Emergency Department Patients' Perceptions of Radiation From Medical Imaging

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ABSTRACT

Objective: To evaluate emergency department patients' knowledge of radiation exposure and subsequent risks from computed tomography (CT) and magnetic resonance imaging (MRI) scans.

Methods: This is a cross-sectional survey study of adult, English-speaking patients from June to August 2011 at 2 emergency departments—1 academic and 1 community-based—in the upper Midwest. The survey consisted of 2 sets of 3 questions evaluating patients' knowledge of radiation exposure from medical imaging and subsequent radiation-induced malignancies and was based on a previously published survey. The question sets paralleled each other, but one pertained to CT and the other to MRI. Questions in the survey ascertained patients' understanding of (1) the relative amount of radiation exposed from CT/MRI compared with a single chest x-ray; (2) the relative amount of radiation exposed from CT/MRI compared with a nuclear power plant accident; and (3) the possibility of radiation-induced malignancies from CT/MRI. Sociodemographic data also were gathered. The primary outcome measure was the proportion of correct answers to each survey question. Multiple logistic regression then was used to examine the relationship between the percentage correct for each question and sociodemographic variables, using odds ratios with 95% confidence intervals. *P*-values less than 0.05 were considered statistically significant.

Results: There were 500 participants in this study, 315 from the academic center and 185 from the community hospital. Overall, 14.1% (95% CI, 11.0%-17.2%) of participants understood the relative radiation exposure of a CT scan compared with a chest x-ray, while 22.8% (95% CI, 18.9%-26.7%) of respondents understood the lack of ionizing radiation use with MRI. At the same time, 25.6% (95% CI, 21.8%-29.4%) believed that there was an increased risk of developing cancer from repeated abdominal CTs, while 55.6% (95% CI, 51.1%-60.1%) believed this to be true of abdominal MRI. Higher educational level and identification as a health care professional were associated with correct responses. However, even within these groups, a significant majority gave incorrect responses to all questions.

Conclusion: Patients did not demonstrate understanding of the degree of radiation exposure from CT scans and the subsequent risks associated with this exposure, namely radiation-induced malignancies. Moreover, they did not understand that MRI scans do not expose them to ionizing radiation and therefore lack this downstream effect. While patient preference is integral to patient-centered care, physicians should be aware of the significant lack of knowledge as it pertains to the selection of medical imaging tests.

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INTRODUCTION

Background

Over the past 3 decades, there has been a dramatic increase in the number of computed tomography (CT) scans ordered in the United States, increasing exposure to medical radiation nearly 6-fold.[1] The most recent national data show that 80.6 million CT scans were performed in 2012, up from 2 million scans in 1983.[1,2] Emergency departments (ED) are a significant contributor to this trend: despite only a 13% increase in overall adult ED volume, CT scanning of the cervical spine, chest, abdomen, and head for adult patients increased 463%, 226%, 72%, and 51%, respectively, in 2000-2005.[3] This was mirrored for children: a 2% increase in pediatric ED volumes was accompanied by a 435% increase in chest CTs, 366% increase in cervical spine CTs, 49% increase in abdominal CTs, and 23% increase in head CTs.[4]

While CT assists with making faster, more accurate diagnoses, physicians have become increasingly aware of the radiation exposure associated with it. This exposure carries the potential long-term risk of radiation-induced malignancies, particularly in children and young adults. Based on epidemiologic data, the radiation exposure of 1 abdominopelvic CT, which is approximately 10 mSv, confers an estimated 1:2000 risk of developing cancer.[5] Brenner and Hall estimated that approximately 2% of all cases of cancer in 2007 in the United States were caused by medical imaging,[1] while Berrington de González and colleagues suggest that this trend will continue, amounting to 29,000 cancers annually.[6]

In 2010, growing concerns over the risks of ionizing radiation from medical imaging led the Food and Drug Administration (FDA) to call for an initiative to decrease the amount of radiation attributable to medical imaging.[7] A key component of this initiative involves raising awareness of the risks medical imaging poses. However, patients' knowledge of the amount of radiation exposed to them from advanced medical imaging tests, as well as the downstream risks of that radiation exposure, has only begun to be characterized.

Importance

Recent studies suggest that patients underestimate the amount of radiation from CT compared to a chest x-ray and do not understand the potential downstream issue of radiation-induced cancers.[8,9] Despite this, patients have substantially increased confidence in their diagnostic evaluation if medical imaging, particularly CT, is performed.[9] While foundational, previous reports were limited in that they restricted patient enrollment to tertiary care centers and did not assess if patients understood the difference between sources of ionizing radiation, like CT, and imaging tests that don't subject patients to such radiation, like magnetic resonance imaging (MRI). Finally, currently published studies have not documented the relationship between patient sociodemographic characteristics and understanding of radiation exposure and subsequent risks.

Goals of This Investigation

Our primary goal was to characterize patients' knowledge of the radiation exposure associated with CT and MRI and the risk of radiation-induced malignancies. Additionally, we set out to evaluate the relationships between patient understanding of these concepts and patient sociodemographic characteristics.

METHODS

Study Design and Setting

This is a survey study of a convenience sample of ED patients conducted at 2 hospitals in the upper Midwest from June to August 2011. The coordinating center was the University of Wisconsin School of Medicine and Public Health, an academic medical center with an emergency medicine residency program and an annual ED census of approximately 45,000. The second center was Beloit Memorial Hospital, a community center with an annual ED census of approximately 35,000 that serves as a secondary training site for the university-based residency program. The study protocol was reviewed by the University of Wisconsin Health Sciences Institutional Review Board and was granted exempt status.

Selection of Participants

All adult patients (≥ 18 years) during the study period were eligible to participate; they were not required to undergo medical imaging to participate. Patients were excluded if they had altered mental status, were unable to read English, or were otherwise unable to fill out the survey. Patients were identified by ED registration personnel, who subsequently gave patients a standardized informational sheet inviting them to participate in the study. Patients were considered enrolled in the study if they submitted this voluntary survey, which lacked any identifiable information.

Methods and Measurements

The survey used in this study is based on a similar, previously published survey that had been field-tested among a small sample of ED patients prior to use on a sample of 1100 ED patients.[9] Our instrument had 2 nearly identical sets of 3 questions, one set pertaining to CT and the other pertaining to MRI (Appendix). The first question in each set gauged the patient's understanding of the relative radiation exposure of CT/MRI compared with a single chest x-ray (CXR). Using a CXR for comparison was based on multiple other studies, including the referenced survey, which universally use CXR as a baseline comparator for radiation exposure. The correct answers were based on previously reported estimates of radiation exposure associated with abdominal CT and the fact that there is no ionizing radiation exposure with MRI.[10,11] The second question assessed the patient's understanding of the relative radiation exposure of CT/MRI compared with a historical reference (Fukushima Daiichi nuclear power plant accident of 2011). This comparison was based on reports from the Japanese Atomic Industrial Forum.[12] Notably, this question was changed from the previously reported survey,[9] which used radiation exposure from the Hiroshima nuclear bomb as its comparison, due to concerns raised by the community site that the nuclear bomb reference was too emotionally charged. The final question in each set evaluated the patient's understanding of the downstream effects of radiation exposure, specifically radiation-induced malignancies.[6,11] All questions had 5 possible answer choices. Because of the change regarding the historical reference, a survey research center was consulted to review and test the modified instrument for construct validity prior to implementation.

The final portion of the survey asked for patient sociodemographic information including gender, age, race, highest level of education, household income, and whether the patient had ever worked as a health care professional. To get a sense of the generalizability of our findings, we compared the sociodemographic profile of our study population to the nationally representative sample of the American Community Survey, which uses the Census Bureau's Master Address File for its sampling frame.[13]

After being taken to a patient room, registration personnel gave patients the paper survey, which was accompanied by a standardized letter inviting patients to participate in the study. These staff were unaware of the research hypothesis and were instructed to direct patient questions regarding the survey to the treating physician. Completed surveys were handed back to ED personnel, who subsequently filed them into 1 of multiple repositories in

Table 1. Respondent Characteristics Divided by Study Site and Reported as Cumulative Data

	Study Sociodemographics			State Census Data		
	Community (N = 185)	Academic (N = 315)	Total (N = 500)	Community	Academic	State
Age in Years, Mean ± SD; Median	41±17	40±17	41±17	33.6	30.7	38.5
Health Care Professional, N (%)						
No	148 (81%)	257 (83%)	405 (83%)	N/A	N/A	N/A
Race						
White	139 (78%)	258 (84%)	397 (82%)	66%	76%	82%
Hispanic	9 (5%)	10 (3%)	19 (4%)	15%	6%	6%
Black	29 (16%)	29 (9%)	58 (12%)	10%	7%	6%
Native Hawaiian/Pacific Islander	0 (0%)	1 (0.3%)	1 (0.2%)	0%	0%	0%
American Indian/Alaska Native	1 (0.5%)	2 (0.6%)	3 (0.6%)	0.3%	0.3%	0.8%
Asian	0 (0%)	7 (2%)	7 (1%)	1%	7%	2%
Income						
< $25,000	81 (47%)	81 (28%)	162 (35%)	32%	23%	22%
$25,000 - $49,999	49 (23%)	69 (24%)	118 (26%)	33%	23%	26%
$50,000 - $74,999	21 (12%)	55 (19%)	76 (17%)	17%	19%	20%
$75,000 - $100,000	15 (9%)	34 (12%)	49 (11%)	10%	14%	14%
> $100,000	5 (3%)	50 (17%)	55 (12%)	9%	21%	19%
Gender						
Female	107 (59%)	179 (58%)	286 (59%)	53%	51%	50%
Education						
Some High School	20 (11%)	14 (5%)	34 (7%)	15%	3%	6%
High School Graduate (or GED)	84 (47%)	54 (17%)	138 (28%)	37%	16%	33.%
Some College	40 (22%)	76 (25%)	116 (24%)	20%	17%	21%
Associate's Degree	17 (9%)	29 (9%)	46 (9%)	7%	8%	9%
Bachelor's Degree	11 (6%)	82 (27%)	93 (19%)	9%	29%	17%
Graduate or Professional Degree	7 (4%)	54 (17%)	61 (12%)	5%	24%	9%

Values listed are the number of participants in each subcategory with percentages of each parent category. Age is reported as mean ± standard deviation. Data from the American Community Survey, 2008-2012 also is presented to compare this study's population with that observed in the city where each hospital was located. These data are presented as percentages, except age, which is presented as a median value. Community = data from the secondary community-based emergency department; Academic = data from the primary academic medical center; State = statewide data obtained from the American Community Survey.

each ED. Patients were informed that physicians could not answer survey questions for patients, but could answer any questions that arose after participating. Completed surveys were collected weekly from both study sites.

Survey responses were entered into Excel 2010 (Microsoft Corp, Redmond, Washington) by one of the investigators and a subset were verified by another.

Outcomes

Since our objective was to determine ED patients' knowledge of radiation exposure caused by CT and MRI, as well as their understanding of risks of radiation-induced malignancies, the primary outcome measure was the proportion of correct answers to each question on the survey. We then examined the relationship between this primary outcome measure and sociodemographic information.

Analysis

Patient sociodemographic data are presented as raw numbers and percentages. Primary outcome data are presented as percentages. We used multiple logistic regression analysis to examine the relationship between the percentage right on each question and sociodemographic variables; *P*-values of less than 0.05 were considered statistically significant. The model was built using backward and forward variable selection, utilizing all demographic variables collected in the survey. Individual missing data were omitted from analyses—we did not use imputation. Analyses were performed using Excel 2010 and SAS Analytics Pro (SAS Institute Inc, Cary, North Carolina).

RESULTS

Characteristics of Study Subjects

During the study period, a total of 315 patients at the academic hospital (of a total of 5589 patients seen) and 185 patients at the community hospital (of a total of 4988 patients seen) completed the survey. Registration personnel did not keep records of how many patients were offered participation, so we were unable to calculate a response rate. Table 1 shows sociodemographic data for survey participants, as well as data reported from the American Community Survey, 2008-2012[10] for each of the cities, as well as the state where the survey was conducted.

Main Results

Participants had a limited understanding of the relative amount of ionizing radiation from CT and MRI compared to a CXR (Table 2). Seventy-one (14.1%, 95% CI, 11.0%-17.2%) correctly indicated that CT has 100 times the amount of radiation, and 103 (22.8%, 95% CI, 18.9%-26.7%) correctly indicated that MRI has essentially no radiation compared to CXR. Similarly, 49 participants (10.1%, 95% CI, 7.5%-12.7%) expressed agreement with the true statement "patients who have 3 to 5 abdominal CTs in their lifetime have received the same radiation exposure as someone near a nuclear power plant disaster." Conversely, this statement is not true for MRI, and 304 (64.3%, 95% CI, 60.0%-68.6%) correctly expressed disagreement. Participants also had a poor understanding of the cancer risk of CT. One hundred twenty-six (25.6%, 95% CI, 21.8%-29.4%) agreed with the true statement "patients who have 3 to 5 abdominal CTs in their lifetime have an increased lifetime risk for developing cancer." However, this statement is not true for MRI, and 263 (55.6%, 95% CI, 51.1%-60.1%) correctly disagreed with this statement. The percentage of correct responses for the entire patient cohort, separated by question is displayed in the Figure.

Relationship to Sociodemographic Factors. Due to a small number of participants in some subgroups, categories for education and income level were consolidated, creating roughly equally sized groups. For education level, patients were divided into those with at least a college degree and those who had less education. For income level, subjects were divided into household incomes over $50,000 and those making less than $50,000. The following is a summary of findings:

Computed Tomography. There was a significant association between correctly answering that an abdominal CT has 100 times the radiation as a CXR and having at least a college degree ($P=0.006$) and experience as a health care professional ($P=0.003$). Only having at least a college degree was significantly associated with correctly answering that 3 to 5 abdominal CTs increased a patient's lifetime risk of cancer ($P=0.004$). For all odds ratios reaching statistical significance, please see Table 3. Questions 1-3 pertain to CT.

Magnetic Resonance Imaging. Being male ($P=0.038$), having at least a college education ($P<0.001$), and having an annual income exceeding $50,000 ($P=0.002$) was statistically significantly associated with correctly answering that MRI has essentially no radiation compared to CXR and that MRI scans do not increase lifetime cancer risk. Identifying as being white ($P=0.008$), having at least a college degree ($P=0.001$), and earning more than $50,000 annually ($P=0.003$) was statistically related to correctly answering that MRI does not expose patients to levels of ionizing radiation similar to a nuclear power plant disaster. For all odds ratios reaching statistical significance, please see Table 3. Questions 4-6 pertain to MRI.

Table 2. Percentage of Questions Answered Correctly, Subdivided by Sociodemographic Categories

Category	Q1	Q2	Q3	Q4	Q5	Q6
Gender						
Female	15	8	28	19	64	51
Male	13	10	22	28	65	62
Race						
White	15	9	25	24	67	57
Black	9	9	33	14	49	42
Hispanic	5	21	16	16	68	68
Education						
High School	8	7	22	13	56	45
College	17	11	27	27	69	61
Income						
< $50,000	11	9	25	18	61	50
> $50,000	19	11	28	32	73	65
Health Care Professional						
No	12	9	22	22	64	56
Yes	25	11	38	27	67	54
Location						
Community	10	8	22	15	57	49
Academic	17	11	27	27	69	60
Age						
<30 years	18	8	28	19	63	52
30-60 years	13	10	25	27	67	55
>60 years	11	8	21	16	62	66

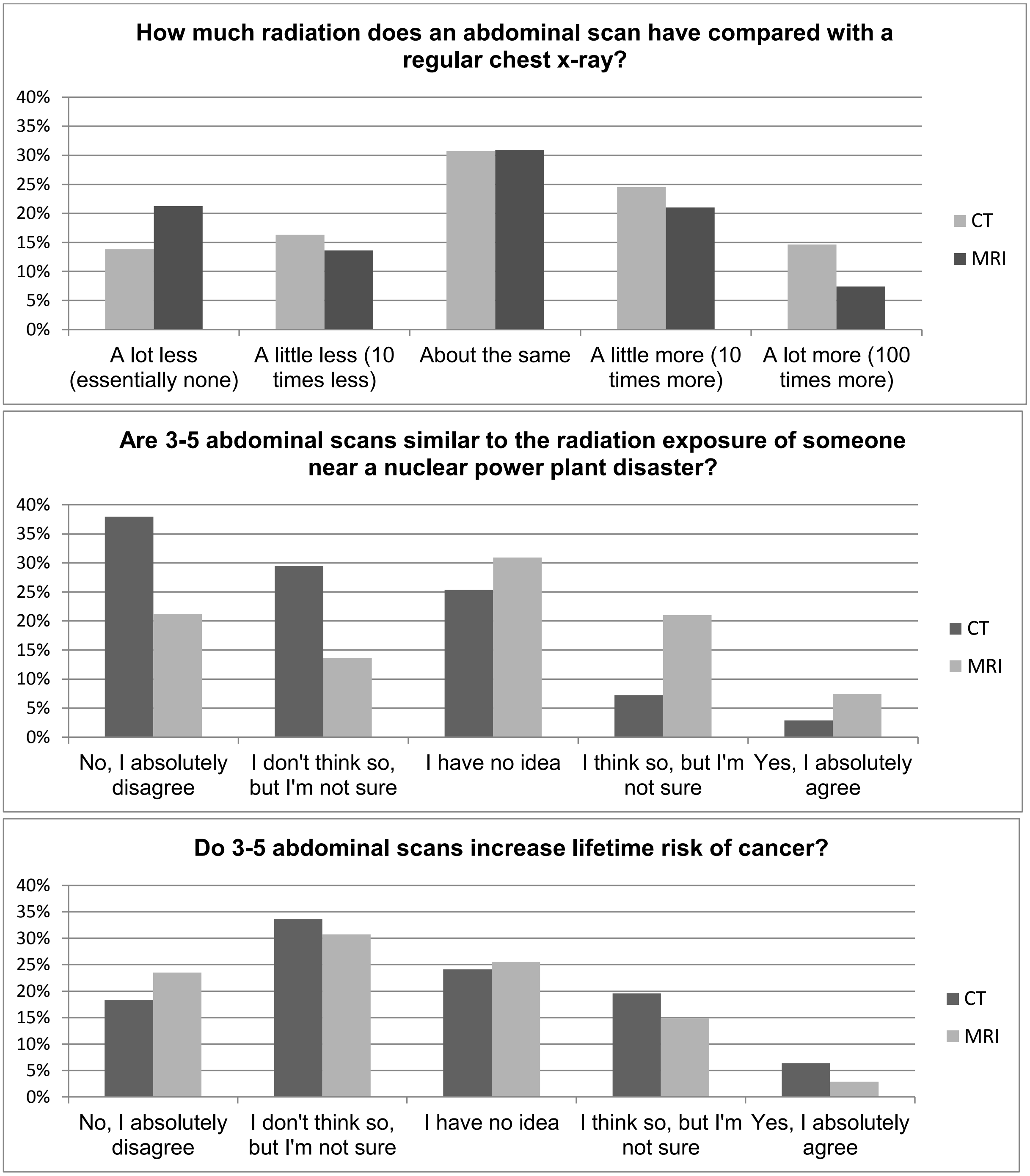
Due to having a small number of participants in some subcategories, education level, household income, and age were combined to make larger subcategories.

DISCUSSION

As reported previously,[8,9,14–16] we found that patients in the ED generally did not understand the amount of radiation associated with CT and also did not understand that this radiation exposure puts them at an increased risk of developing cancer. Our study builds upon previous findings by reporting that these same patients did not understand that MRI lacks ionizing radiation exposure and its downstream effects. Perhaps not surprisingly, we found that there was a significant relationship between answering questions correctly and having at least a college degree or experience as a health care professional. However, most patients in these categories still did not answer survey questions correctly. To date, no other study has reported patient knowledge of MRI, so we have no data to which we can compare our findings.

Few studies have delved into the field of patient preferences for medical imaging, though the funding priorities for federal agencies are now emphasizing patient-centered care and shared decision-making. We have seen that patients generally have greater confidence in their diagnostic evaluation when an imaging test is performed (particularly CT), though as we found in this study, patients don't understand the downstream radiation effects of

Figure. Distribution of Answers for Questions



Patients' answers to questions are graphed here for each question in the survey, reported as percentages, with corresponding CT/MRI questions combined. The first question in each set asked patients to estimate the amount of radiation in 1 abdominal CT/MRI compared with a chest x-ray. The second question asked patients if they believed 3 to 5 abdominal CTs/MRIs had the same radiation exposure as someone near the Fukushima Daiichi power plant disaster. The last question asked patients if they believed 3 to 5 abdominal CTs/MRIs increase someone's lifetime risk of developing cancer.

these tests.[9,15] Perhaps this lack of knowledge shouldn't be surprising since several studies have shown physicians don't have a good grasp of relative radiation exposure with CT and its downstream effects.[17–22] However, this understanding seems to be improving recently, with 95%-98% of physicians understanding that CT exposes patients to ionizing radiation[23] and 82% understanding that this radiation increases a patient's baseline risk of cancer.[24]

When Feger and colleagues sought to understand patient's preferences regarding cardiac imaging, there was general patient acceptance and comfort with use of noninvasive tests like CT coronary angiography when compared to traditional tests like conventional angiography.[25] Moreover, there was a general preference for CT over MRI, though discussion regarding radiation effects was not part of the study. However, Hull et al showed that parents of pediatric patients' preferences for imaging were affected by a brief educational intervention regarding radiation risks of CT. Moreover, the investigators found that 93% of parents expected to have a discussion with health care providers regarding the potential benefits and harms of undergoing medical imaging.[26] Another study found that a majority of noncritical trauma patients were interested in knowing not only the risks of medical imaging, but also the costs.[27] This would make it appear that interest in shared decision making is gaining momentum and, in fact, is advocated by both emergency medicine and radiology thought leaders.[28–30] While traditionally done as a discussion, at least 1 study reports that patients were actually more interested in obtaining a handout while in the ED to review prior to undergoing CT imaging.[31]

In summary, providers should be aware that their patients do not have the knowledge base to appropriately weigh the possible harms against the possible benefits when considering whether to undergo medical imaging, particularly CT. This points to the need for better patient education as recommended by the Food and Drug Administration so that patients can make a more informed decisions regarding their health care.[7] Future directions in this field could focus on what minimum level of information would suffice for patients to truly engage in shared decision-making as it relates to choice of imaging test. As the science of medical imaging advances, particularly in the realm of ultrasound and MRI use in the ED, this will be an even more critical part of the patient encounter. Clinical decision support will be of particular value when more information and diagnostic options become available.[32]

LIMITATIONS

This is a small survey study of ED patients presenting to 2 Wisconsin hospitals over a 2-month period in 2011. Registration personnel were asked to hand out surveys to eligible participants, however less than 5% of the total ED census during the study period actually participated. There were no records kept regarding how many patients were offered participation, so we are unable to calculate a true response rate. This potentially low response rate may lead to selection bias. However, our surveyed population has similar characteristics to that reported in the American Community Survey[13] for each site (Table 1). Furthermore, patients were not monitored while taking this survey. They may have had access to online materials through smartphone-type devices, which may have artificially increased the percent of correct answers; however, few patients answered questions correctly, so we do not believe this substantially influenced the results. Finally, we did not explicitly define what should be considered as "having health care provider experience." This may have led to information bias due to people perceiving the definition differently.

Table 3. Regression Analysis Results

Question	Backward Selection Model Variable	Backward Selection Odds Ratio (95% CI)	Forward Selection Model Variable	Forward Selection Odds Ratio (95% CI)
1	College degree	2.4 (1.3,4.2)	College degree	2.4 (1.3,4.2)
	Health care provider	2.3 (1.2,4.4)	Health care provider	2.3 (1.2,4.4)
2	None		None	
3	College degree	1.7 (1,2.7)	College degree	1.7 (1.1,2.7)
4	Male	1.6 (1,2.5)	Male	1.6 (1,2.5)
	Younger age	3 (1.3,6.8)	Younger age	3 (1.3,6.8)
	College degree	1.9 (1.2,3)	College degree	1.9 (1.2,3)
5	Male	1.7 (1.2,2.8)	Male	1.7 (1,2.9)
	College degree	2.9 (1.7,4.7)	College degree	3.1 (1.9,5.2)
6	College degree	2 (1.2,3.2)	College degree	2 (1.2,3.2)

Those variables with statistically significant odds ratios are reported in this table as point estimates with 95% confidence intervals. Both backward and forward variable selection were done as part of this analysis and yielded very similar results.

CONCLUSIONS

Patients at both academic and community EDs did not demonstrate an understanding of the radiation dose and risk associated with CT imaging. Moreover, they did not understand that MRI does not expose them to radiation and, therefore, does not impart an increased risk for developing cancer over one's lifetime. Factors associated with improved understanding were higher education and identification as a health care professional. Future directions in this line of research may focus on effective means of shared decision-making as it pertains to use of medical imaging in the diagnostic workup.

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