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How Radiation Exposure Histories Influence Physician Imaging Decisions: A Multicenter Radiologist Survey Study

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OBJECTIVE. The purpose of this article is to evaluate the influence of patient radiation exposure histories on radiologists' imaging decisions.

MATERIALS AND METHODS. We conducted a physician survey study in three academic medical centers. Radiologists were asked to make an imaging recommendation for a hypothetical patient with a history of multiple CT scans. We queried radiologists' decision making, evaluating whether they incorporated cancer risks from previous imaging, reported acceptance (or rejection) of the linear no-threshold model, and understood linear no-threshold model implications in this setting. Consistency between radiologists' decisions and their linear no-threshold model beliefs was evaluated; those acting in accordance with the linear no-threshold model were expected to disregard previously incurred cancer risks. A Fisher exact test was used to verify the generalizability of results across institutions and training levels (residents, fellows, and attending physicians).

RESULTS. Fifty-six percent (322/578) of radiologists completed the survey. Most (92% [295/322]) incorporated risks from the patient's exposure history during decision making. Most (61% [196/322]) also reported acceptance of the linear no-threshold model. Fewer (25% [79/322]) rejected the linear no-threshold model; 15% (47/322) could not judge. Among radiologists reporting linear no-threshold model acceptance or rejection, the minority (36% [98/275]) made decisions that were consistent with their linear no-threshold model beliefs. This finding was not statistically different across institutions ($p = 0.070$) or training levels ($p = 0.183$). Few radiologists (4% [13/322]) had an accurate understanding of linear no-threshold model implications.

CONCLUSION. Most radiologists, when faced with patient exposure histories, make decisions that contradict their self-reported acceptance of the linear no-threshold model and the linear no-threshold model itself. These findings underscore a need for educational initiatives.

Advances in dose-capturing technologies and electronic medical record systems will soon afford physicians real-time knowledge of patients' radiation exposure histories [1–4]. From a quality assurance standpoint, these data will have clear benefits, enabling institutions to identify protocol violations, investigate high cumulative exposure levels, and track adherence to national benchmarks [5–7]. However, in everyday clinical practice—when trying to decide whether to order an imaging test—how should a physician use this information? Although several authorities and organizations have commented on the value of exposure histories for patient-centered imaging decisions, there are no guidelines that define how to use this information [8–10].

In theory, a physician's use of a patient's exposure history should depend on his or her acceptance of the linear no-threshold model, a commonly proposed explanation of the relationship between radiation exposure and cancer risk [6, 7, 11]. The linear no-threshold model, which is endorsed by the National Academy of Sciences' Biologic Effects of Ionizing Radiation (BEIR) committee (a decision informed by the outcomes of a large Japanese atomic bomb survivor cohort) [12], asserts that this relationship is at all times linear and that there is no threshold below which this linearity is violated. Although the linear no-threshold model represents the most widely accepted model for projecting radiation-induced cancer risks from low levels of ionizing radiation, its direct translation to medical radiation exposure is commonly questioned because of clear differences in exposure conditions [12–15].

An undeniable, although counterintuitive, mathematic implication of the linear no-threshold model when applied to cumulative exposures is that previously incurred risks should never factor into prospective imaging decisions [6, 7, 11]. According to the linear no-threshold model, a new exposure (e.g., CT) confers the same risk whether or not a patient has experienced prior exposures [6, 7]. Put another way, for a given patient, there is no threshold beyond which a disproportionate increase in cancer risk will occur with an additional radiation exposure. Therefore, when a physician considers ordering a CT for a patient with an exposure history, the physician's risk-benefit analysis should include only risks from the CT under consideration; previously incurred risks cannot be mitigated and should not affect decision making. In contrast, a physician who does ~~not~~ accept the linear no-threshold model may weigh risks from a patient's exposure history when considering a new CT study, under the assumption that past exposures may influence the patient's future radiation-induced cancer risks. However, there is no evidence to suggest the extent to which prior exposures should be considered.

Given the complexity, and counterintuitive nature, of these concepts, referring physicians may turn to the radiology community for guidance. However, these concepts may not be well understood by many radiologists. To evaluate radiologists' knowledge base and beliefs in this area, we conducted a multicenter survey study at three large academic centers. We used a hypothetical clinical scenario to evaluate whether radiologists incorporate risks from exposure histories into prospective imaging decisions, make decisions that are consistent with their self-reported acceptance (or rejection) of the linear no-threshold model, and understand linear no-threshold model implications in this setting. Our purpose was to evaluate the influence of patient radiation exposure histories on radiologists' imaging decisions.

Materials and Methods

Institutional Review Board and HIPAA Compliance

Institutional review board exemptions were obtained before initiating the study at each participating center. This study was conducted in compliance with HIPAA.

Overview of the Study: Operations, Recruitment, and Eligibility

We conducted a web-based survey study at three large academic medical centers, located within three separate cities in the Eastern and Northwestern regions of the United States, from April through June 2012. Survey questions were programmed into LimeSurvey, an open-source survey tool with data storage capabilities behind the coordinating center's institutional firewall. All radiologists (residents, fellows, and attending physicians) at each center were sent a recruitment e-mail describing the study. It was specified that, to be eligible, a physician must be clinically active. Within each e-mail, a unique link was provided that directed physicians to the survey; once the survey was completed, the link was deactivated. To minimize potential effects of intrainstitutional discussions (triggered by our study) on our results, the survey study was open for 1 week only at each medical center. Modest remuneration was provided; fifteen $20 coffee cards were raffled to participating radiologists at each institution.

Survey Development, Design, and Items

The survey instrument was developed and piloted for approximately 1 month among topical and methodologic experts, including clinical radiologists, researchers in public health and patient outcomes, and a dedicated survey science investigator. The instrument consisted of a patient vignette followed by four multiple-choice questions related to radiation-induced cancer risks. A final question allowed respondents to indicate their training level (e.g., resident, fellow, or attending physician). The full instrument is included in Appendix 1. An overview of the survey is provided below.

Patient Vignette

The survey began with the following vignette: "A PCP (Primary Care Provider) calls you, a radiologist, to discuss imaging options for a patient that he recently saw in clinic. The patient is a 35-year-old man with non-specific abdominal pain.

"After discussing the nature of the patient's pain and presentation, and after weighing the risks and benefits of all possible imaging options, you recommend a standard abdominopelvic CT. You determine that in this patient's case, its net benefit is likely to be superior—albeit only slightly—to all other imaging options.

"As you are about to hang up, the PCP remembers some additional information. He states that the patient has had 15 prior CT studies, totaling 150 mSv. These took place after a car accident 10 years ago. Initial scans were performed routinely as part of a trauma protocol—no abdominal injuries were detected, and the patient did not undergo surgery. Subsequent scanning was for follow-up of incidental findings, all benign. You and the PCP agree that the patient's accident and incidental findings are not related to his current abdominal pain.

"The PCP asks for your final recommendation, in light of the patient's prior radiation exposure history."

Questions 1 and 2: Did the Patient's Exposure History Influence Decision Making?

The goal of the first two questions was to identify the respondent's specific management choice and to determine whether the patient's exposure history played a role in the decision. In question 1, the respondent was asked to indicate, among several options, their final recommendation to the primary care physician. These included a standard abdominopelvic CT (e.g., adherence to the original recommendation) or one of four alternatives: outpatient clinical follow-up alone, ultrasound, radiograph, or reduced-dose CT. Hereafter, we collectively refer to these alternatives as "reduced-dose" strategies.

Question 2 allowed determination of whether the patient's exposure history was relevant to the respondent's decision. This approach was necessary because it was possible that a respondent who thought that a patient's exposure history should be factored into the decision might continue to recommend a standard abdominopelvic CT, deciding that its benefit outweighed the combined risk of current and prior CT studies. Conversely, a respondent who selected a reduced-dose strategy may have done so for reasons that did not pertain to the patient's exposure history; they may have thought that under no circumstances was a standard abdominopelvic CT warranted for the scenario described. Accordingly, for question 2, respondents were triaged to one of two survey items (Appendix 1, questions 2A and 2B), depending on their response to question 1. Both required respondents to indicate the rationale for their final recommendation—in particular, whether the patient's exposure history played a role.

Question 3: Does the Respondent Accept and Use the Linear No-Threshold Model?

Question 3 determined whether the respondents thought that they accepted and used the linear no-threshold model in clinical practice. A brief description of the linear no-threshold model was provided. Respondents were then asked to indicate whether they accepted and used the linear no-threshold model in clinical practice, or whether they did not, instead operating on the basis of the possibility that the model may be incorrect. Respondents could alternatively indicate that they could not make a judgment, because of inadequate familiarity with the model.

Question 4: Does the Respondent Understand Linear No-Threshold Implications in This Setting?

Question 4 determined whether respondents had an accurate understanding of linear no-threshold model implications when applied to settings of multiple prior exposures. Respondents were asked to indicate whether the linear no-threshold model

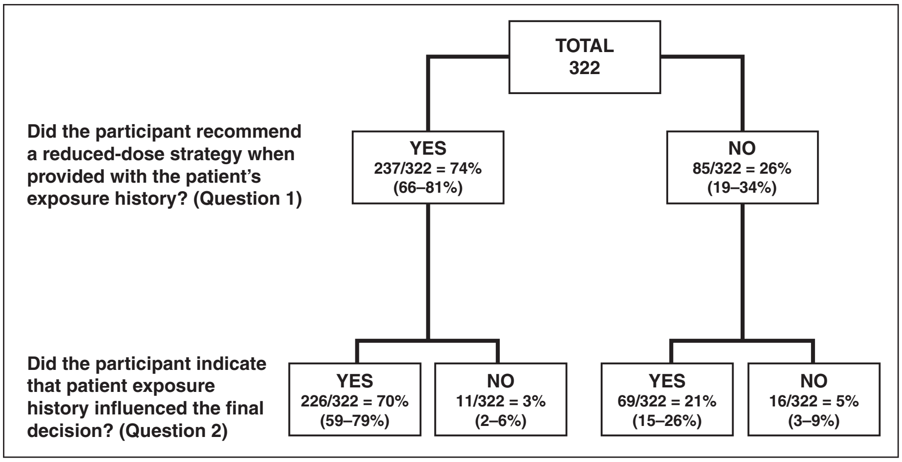

Fig. 1—Influence of patient exposure history on radiologist decision making. Responses to questions 1 and 2 of survey are presented, including proportion of multicenter radiologists who recommended reduced-dose strategy (outpatient clinical follow-up alone, or ultrasound, radiograph, or reduced-dose CT options), as opposed to standard abdominopelvic CT (question 1), and, for each resulting group, proportion who incorporated cancer risks from prior imaging during decision making (question 2). Most radiologists (92% [295/322]) incorporated risks from patient's exposure history during decision making (institutional range, 85% [99/116] to 96% [110/115]). Percentages in parentheses in each box are ranges of three individual participating institutions.

implied that cancer risks from past exposures should, or should not, be used in prospective imaging decisions; alternatively, respondents could indicate that the model made no related implications.

Statistical Analyses

Analyses for core study questions—For questions 1 and 2, we computed proportions of respondents who recommended a reduced-dose strategy and who indicated use of the patient's exposure history during decision-making, respectively.

For questions 2 and 3, we computed the proportion of respondents whose decision making was consistent with their self-reported acceptance (or rejection) of the linear no-threshold model. Respondents who reported linear no-threshold model acceptance were required to disregard risks from the patient's exposure history to be counted as operating consistently with their linear no-threshold model beliefs. If they incorporated prior risks, their decision-making process was considered inconsistent. Respondents who did not incorporate previously incurred risks were designated as operating consistently regardless of whether they accepted the linear no-threshold model, because the linear no-threshold model is not the only radiation-risk model that might lead a physician to disregard a patient's exposure history [14]. We also computed the proportion of respondents who were unable to judge their acceptance of the linear no-threshold model; these respondents were removed from the analysis of consistency.

For question 4, we computed the proportion of participants who understood linear no-threshold model implications in the setting of prior exposures (e.g., that physicians should not incorporate risks from prior exposures when making prospective imaging decisions).

Uncertainty and generalizability across centers—Analyses were performed including all sites and at single-institution levels. For core study questions, Fisher exact test was used to determine the statistical significance of institutional differences (using $\alpha = 0.05$ as the level of significance). If proportions were not found to be statistically different across centers ($p > 0.05$), then multicenter results were reported with 95% CIs. If proportions were different, multicenter results were reported with institutional ranges. For observed proportions that were unrelated to core study questions, multicenter results were also reported with institutional ranges.

Role of training level: resident, fellow, and attending physician—For each core study question, Fisher exact test was used to determine whether there was a difference in responses across training levels (again, using $\alpha = 0.05$ as the level of significance). Where appropriate, logistic regression analysis was used to determine whether institutional differences could be explained by differences in the proportions of residents, fellows, and attending physicians across centers.

Results

Study Group Response Rates and Characteristics

The survey was sent to a total of 578 radiologists (128 residents, 117 fellows, and 333 attending physicians); 57% (328/578) responded to at least one question. Per institution, response rates ranged from 52% (92/178) to 59% (120/202).

Responses were complete in 56% (322/578) of cases. The 322 respondents who completed the survey (86 residents, 60 fellows, and 176 attending physicians) constituted the multicenter study group. For each site, the training level distribution was 26% residents, 8% fellows, and 66% attending physicians (institutional total, 91); 34% residents, 18% fellows, and 48% attending physicians (institutional total, 116); and 20% residents, 28% fellows, and 52% attending physicians (institutional total, 115).

Influence of Patient Exposure History on Respondent Imaging Decisions

Did respondents preferentially recommend reduced-dose strategies?—Results are summarized in Figures 1 and 2. Overall, 74% of respondents (237/322) did not adhere to the original recommendation of a standard abdominopelvic CT when presented with the patient's exposure history and instead selected a reduced-dose strategy (institutional range, 66% [76/116] to 81% [74/91]) (Fig. 1). Among all reduced-dose strategies, ultrasound was the most frequently selected option (57% [136/237]; institutional range, 54% [40/74] to 62% [54/87]) (Fig. 2).

Trainees (residents and fellows) were more likely to adhere to the original imaging recommendation than were attending physicians (Fig. 2). Although 81% (142/176) of attending physicians selected one of the reduced-dose strategies, only 65% (95/146) of trainees did ($p = 0.002$). When controlling for training level using logistic regression analysis, there were no statistically significant institutional differences in the proportion of respondents recommending a reduced-dose strategy ($p = 0.077$). This finding indicated that institutional differences could be explained by differences in the proportions of residents, fellows, and attending physicians who completed surveys at each site.

Did respondents use the patient's exposure history for decision making?—In total, 92% of all respondents (295/322) indicated use of the patient's exposure history when making their final imaging recommendation. Notably, this group included respondents who both did (77% [226/295]) and did not (23% [69/295]) recommend a reduced-dose strategy when faced with the patient's exposure history (Fig. 1). Although this metric differed statistically across institutions ($p = 0.014$), proportions were high in all centers (institutional range, 85% [99/116] to 96% [110/115]). No differences could be detected across training levels ($p = 0.201$).

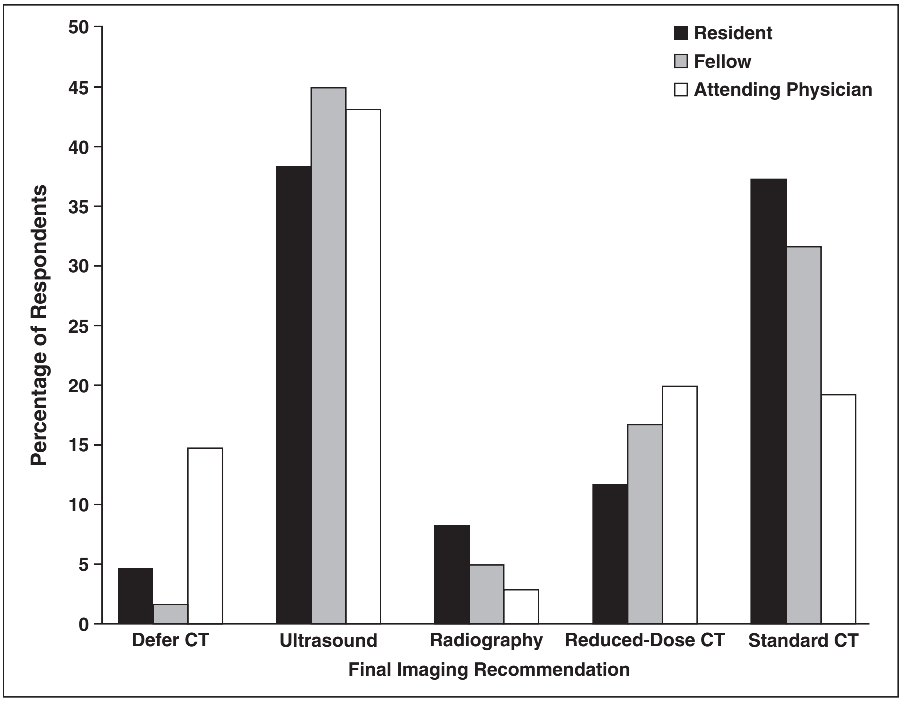

Fig. 2—Imaging recommendations for evaluation of abdominal pain in patient with substantial radiation exposure history. Graph presents multicenter responses to question 1 of survey, according to training level, in which radiologists' imaging recommendations were queried for patient with substantial exposure history. Ultrasound was favored option. Trainees (residents and fellows) were more likely to recommend standard abdominopelvic CT than were attending physicians ($p = 0.002$).

Interestingly, even among respondents who did not select a reduced-dose strategy, the majority still used the patient's exposure history to guide decision making (81% [69/85]; institutional range, 75% [30/40] to 89% [25/28]). These respondents indicated that, in the provided vignette, the benefits of a standard abdominopelvic CT would typically outweigh the combined risks of the prior CT scans and the scan under question.

Consistency Between Linear No-Threshold Model Beliefs and Imaging Recommendations

Did respondents indicate acceptance of the linear no-threshold model?—Results are included in Figure 3. In total, 61% of respondents (196/322; institutional range, 50% [57/115] to 71% [82/116]) reported acceptance and use of the linear no-threshold model in practice, whereas 25% (79/322; institutional range, 18% [16/91] to 37% [42/115]) reported rejection of the linear no-threshold model. A total of 15% of respondents (47/322; institutional range, 11% [13/116] to 20% [18/91]) could not judge whether they accepted the linear no-threshold model. Proportions of respondents in each category were statistically different across centers ($p = 0.002$) but not across training levels ($p = 0.118$).

Were respondents' linear no-threshold model beliefs consistent with their imaging decisions?—Among respondents who were able to judge their acceptance (or rejection) of the linear no-threshold model, only 36% (98/275; 95% CI, 30–42%) demonstrated decision making that was consistent with their linear no-threshold model beliefs. This proportion was not statistically different across centers ($p = 0.070$) or training levels ($p = 0.183$).

Notably, among the 92% of participants (295/322) who indicated use of the patient's exposure history during decision making, a substantial proportion (60% [177/295]) reported acceptance of the linear no-threshold model (Fig. 3). As described in Materials and Methods, their decision making and reported linear no-threshold model beliefs were considered inconsistent. Although this proportion was statistically significantly different across centers ($p = 0.008$), values were high in all centers (institutional range, 50% [55/110] to 71% [70/99]).

Demonstration of Accurate Understanding of the Linear No-Threshold Model

Results are included in Figure 4. Only 4% of multicenter respondents (13/322; 95% CI, 2–7%) correctly indicated that, according to the linear no-threshold model, physicians should not incorporate cancer risks from past radiation exposures when making prospective imaging decisions. The majority of respondents (69% [221/322]; 95% CI, 63–74%) incorrectly indicated that, according to the linear no-threshold model, physicians should incorporate previously incurred radiation-induced cancer risks. Relatively fewer (27% [88/322]; 95% CI, 23–33%) indicated that the linear no-threshold model makes no

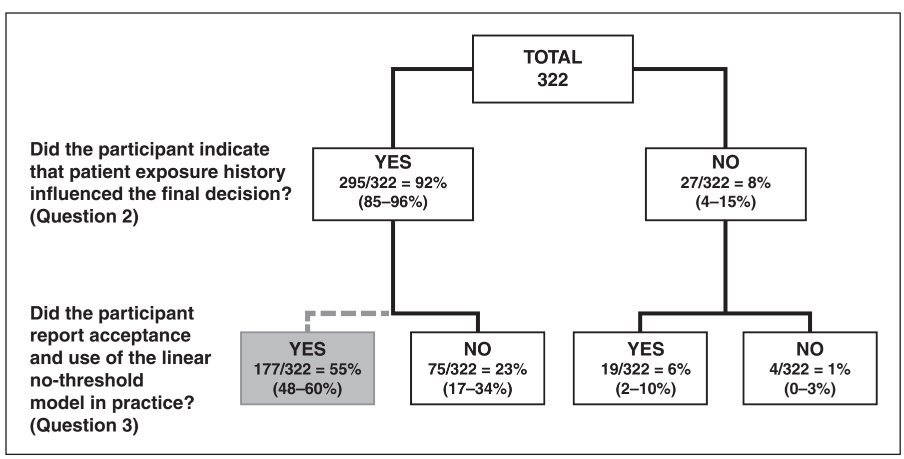

Fig. 3—Consistency between radiologists' decision making and self-reported acceptance (or rejection) of linear no-threshold model. "Consistent" respondents are designated by black boxes in second row of flowchart, whereas "inconsistent" respondents are designated by gray box. Among respondents (275/322) who were able to judge their acceptance or rejection of linear no-threshold model, minority demonstrated decision making that was consistent with their self-reported linear no-threshold model beliefs (36% [98/275]; 95% CI, 30–42%). This finding was not statistically different across centers or training levels. Percentage ranges in parentheses are institutional ranges. Note that 15% of respondents (47/322) could not judge linear no-threshold model acceptance or rejection (question 3). These respondents were removed from analysis of consistency and excluded from this flowchart.

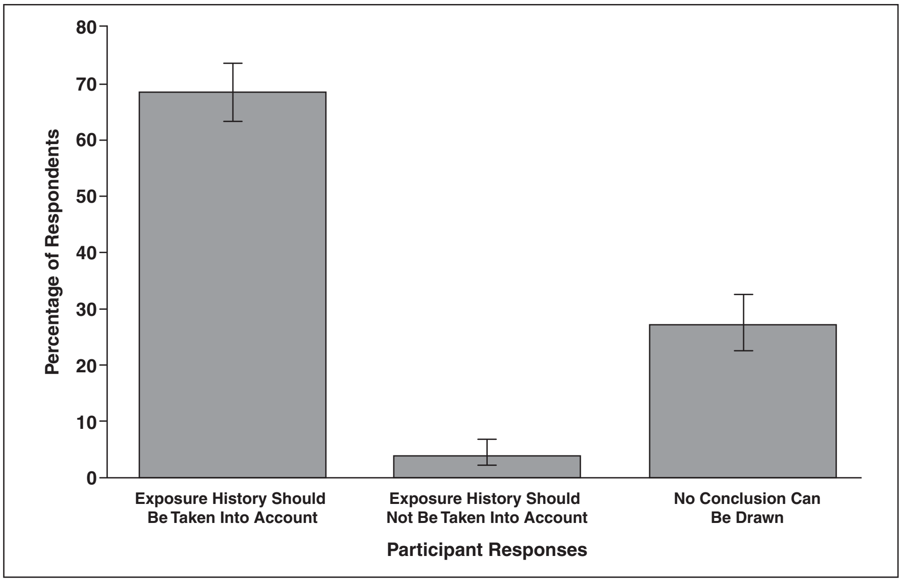

Fig. 4—Radiologists' understanding of linear no-threshold model implications in setting of multiple prior radiation exposures. Proportions of radiologist responses to question 4 are presented with corresponding 95% CIs (whiskers). Only 4% of multicenter respondents (13/322; 95% CI, 2–7%) correctly indicated that, according to linear no-threshold model, physicians should not incorporate risks from past radiation exposures when making prospective imaging decisions. Proportions of respondents in each category were not statistically different across centers or training levels.

implications in this setting. Proportions of respondents in each category were not statistically different across centers ($p = 0.054$) or training levels ($p = 0.964$).

Discussion

In this multicenter survey study, we found that when radiologists are asked to guide imaging decisions for patients with known radiation exposure histories—a scenario that will soon be commonplace—most incorporate previously incurred risks in their risk-benefit analysis, and most recommend a lower-dose imaging option. Although this approach is not consistent with the linear no-threshold model, most radiologists think that it is. Our results also suggest that a minority of radiologists are likely to pursue decision making that is consistent with their own acceptance (or rejection) of the linear no-threshold model. Even fewer have an accurate understanding of how the linear no-threshold model may be used to guide decision making in this setting. Key study results were not meaningfully different across institutions and are likely generalizable to other academic centers. Our findings raise concern that many radiologists have a limited understanding of how to address patient exposure histories when making prospective imaging decisions and underscore the need for related educational interventions. Our results also suggest that making individual patient exposure histories available to ordering physicians may lead to undesirable effects on decision making regarding the use of imaging.

In our analysis, we were not prescriptive about the "correct" radiation-risk model. Instead, radiologists were evaluated by the consistency between their decision making and self-reported linear no-threshold model beliefs. However, it may be argued that incorporating risks from prior imaging is also inconsistent with other commonly proposed alternative models [12, 14]. For example, the linear-threshold model suggests that individual exposures from diagnostic imaging may not incur any risk; however, the "no-risk" exposure threshold is unknown [12, 14]. A radiologist who supports this model must think either that individual imaging tests (e.g., a CT scan) impart no risk, in which case previous exposures are irrelevant, or that many imaging tests likely exceed a no-risk threshold and use a linear risk-exposure relationship for considering cumulative risks, in which case risks from past exposures should also not be considered, as in the case of the linear no-threshold model. The hormesis model similarly invokes a no-risk threshold [14]; if exposures from individual imaging tests are perceived as falling below this threshold, then previous exposures would similarly be irrelevant for prospective decision making.

A linear-quadratic risk-exposure model with an upward-sloping curve may, in theory, justify consideration of prior risks [14]. According to this model, patients with an exposure history would be at slightly higher risk from a subsequent CT study, as compared with previous CT studies [14]. In the BEIR VII report [11], the most widely used reference for radiation risk projection in diagnostic imaging, the BEIR VII investigators considered a linear-quadratic model for both leukemia and solid cancers, ultimately adopting the linear-quadratic model for leukemia only and a linear model for all solid cancers. Although the linear-quadratic model seems to match the intuitive bias toward incorporating prior risk, it is important to recognize that the curvature of the risk-exposure relationship is very slight at low levels of exposure (as would be encountered in diagnostic imaging), making this model very similar to the linear no-threshold model [11]. Although radiologists who favor use of the linear-quadratic model would be consistent in incorporating prior risks during decision making, in practice, such radiologists are faced with the operational challenge of judging the magnitude of curvature in the risk-exposure relationship, which defines the impact of cumulative doses, in the absence of clear evidence-driven benchmarks.

Although our study provides insight into the nature of radiologists' decision making, we did not investigate why respondents favored specific reduced-dose strategies or elected to incorporate prior risks into prospective imaging decisions. A "sunk-cost" bias has been put forth as a possible explanation for why physicians are likely to consider risks from prior imaging in this setting [7]. This bias refers to the human tendency to want to mitigate past events, even when they cannot be altered by future actions [16–18]. Although radiologists' decision making was consistent with the proposed sunk-cost theory (e.g., most selected a reduced-dose strategy when provided with the patient's exposure history), to assume that this bias is explanatory would be overly speculative given our study design. Further research aimed at uncovering the reasons for radiologists' decisions will ultimately optimize the quality of related educational efforts.

Our study has additional limitations that merit specific consideration. First, we used a hypothetic patient scenario. Ideally, radiologists' behaviors would be studied in the course of "real-time" patient care. However, such a study design was not practical or feasible for the research question at hand. Variability in patient circumstances would make it difficult, if not impossible, to determine whether observed differences in radiologists' responses were true or, instead, due to (confounded by) patient differences. An additional premise of our scenario was that a radiologist would be consulted for the imaging decision; however, referring physicians may make similar decisions without consulting a radiologist. Although further research is needed to investigate the decision-making processes of referring physicians in the absence of a radiologist's input, given that most have less training in radiation biology than radiologists, it is unlikely that they would have a superior knowledge base.

Second, a selection bias may have been present if radiologists who elected to respond were different in their use of patient exposure histories, compared with those who did not respond. However, a selection bias of this type is unlikely to have substantially influenced our results; our response rate was adequately high for a study of this type [19], and the magnitude of key findings was also high, diminishing the likelihood of meaningful differences between respondents and nonrespondents.

Third, our study focused on academic radiologists. Although the results may not be generalizable to private practice settings, given the likelihood that academic radiologists have greater exposure to educational opportunities regarding radiation-induced cancer risks, it is unlikely that radiologists in private practice would, on average, have a superior knowledge base. Regarding attending physicians surveyed, it is important to note that they were predominantly subspecialists. The vignette we used would be most familiar to attending physicians who practice abdominal imaging and least familiar to attending physicians whose practice excludes consideration of CT entirely. To address this potential concern, we designed the clinical vignette so that minimal subspecialty-specific knowledge was required. However, the preferential selection of ultrasound as a first-line reduced-dose strategy should be interpreted with caution, because many of the attending physicians who participated in this study may not routinely give advice on which reduced-dose strategy is optimal for the evaluation of abdominal pain.

Fourth, some respondent behaviors were not explicitly regulated in the current study. All radiologists (residents, fellows, and attending physicians) on clinical distribution lists at each center were sent a recruitment e-mail. Although recipients were instructed, in this e-mail, that to be eligible, they must be a clinically active resident, fellow, or attending physician, we did not independently verify the clinical activity of each respondent. In addition, despite the short (1-week) survey period within each center, respondents may have discussed survey items among themselves before submitting responses, or may have studied related literature, making our study less able to capture genuine real-time decision making. However, given the magnitude of key findings, both circumstances are unlikely to have meaningfully affected our results.

It must be emphasized that the knowledge that a patient has undergone prior imaging tests, and of their results, remains highly valuable to clinical decision making. For example, if a patient with nonspecific abdominal pain has undergone five negative abdominopelvic CT studies within a month, then the benefit of an additional CT must be questioned, because of the lower likelihood of finding correlative pathologic abnormalities on CT. In this scenario, although the cancer risk from the CT under consideration remains constant according to the linear no-threshold model, the same as for the other CT studies, the described change in benefit may mean that the risk-to-benefit ratio would not favor another CT.

In conclusion, when patient exposure histories become routinely available to referring physicians, radiologists may serve as a primary resource regarding their appropriate use. We found that, at present, most radiologists incorporate risks from past exposures to guide prospective imaging decisions and think that this practice is in keeping with linear no-threshold model implications. However, the linear no-threshold model implies that past risks should not be used in prospective decision making; in fact, most alternative radiation-risk models would suggest the same. If radiologists, as well as the general medical community, operate using the most common decision-making processes evident in our study, an inappropriate shift toward less-beneficial imaging tests may occur, creating the potential for substantial patient harms. It is critically important that educational interventions in this area become a priority now, before the widespread availability of patient-level exposure histories.

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APPENDIX 1: Survey Instrument

A PCP (Primary Care Provider) calls you, a radiologist, to discuss imaging options for a patient that he recently saw in clinic. The patient is a 35-year-old man with non-specific abdominal pain.

After discussing the nature of the patient's pain and presentation, and after weighing the risks and benefits of all possible imaging options, you recommend a standard abdominopelvic CT. You determine that in this patient's case, its net benefit is likely to be superior—albeit only slightly—to all other imaging options.

As you are about to hang up, the PCP remembers some additional information. He states that the patient has had 15 prior CT scans, totaling 150 mSv. These took place after a car accident 10 years ago. Initial scans were performed routinely as part of a trauma protocol—no abdominal injuries were detected, and the patient did not undergo surgery. Subsequent scanning was for follow-up of incidental findings, all benign. You and the PCP agree that the patient's accident and incidental findings are not related to his current abdominal pain.

The PCP asks for your final recommendation, in light of the patient's prior radiation exposure history.

1. Which of the below options comes closest to your final recommendation?
   A. Defer CT, and instead pursue close outpatient follow-up.
   B. Obtain an ultrasound first, and triage to abdominopelvic CT as necessary.
   C. Obtain a plain film (KUB) first, and triage to abdominopelvic CT as necessary.
   D. Obtain an abdominopelvic CT scan at a reduced radiation dose.
   E. Obtain a standard abdominopelvic CT scan.

2A. [Issued only to participants who responded "A–D" to question 1.]
   The PCP thanks you for your recommendation. He asks you, for future reference, at what threshold you begin to consider prior radiation exposures in your decision-making process.
   Which of the below options would best represent your response?*
   A. > 50 mSv of prior radiation exposure.
   B. > 100 mSv of prior radiation exposure.
   C. > 150 mSv of prior radiation exposure.
   D. I do not use a specific threshold. In my decision-making process, I weigh the combined risks—from the current imaging study under consideration, and from prior exposures—against the current study's benefit.
   E. The basis for my final recommendation did not pertain to the patient's prior exposure history.
   *For the purposes of our analysis, responses A–D indicated use of risks from the patient's exposure history during decision making, whereas response E did not.

2B. [Issued only to participants who responded "E" to Question 1.]
   The PCP thanks you for your recommendation. He asks why you did not change your recommendation in light of the patient's radiation exposure history.
   Which option best explains why your final recommendation was for a standard abdominopelvic CT?
   A. I think that in the clinical setting of abdominal pain, the benefits of a standard abdominopelvic CT would typically outweigh the combined risks of the prior CT scans and the current scan in question.
   B. I do not think that risks from past radiation exposures should factor into prospective imaging decisions, so my recommendation did not change with knowledge of the patient's exposure history.

3. The Linear No-Threshold Model is the most widely accepted model in radiology explaining the relationship between radiation exposure and cancer risk. This model, which is based on the outcomes of Japanese atomic bomb survivors, asserts that radiation exposure and cancer risk are linearly related and that there is no threshold below which this relationship becomes nonlinear.
   Which of the below statements is closest to what you believe?
   A. I accept the Linear No-Threshold Model—I use it when considering the relationship between radiation exposure and cancer risk in my clinical practice.
   B. I do not accept the Linear No-Threshold Model—I believe that the relationship between radiation exposure and cancer risk may be nonlinear and I operate based on this possibility in my clinical practice.
   C. I am not adequately familiar with the Linear No-Threshold Model to judge whether I accept or use it.

(Appendix 1 continues on next page)

APPENDIX 1: Survey Instrument (continued)

4. Which of the below statements is closest to what you believe?
   - A. The Linear No-Threshold Model implies that physicians should incorporate risks from patients' past radiation exposures when making future imaging decisions.
   - B. The Linear No-Threshold Model implies that physicians should not incorporate risks from patients' past radiation exposures when making future imaging decisions.
   - C. No conclusions can be drawn, from the Linear No-Threshold Model, regarding how physicians should use risks from patients' prior radiation exposures when making future imaging decisions.
5. Please select the category that best characterizes you.*
   - A. Resident.
   - B. Fellow.
   - C. Attending (< 5 years since completion of training).
   - D. Attending (5–10 years since completion of training).
   - E. Attending (> 10 years since completion of training).

   *Responses C–E were collapsed into a single "attending" category for analysis.

FOR YOUR INFORMATION

This article has been selected for *AJR* Journal Club activity. The accompanying Journal Club study guide can be found on the following page.

Study Guide

How Radiation Exposure Histories Influence Physician Imaging Decisions: A Multicenter Radiologist Survey Study

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Introduction

1. Is the topic timely and relevant? Do the authors implicitly or explicitly state their hypothesis? How would you state the null hypothesis? How would you state the alternative hypothesis?
2. What is the linear no-threshold (LNT) model?

Methods

3. What were the inclusion criteria for the survey? What were the exclusion criteria?
4. Why did the authors remove the respondents who were unable to judge their acceptance of the LNT model from the analysis?
5. What are the limitations of this study? How do the authors address these limitations?
6. What does the Fisher exact test measure? Why did the authors perform logistic analysis?

Results

7. Did the authors answer their question?
8. Did the authors detect a difference in the respondents' use of the patient's exposure history for decision making based on training level?
9. Was there any statistical difference across centers or training levels of respondents who were inconsistent between their decision making and self-reported acceptance of the LNT model?

Physics

10. Besides the LNT model, what are other models for assessing the biologic effects of radiation? Briefly describe those models.

Discussion

11. Does your institution or practice track patient radiation dose histories?
12. Do you consider a patient's previous radiation exposure when recommending a particular study?
13. Is the study generalizable to your practice or institution?

Background Reading

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*Please note that the authors of the Study Guide are distinct from those of the companion article.