Patient Knowledge and Perception of Radiation Risk in Diagnostic Imaging: A Cross-Sectional Study

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Abstract
Background: Informed consent dictates that patients appreciate the risks and benefits of imaging techniques that use ionizing radiation. Computed tomography (CT) and X-ray carry a stochastic lifetime risk of inducing malignancy. This risk is difficult to convey and often overlooked. Objective: This work aims to establish some basics regarding patient knowledge and perception of medical imaging to facilitate an informed consent process. Method: A questionnaire survey was conducted in a general orthopedic outpatient clinic in a United Kingdom tertiary center. Results: There were 219 respondents. Twenty-two percent understood that CT produces ionizing radiation associated with cancer risk, but only 6% knew about cancer risk from natural background radiation. Only 25% knew that CT has a higher cancer risk than X-ray. The majority (93%) knew that smoking poses higher risk than X-rays. The Internet as an information source was statistically associated with concern about X-rays. Conclusions: Patients underestimated CT cancer risk and were unable to compare risk between imaging modalities. Risk can be more effectively conveyed using better known relatable risks as comparators. Patient groups associated with lower knowledge, most in need of education, were highlighted.

Keywords
X-ray, radiation, risk, knowledge, perception, attitude

Introduction
X-rays and computed tomography (CT), imaging techniques employing ionizing radiation, carry with them a stochastic lifetime risk of inducing malignancy in accordance with the linear no threshold model (1,2). Patient-centered care would dictate that patients appreciate the risks as well as the benefits of such imaging. A recent United Kingdom supreme court judgment (3) highlighted that this information, based on its material relevance to the patient, should be part of an informed consent process. The American College of Cardiology (4) has developed a “patient centered imaging” framework, which incorporates a graded system for imaging consent based on level of risk. A study showed that patients tend to realize that CT scans involve radiation (5), while another showed patients don’t associate this with a cancer risk (6). A lack of understanding has been demonstrated to exist between radiation dose and level of risk (7). When asked to directly compare X-ray verses CT radiation dose, the majority of patients in studies did so incorrectly (7,8). This may be due to doctors not properly discussing risk with patients (6), through omission or having insufficient knowledge themselves (4,9). Few patients were concerned about CT in a study (5), with diagnosis being of paramount importance (5,7,10), yet the majority wanted to be informed of the risks involved (5). This work aims to supplement the small amount of research addressing patient knowledge, perception, and attitude toward X-ray radiation risk to facilitate the consent process.

Methods
Study Design and Setting
A piloted, paper-based questionnaire survey was conducted in a general orthopedic outpatient clinic in a UK tertiary...
centert. Convenience sampling was used to distribute questionnaires during clinic hours from 9 AM to 6 PM over a 4-day period in June 2015. The study was approved by the designated institutional representative.

Participants
Eligibility criteria was to be over 16 years old, understand the questionnaire in English and have an appointment in the clinic. There was no requirement to have had or be due to have any imaging.

Data Collection
Patients were approached in the clinic waiting room, where the purpose of the study was explained and informed consent obtained. Patients were given a paper questionnaire and asked to hand it back when complete. Assistance to complete the questionnaire was not offered but given if specifically requested for reading or writing.

Methods of Measurement and Data Analysis
The questionnaire in Online Resource A was piloted on 4 non-medics, covering both sex and age categories, such that questions could be refined to aid understanding. Descriptive analysis was done in Microsoft Excel (16.0). IBM SPSS version 21 was used for cross-tabulation and \( \chi^2 \) analysis. The critical level of significance was 0.05 (5%). For analysis of associations, conversion to binary variables was done as follows. Age was categorized into \( \leq 30 \) and \( >30 \) years old. Pain was categorized into “No pain” (0 on the pain scale) and “Pain” (1-10 on the pain scale). To create a binary variable describing patient knowledge of radiation risk, correct answers to questions 6 and 7 were summed for each respondent, then knowledge was categorized as “low” (score of 0-3) and “high” (score of 4-10). Rather than an arbitrary choice, the cutoff was based on consideration of question difficulty, with knowledge of X-ray, CT, and sun radiation risk perceived to be fairly straightforward questions (3 easier questions, hence 0-3 category), whereas background radiation in air and probability questions were harder. For Q8, which graded the amount of danger perceived in X-rays, any positive answer given was lumped into a single “yes” category. Answers to other questions were already binary, that is, a patient had either indicated they receive health information from a particular source, such as from a “doctor,” or they had not.

Results
Response Rate
Two hundred and fifty patients were assessed for eligibility; 8 failed to meet inclusion criteria. Completed questionnaires were received from 219 of the 242 eligible patients, giving a response rate of 90.5%.

Demographics
The mean age of respondents was 48.2 years (n = 214, standard deviation = 17.79, min = 16, max = 88). Fifty-six percent (n = 217) were male; 98% (n = 218) had an X-ray in the past; and 91% (n = 217) indicated they were in pain.

Knowledge of Risk
The responses to Q6 (Do any of the following produce radiation that may lead to cancer at a later age?) were as follows: sun 76%, X-ray 53%, mobile phone 37%, CT 22%, magnetic resonance imaging (MRI) 20%, air 7%, ultrasound 6% (n = 219). Table 1 shows the responses to Q7 assessing knowledge of lifetime cancer risk (or risk of death for a road accident) from common imaging techniques and from other causes.

Knowledge of Risk Comparisons: Risk of Cancer From an Arm X-Ray Versus Other Scenarios
Figure 1 presents an indirect risk comparison derived by comparing answers to the individual parts of Q7. The risk assigned of cancer from an arm X-ray was compared to the other scenarios (ie, risk of cancer from arm X-ray vs risk of cancer from spine CT), to see whether an arm X-ray was comparatively lower, higher, or equal risk. The aim of this analysis was to understand how risks were compared, hence comparisons were made regardless of whether the answers to specific risk probabilities were correct or not. With regard to imaging modalities, only 25% of comparisons between X-ray and CT risk were correct (ie, X-ray risk far lower) and 38% of comparisons between X-ray and MRI risk were correct (MRI has no risk). Conversely, nearly all comparisons between X-ray and nonimaging risks were correct (88%, 93%, and 77% correctly compared the risk of cancer from an arm X-ray to the risk of cancer in general, cancer from smoking, and dying in a road accident, respectively).

Perception and Attitude (Q8-16)
Responses to questions about perception and attitude toward imaging are shown in Table 2.

Risk Factors Associated With Knowledge, Perception, and Attitude
Table 3 shows the relationship between 11 risk factors and 3 dichotomous outcome variables—see Methods section for calculation. Risk factors which showed a statistically significant association with knowledge of radiation risk were age (those younger than 30 were 2.07 times as likely to have better knowledge relative to those over 30, \( P < .01 \)), obtaining health information from a doctor (those who obtained health information from a doctor were 0.58 times as likely to have better knowledge, \( P = .03 \)) or general knowledge (those who obtained health information from general knowledge were 1.94 times as likely to have better knowledge, \( P < .01 \) or
taught knowledge (those who obtained health information from taught knowledge were 2.36 times as likely to have better knowledge, \(P < .01\)), and pain (those who were in pain were 0.43 times as likely to have better knowledge, \(P < .01\)).

Risk factors which showed a statistically significant association with perception of X-rays as dangerous were sex (females were 1.4 times as likely to perceive danger, \(P = .01\)), obtaining health information from a doctor (those who obtained health information from a doctor were 0.72 times as likely to perceive danger, \(P = .03\)) or taught knowledge (those who obtained health information from taught knowledge were 1.57 times as likely to perceive danger, \(P < .01\)), and knowledge level (those who had a high level of knowledge were 1.4 times as likely to perceive danger, \(P = .01\)).

The only risk factor to show a statistically significant association with concern about X-rays was using the Internet as a source of health information (patients who obtained health info from the Internet were 2.17 times as likely to be concerned about X-rays, \(P = .03\)).

### Discussion

#### Knowledge of Risk

There was a good appreciation of the sun’s link to cancer risk attributable to the various UK national government and charity skin cancer campaigns, demonstrated by the office of national statistics to have a measurable impact. This may be replicable globally in countries with similar campaigns, such as Australia. The link between X-rays and cancer was realized by far more patients than for CT; this is thought to be due to the relative contemporary nature of CT, with less time for knowledge acquisition and perhaps an association of newer technology with less risk. The latter argument is supported by the fact few patients linked MRI to cancer risk. Very few patients realized there was a cancer risk associated with air (from naturally occurring background radiation). This is pertinent as the NHS uses background radiation as way of explaining ionizing radiation risk (15).

Exact knowledge of absolute risk probability for the scenarios in Q7 was low (16%-26%); however, this was a difficult question, and because responses tended to be close to

### Table 1. Distribution of Assigned Risk Probabilities (% Respondents) to Scenarios in Q7.

| Scenario                        | 1/3 | 1/10 | 1/100 | 1/1000 | 1/1 × 10^5 | 1/1 × 10^6 | 0 | Don’t Know | n |
|--------------------------------|-----|------|-------|--------|------------|------------|---|------------|---|
| Cancer from arm X-ray (11)     | 2   | 1    | 2     | 4      | 15         | 25*        | 15| 35         | 213|
| Cancer from spine CT (11)      | 1   | 1    | 3     | 6*     | 11         | 13         | 16| 48         | 211|
| Cancer from MRI                | 0   | 2    | 2     | 6      | 9          | 13         | 24*| 43         | 211|
| Cancer in general (12)         | 22* | 22   | 11    | 15     | 12         | 3          | 0 | 14         | 214|
| Cancer from smoking (13)       | 26* | 26   | 15    | 15     | 5          | 1          | 0 | 11         | 212|
| Dying in a road accident (14)  | 26  | 26   | 15    | 15     | 5          | 1          | 0 | 11         | 212|

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging.

*Correct answer denoted by asterisk (*). The 3 most frequently picked answers are highlighted in grey.

### Table 2. Responses to Q8-16 About Perception of Danger and Attitude Toward X-Rays.

| Question                                                                 | n   | % Yes |
|--------------------------------------------------------------------------|-----|-------|
| Q8. Do you consider X-rays as dangerous?                                 | 214 | 53    |
| Q9. Do you have any worries or concerns about having an X-ray?           | 214 | 11    |
| Q11. Have you ever refused an X-ray that the doctor recommended, due to your concern? | 214 | 1.4   |
| Q12. Do you consider nuclear power plants as acceptable?                 | 207 | 50    |
| Q13. Have you ever thought you needed an X-ray, but not had one carried out? | 212 | 22    |
| Q14. Should the patient have the final say (rather than the doctor) on deciding whether to have an X-ray? | 212 | 52    |
| Q15. If a new X-ray machine were available that used significantly less radiation, would you be prepared to travel an extra 50 miles to a hospital with this technology? | 212 | 38    |
| Q16. If a new X-ray machine were available that produced better quality imaging, would you be prepared to travel an extra 50 miles to a hospital with this technology? | 211 | 64    |

*Danger categories = 44% low, 8% medium, 1% high.

Content analysis of written answers (to Q10) detailing the concern revealed that 5% mentioned cancer, 45% mentioned radiation, and 10% mentioned both.
the correct answer, highlighted in gray in Table 1, it could be argued that patients understood the risk enough to appreciate the risk–benefit balance. This pattern coincides with other research on X-ray and CT (7) using verbal risk descriptors (eg, low risk, high risk) that mapped onto the numerical risks used here (eg, 1/100, 1/10). Computed tomography was an exception, wherein only 6% answered correctly and furthermore the top 3 answers did not include the correct one, as with all other scenarios. In fact, 88% underestimated CT risk, consistent with 85% found in other research (5). The underestimation of CT risk could be due to patients not realizing that a CT scan comprises multiple X-rays, due to reasons explained above.

Knowledge of Risk Comparisons: Risk of Cancer From an Arm X-Ray Versus Other Scenarios

Knowledge of absolute risk, as discussed above, may not be as important as being able to compare risks, that is to say one risk is greater than another. Communicating uncertainty and individual probabilities can be very difficult, so being able to simply compare risks offers patients a way to contextualize and understand risk. This was tested by comparing allocated risks. The lack of correct risk comparisons between imaging modalities agrees with other research (7,8,16) directly asking patients to compare risk. No research has compared MRI to X-ray risk: the 62% of cases wherein MRI was incorrectly greater or equal risk to X-ray weighs against the earlier argument that MRI technology is considered safer by virtue of its novelty. This discrepancy may represent a lack of understanding which needs to be addressed together with the comparative risk of other imaging techniques, which can be done by using an X-rays as a risk denominator that is one CT equals n number of X-rays. Comparison of X-ray risk to nonimaging risks was far more accurate; this finding suggests that it may be more useful in discussions to offset imaging risk against these better understood everyday risks than referring to concepts like natural occurring radiation.

Perception and Attitude

The majority of patients perceived X-rays as having an inherent danger, but this did not manifest in decision limiting concern (17) with only 3 indicating that they had refused imaging. Conversely, patients can underestimate the risks (5,8) involved and expect imaging (8,10). Expectation exceeding clinically indicated imaging, assessed by asking patients if they had ever wanted an X-ray but not had one done, was present in 22% of cases wherein MRI was incorrectly greater or equal risk to X-ray. This was lower than expected but may have been due to patients’ expectations influencing decisions, an effect reported to lead to increased antibiotic prescribing in primary care (18). This argument is supported by the higher percentage of patients wanting the final say on ordering an X-ray. The final 2 questions, where almost twice as many agreed with Q16, indicated that patients may prioritize immediate diagnosis (thorough better quality imaging) over considering long-term cancer risks (through lower radiation techniques) (5,7,17). This tendency to think for the short term may interfere with proper appreciation of risk.

Risk Factors Associated With Knowledge, Perception, and Attitude

Knowledge of radiation risk. More up-to-date school teaching incorporating CT and MRI (established in the 1980s) may have led to younger patients (<30) being twice as likely to have better knowledge; this is consistent with the strong positive effect of teaching on radiation knowledge. Both

| Risk Factors | Outcome Variables |
|--------------|-------------------|
|              | Knowledge of Radiation Risk: High Versus Low | Perceive X-Rays as Dangerous: Yes Versus No | Concern About X-Rays: Yes Versus No |
|              | RR (95% CI) | P | RR (95% CI) | P | RR (95% CI) | P |
| Age (years)  | ≤30 vs >30 | 2.07 (1.35-3.17) | .00 | 1.04 (0.77-1.41) | .79 | 0.53 (0.17-1.67) | .26 |
| Sex          | F vs M   | 0.96 (0.61-1.52) | .88 | 1.40 (1.09-1.78) | .01 | 1.60 (0.79-3.25) | .19 |
| Health info  | Y vs N   | 0.58 (0.37-0.91) | .03 | 0.72 (0.56-0.93) | .03 | 0.92 (0.37-2.27) | .86 |
| Doctor       | Y vs N   | 1.94 (1.27-2.96) | .00 | 1.23 (0.96-1.58) | .12 | 0.92 (0.41-2.06) | .84 |
| Taught Knowledge | Y vs N | 2.36 (1.56-3.57) | .00 | 1.57 (1.25-1.98) | .00 | 1.41 (0.61-3.25) | .42 |
| Internet     | Y vs N   | 1.08 (0.69-1.67) | .75 | 1.19 (0.93-1.52) | .16 | 2.17 (1.04-4.52) | .03 |
| Reading      | Y vs N   | 1.28 (0.79-2.08) | .33 | 1.27 (0.99-1.64) | .09 | 1.83 (0.88-3.80) | .11 |
| TV           | Y vs N   | 1.14 (0.53-2.45) | .74 | 1.17 (0.78-1.74) | .49 | 2.15 (0.85-5.46) | .12 |
| Word of mouth| Y vs N   | 1.15 (0.63-2.07) | .66 | 0.95 (0.65-1.38) | .77 | 1.11 (0.41-2.98) | .84 |
| Pain         | Y vs N   | 0.43 (0.27-0.68) | .00 | 1.03 (0.66-1.61) | .90 | 1.22 (0.31-4.76) | .77 |
| Knowledge    | High vs low | 1.40 (1.10-1.78) | .01 | 0.79 (0.34-1.89) | .60 |

Abbreviations: CI, confidence interval; F, female; M, male; N, No; RR, relative risk; Y, yes.

*For each risk factor, the reference category is the comparator, for example, for age the reference category is >30; n varies from 208 to 214.
findings agree with work (7) that showed similar associations for age and education level. The negative effect of doctors on radiation knowledge may be explained by research showing few patients are told about risks and benefits before CT scans (6). Furthermore, imaging knowledge of doctors themselves can be lacking (9). The results also suggested that the presence of pain (98% of participants were in pain) interfered in some way with learning or knowledge recall, possibly as a result of impaired cognitive function, an effect particularly linked with chronic pain.

**Perception of X-rays as dangerous.** The patient doctor relationship is central to shaping patient views as the majority (83% \( n = 219 \)) of patients rely on doctors for health information, and this is associated with being less likely to perceive danger. It is important that this association is not a product of lacking or absent explanation of the risks involved in imaging as may be suggested by the association highlighted above and that it is trust and reassurance that underpins the consent process. When educating patients, clinicians should be mindful of the increased likelihood of danger perception with greater knowledge, so that a balanced view of dangers and risks is presented; it seems that this balance is being struck, as the perception of danger does not seem to translate into an association of knowledge with concern.

**Concern about X-rays.** The association of Internet health information with concern may signify an increasing reliance on the Internet for self-diagnosis and health information, many finding it difficult to filter irrelevant information. The Internet was second only to doctors as source of health information and as such clinicians should allow for views influenced rightly or wrongly by Internet searches when consenting.

**Limitations**

The results may not be generalizable to all other hospitals due to a limited sample size. Convenience sampling may have introduced selection bias. There may have been a non-response bias if patients did not participate due to concern about X-rays, resulting in underestimation of concern. There may have been response bias if patients were worried that showing concern would affect their relationship with the doctor or delay their treatment. Furthermore, it is recognized that bias may have been introduced due to misinterpretation of the “air” option in question 6; however, it was felt this provided the best answer in terms of questionnaire design, without mentioning background radiation. As multiple hypothesis testing was performed, caution should be exercised when interpreting those results with a \( P \) value between .01 and .05 due to the reduced evidence for association.

**Conclusions**

Patients underestimate CT risk and are unable to compare risk between imaging modalities. Risk can be more effectively conveyed using better known relatable risks as comparators. Patient groups associated with lower knowledge, most in need of education, are highlighted and it is demonstrated how perception and attitude may influence understanding of risk.

**Authors’ Note**

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**Supplemental Material**

Supplemental material for this article is available online.

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