrar[1]
1 Department of Emergency Medicine, Gold Coast Hospital, Gold Coast, QLD.
2 Faculty of Health Sciences and Medicine, Bond University, Gold Coast, QLD.
***Correspondence:***
**gerben_keijzers@health.qld.gov.au**


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