Clinician perspectives on considering radiation exposure to patients when ordering imaging tests: a qualitative study

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ABSTRACT

Background and objectives Increased computer tomography (CT) scan use has contributed to a rise in medically-associated radiation exposure. The extent to which clinicians consider radiation exposure when ordering imaging tests is unknown. We examined (1) outpatient clinician attitudes towards considering radiation exposure when ordering CT scans; and (2) clinician reactions to displaying radiation exposure information for CT scans at clinician electronic order entry.

Methods We conducted nine focus groups with primary care clinicians and subspecialty physicians (nephrology, pulmonary and neurology) (n=50) who deliver outpatient care across 12 hospital-based clinics and community health centres in an urban safety-net health system, which use a common electronic order entry system. We analysed focus group transcripts using an inductive framework to identify emergent themes and illustrative quotations.

Findings Clinicians felt they had limited knowledge of the clinical implications of radiation exposure. Many believed clinically relevant information such as the increased risk of malignancy from CT scans would be useful to inform decision-making and patient–clinician discussions. Clinicians noted that patient vulnerability and long wait times for tests with less radiation exposure (such as MRI or ultrasound) often acted as barriers to minimise patient radiation exposure from CT scans. Clinicians suggested providing patients' cumulative radiation exposure or formal decision aids to improve the usefulness of the radiation exposure information.

Conclusions Displaying clinically relevant radiation exposure information at order entry may improve clinician knowledge and inform patient–clinician discussions regarding risks and benefits of imaging. However, limited access to tests with lower radiation exposure in safety-net settings may trump efforts to minimise patient radiation exposure.

BACKGROUND

The use of diagnostic imaging tests has increased dramatically over the past 15 years,[1–3] resulting in a significant rise in patients' radiation exposure. Some of these imaging tests are thought to be medically unnecessary.[4–8] Of particular concern is the increase in the use of CT scans due to the high radiation exposure associated with many of these tests. The use of these tests doubled in the USA between 1997 and 2006.[9] One study estimated that 29 000 future cases of cancer could be related to CT scans performed on patients in the USA in 2007 alone.[10] The Image Gently campaign has targeted paediatricians' awareness of radiation exposure from CT scans to improve paediatric patient safety.[11 12] There remains a lack of awareness of the specific cancer risks associated with CT scans among referring physicians for adult patients[13–15] who are rarely informed of these risks.[13 14]

It is important for hospitals and health systems to understand how to deliver this information to physicians who provide care to adults now that data on the cancer risk associated with CT scans is more available.[16] Studies have examined how educational interventions focusing on radiation exposure from imaging tests impact physician imaging ordering practices.[17 18] Yet research is lacking on how best to design interventions to provide

useful information to clinicians and potentially improve the appropriateness of imaging tests ordered. As clinicians' practice patterns often vary by practice setting,[19–21] clinician specialty[22 23] and patient population served,[20 24] interventions to improve clinicians' awareness of radiation exposure and appropriateness of imaging ordering practices should consider the context in which clinicians practice.

San Francisco General Hospital, an urban public hospital affiliated with the University of California San Francisco, decided to display radiation exposure information at clinician electronic order entry to raise awareness about radiation exposure among outpatient clinicians ordering imaging tests. To better understand how patients' radiation exposure affects clinicians' imaging ordering practices, we conducted a qualitative study using focus groups of clinicians practising in outpatient clinics in this urban health system. Qualitative research is a useful methodology to explore complex, rapidly changing phenomena in-depth.[25] We assessed clinician beliefs, attitudes and practices regarding the consideration of radiation exposure information when ordering diagnostic imaging tests, and sought recommendations regarding how best to present this information to clinicians to inform clinical decision-making and patient–clinician discussions regarding radiation exposure.

METHODS

We conducted focus groups with primary care clinicians and subspecialty physicians who deliver patient care in San Francisco General Hospital's hospital-based outpatient clinics and associated community health centres. This study was approved by the Institutional Review Board at the University of California, San Francisco.

Setting and context

This study occurred in an urban health system in San Francisco, which includes a large public hospital with comprehensive ambulatory specialty care and four hospital-based primary care clinics and more than 20 free-standing primary care clinics. These clinics all use the same electronic order entry system for outpatient diagnostic tests and subspecialty referrals performed at San Francisco General Hospital.

Eligibility and recruitment

Participant eligibility was determined by the following criteria: (1) clinicians who deliver outpatient clinical care in the public hospital-based clinics or the associated network of primary care clinics in San Francisco; and (2) clinicians who order diagnostic imaging tests for patients through the electronic order entry system. Primary care clinicians included physicians, nurse practitioners and physician assistants. Subspecialty physicians included neurologists, nephrologists and pulmonologists, as these specialties frequently order diagnostic imaging tests. Clinicians-in-training (such as medical students and residents) were excluded. We sampled geographically diverse primary care clinics in San Francisco to maximise the heterogeneity of the sample population with regard to clinical practice setting and patient population. Invitations to participate in the focus groups were sent via email to individual clinicians and the medical directors of clinics; follow-up emails were sent to non-respondents 2 weeks after the initial emails were sent. Clinician email addresses were available through the health system clinician directory and informed consent was obtained from all participants prior to each focus group. Primary care clinicians and subspecialty physicians were interviewed in separate groups to encourage frank discussion as homogenous groups are recommended when discussing complex topics.[26] Focus groups were led in locations at the convenience of the participants, and were kept confidential. Each focus group lasted approximately 30–60 min, and breakfast or lunch was provided during each session to incentivise participation.

Data collection

Two researchers (LEG, JFK) trained in qualitative research methods conducted all focus groups using a semi-structured focus group guide. The guide was developed based on a literature review of clinician knowledge of radiation exposure from imaging tests, and informed by the Theory of Planned Behaviour, which posits that physicians' attitudes, beliefs, perceived behavioural control and social norms influence their behaviour.[27] The focus group guide was developed by a multidisciplinary team including a primary care physician, a master's level public health researcher and a qualitative research expert with a doctorate in psychology. The questions focused on clinicians' beliefs, attitudes and practices towards incorporating radiation exposure information in clinical decision-making when deciding whether to order diagnostic imaging tests, how these were affected by the practice setting in which they worked, and suggestions for the presentation and content of radiation exposure information for imaging tests if it were posted at the point of clinician electronic order entry (see the focus group guide in the online supplementary appendix). All focus groups were audio-recorded and transcribed. We initially planned to conduct six focus groups; through the iterative process of thematic analysis, the research team concluded that we reached thematic saturation[28] after conducting nine focus groups.

Data analysis

While our interview guide was informed by the Theory of Planned Behaviour, including questions that reflected various domains, we used an inductive framework to identify emergent themes from the focus group transcripts.[29] We selected this qualitative

approach to analyse our data as our goal was to understand key themes that emerged from the data, not to determine explicitly whether this model was appropriate for this circumstance. Two researchers (JFK, LEG) independently coded each transcript using Atlas.ti software[30] and compared the coded transcripts to establish consensus and develop a coding structure. A third researcher (AS) compared the coded transcripts independently to verify consensus among the coders. We then merged similar codes and eliminated duplicate codes. Next we grouped codes into major themes and identified relationships between the emergent themes. The coding structure and themes were presented to a multidisciplinary group of researchers and clinicians to test the clarity of our resulting thematic coding structure and clarify any remaining ambiguity.

RESULTS

Of 221 invited clinicians, 50 (23%) participated in one of nine focus group sessions (3–9 participants per focus group). Primary care clinicians who practised clinical patient care across nine primary care clinics participated in six of the focus groups. Subspecialty physicians in the nephrology, neurology and pulmonary departments of the public hospital-based outpatient clinics participated in the other three focus groups. Half of the clinicians who participated were female, and 38 (76%) of the participants were physicians (table 1). Among participants, 28 (56%) were primary care clinicians, 20% practised neurology and 12% represented each of the nephrology and pulmonary subspecialties. We identified several salient themes described below.

Provision of radiation exposure information would be useful to improve clinician knowledge, and inform clinical decision-making and patient–clinician discussions

Clinicians primarily identified three uses for the radiation exposure information: to improve clinician knowledge, inform clinical decision-making, and inform patient–clinician discussions about clinical care (table 2). Clinicians expressed awareness of radiation risks associated with CT scans, but were uncomfortable with their current knowledge of the clinical risk (ie, increase in cancer risk) associated with any given imaging test such as abdominal CT or high resolution chest CT. Most clinicians reported general knowledge that CT scans are associated with more radiation exposure compared to other imaging tests, but many expressed a desire for more updated and clinically relevant radiation exposure information.

> Sometimes I need some information. There are so many studies...I really want to know what are those [imaging tests] that can cause harm…Then you can talk to the patient more surely. (Primary care nurse practitioner, primary care focus group #5)

Clinicians felt that having available detailed radiation exposure information for specific tests would inform clinical decision-making. Clinicians reported that the radiation exposure information would be most useful for clinical decision-making in clinically ambiguous scenarios where one diagnostic imaging test is not clearly indicated by evidence-based guidelines.

> We are starting to have conversations about how much radiation [patients are exposed to]. Just getting a CT because it's the easiest thing to do to feel more secure [in clinically ambiguous cases to]—'is that really the best thing to do for the patient?' (Primary care physician, primary care focus group #3)

Clinicians also believed the radiation exposure information could improve patient–clinician discussions about the risks and benefits of diagnostic imaging, particularly in situations where patients are asking for specific imaging tests that are not clinically indicated.

> I am thinking of a couple of [patients] that are very focused on insisting on tests and I think that having some [radiation exposure] information to just give them the balance of what the risk is [of these imaging tests]…is a good thing. (Primary care physician, primary care focus group #2)

Table 1 Characteristics of focus group participants (N=50)

Characteristic	N (%)
Gender	
Male	25 (50)
Female	25 (50)
Clinical level	
Physician	38 (76)
Nurse practitioner	11 (22)
Physician assistant	1 (2)
Specialty	
Primary care	28 (56)
Nephrology	6 (12)
Neurology	10 (20)
Pulmonary	6 (12)

Patient population influences clinician attitudes towards radiation exposure and imaging ordering practices

Clinicians reported that patient characteristics influenced their imaging ordering in several ways, and three subthemes emerged within this topic. First, clinicians expressed that radiation exposure risk from imaging tests becomes a lower priority in clinical decision-making depending on patients' clinical risk for poor outcomes. Clinicians that served a predominately homeless patient population reported that they were often more concerned with immediate diagnosis and treatment of these patients rather than long-term risks of radiation exposure. For these patients who

Table 2 Reported uses for radiation exposure information in clinical care

Theme	Illustrative quote
Improve clinician knowledge	
Current specific knowledge about radiation exposure from imaging is lacking	"[My current understanding of radiation exposure] is fuzzy right now. People want to know about [radiation exposure from imaging tests] and even providers have difficulty putting a perspective. So [displaying] all the …radiation [exposure information] that's easy to visualize and explain…is a very positive thing."
Inform clinical decision-making regarding imaging study ordering	
Individualise patient care decisions	"My feeling is that radiation is individual patient risk benefit. It's something that I think I would like to personally consider more carefully."
Clinical scenarios where more than one imaging test is recommended in clinical guidelines	"Maybe 10% of the time if I'm really trying to decide between …an ultrasound and a CT [scan]. Having [the radiation exposure information] there would be like, 'Oh, yes. Okay. The ultrasound is probably better as long as I think that it would be equal and… [would] remind me that that's okay'."
Clinically ambiguous cases	"If I was kind of on the fence …, we sometimes order things for our reassurance so we can sleep at night. 'See, nothing's wrong.' So I think [the radiation exposure information] would make me more conscious not to do that."
Inform patient–provider discussions about clinical care	
Inform discussions with patients regarding requests for clinically not indicated tests	"It would be helpful to be versed, which is if somebody is asking for CT or x-ray, and I know they don't need it…. If the amount of radiation information or the causes there, then I can …say, 'Hey, I really don't think you need this CT. But if you get it, you're going to expose yourself to x number of radiation exposure'."
	"I have a couple of patients who have lung cancer and they have CT scans of their chest annually for five years …They need to understand that there are benefits and risks associated with that and this would be useful information for them."

typically had higher rates of trauma and less regular contact with healthcare providers, clinicians were more likely to order imaging tests without considering radiation exposure.

> With my homeless outreach primary care patients, these are people who haven't had primary care and I'm not as worried about [radiation exposure] because I'm usually thinking of a pretty bad outcome. I want to get them their [imaging study] as soon as possible. (Primary care physician, primary care focus group #1)

Clinicians were particularly concerned about radiation exposure in patients who have received multiple CT scans in a short time period and patients without continuity of care, as they worried that these patients had multiple scans at different hospitals which they were unable to track. Clinicians noted that they tried to minimise imaging ordering among these patients.

> I can count maybe five people that I know that—God knows what we're creating in them because of all the scans that have been done at [different hospitals] depending on where they've ended up and it's just sort of mind boggling. (Primary care physician, primary care focus group #2)

Overall, while clinicians reported that patients often insisted on getting specific imaging tests, the concern about radiation exposure for their patients was mostly their own. They noted that patients rarely raised concerns about radiation exposure from imaging tests.

> I've never been asked [by patients about the radiation exposure from imaging tests]. [Patients] just want the [imaging] tests. (Primary care nurse practitioner, primary care focus group #6)

Clinicians were also concerned about how to use the radiation exposure information with their low literacy patient populations, and the potential risks with inadequate patient communication. Clinicians believed that many of their patients had fairly low health literacy, and perceived these patients may have difficulty understanding discussions about the risks of radiation exposure. They anticipated that it may take additional time to inform their low health literacy patients about the risks of radiation exposure, and expressed concern about the perceived difficulty of engaging patients in meaningful and informed discussions about radiation exposure from imaging tests with short appointment times in a resource-constrained setting.

> Well, I think a lot of patients we see don't process numbers and statistics...'I definitely don't want this test because it's going to increase my cancer' kind of thing. So it might take a lot of time explaining the value. (Primary care physician, primary care focus group #2)

Clinicians also worried that discussions with patients about the risks of radiation exposure from imaging might deter patients from getting tests they actually need.

> Using the word cancer perhaps in a community where just general medical information [and] general education background are a little bit lower than other parts of San Francisco could dissuade someone from being willing to do a particular study…That's the art of…

the conversations that we have with our patients in a low literate community where English is not a primary language. Those words could potentially scare people. (Primary care physician, primary care focus group #6)

Working in a resource limited practice setting influenced clinician attitudes towards radiation exposure and imaging ordering practices

Clinicians reported that setting-specific factors made it particularly challenging to prioritise radiation exposure information in clinical care, specifically related to the availability of resources. Clinicians' awareness of existing resource limitations and long wait times for particular imaging tests in this urban safety-net health system influenced their decision to order certain tests. For example, in instances when either CT scans or ultrasounds were recommended by clinical guidelines, clinicians reported ordering the test with shorter wait times regardless of radiation exposure.

Access to certain types of radiological services sometimes will guide which imaging [test] we choose to order. If a waiting time for a particular diagnostic study is several months and [a CT scan] I can get within a couple of weeks, I might be more inclined to order that CT scan if it's indicated. (Primary care physician, primary care focus group #6)

Frequently, wait times or resource availability did not allow for clinicians to opt for ordering imaging tests with less radiation.

I see the patients with mild traumatic brain injury and you say, 'I don't want a CT, I want an MRI', but you need a scan and can't get the MRI scan within the time frame that we need to evaluate the case. (Neurologist, neurology focus group #7)

Moreover, many clinicians believed that their diagnostic imaging ordering was already limited to clinically necessary tests as a result of resource limitations. Most clinicians had the perception that they followed clinical guidelines when available when ordering diagnostic imaging tests.

In my clinic, the providers are pretty good about not ordering extra tests and [having] conversation[s] with patients about their thought processes about what they're ordering and why they're not ordering that test that the patient wants to get ordered. (Primary care physician, primary care focus group #3)

Suggestions for increasing radiation exposure awareness among clinicians

While clinicians wanted access to updated radiation exposure information from imaging tests, they were concerned about the usefulness of displaying this information at the site of clinician order entry. Clinicians perceived that time constraints, due to short visits with complex patients and a large volume of information on the electronic order entry site, precluded them from realistically using this information in clinical decision-making on a daily basis.

There is a [large] volume of information [in the electronic order entry system]. I've got to get this study ordered and I need to get on to my next overbooked patient. I don't spend a lot of time reading the flags. (Pulmonologist, pulmonary focus group #9)

Furthermore, clinicians stated that they would need very specific radiation exposure information to sufficiently inform most cases of clinical decision-making.

Clinicians discussed several additional tools that they believed would make it easier for them to incorporate radiation exposure information in clinical decision-making (table 3). Clinicians cited that cumulative radiation exposure for each patient would be the most useful tool to minimise patients' radiation exposure, rather than the provision of general radiation exposure information for individual imaging tests.

If there were a way [for each patient's] cumulative radiation exposure to come up [on the ordering screen] when you're ordering these [imaging tests], that would be very helpful. (Primary care physician, primary care focus group #1)

Clinicians believed that formal clinical decision support that incorporated radiation information would help to make the information more useful in individual patient care decisions. Clinicians suggested that the provision of a literacy appropriate patient education tool and clinician guidance to facilitate patient–clinician conversations might mitigate the challenges clinicians anticipated in discussing the risks and benefits of imaging tests with their patients.

Hyperlinks with patient education handouts on radiation exposure in English and Spanish…inserted on the [ordering screen would be helpful]. (Primary care clinician, primary care focus group #6)

DISCUSSION

In this qualitative study of primary care clinicians and subspecialists, we found that most clinicians would welcome radiation exposure information related to diagnostic imaging tests to inform patient–clinician discussions and clinical scenarios where there could be multiple approaches to imaging. Whether an intervention at the point of clinician order entry is the best strategy is less clear. The provision of information about the cancer risk associated with specific imaging tests and patient-specific information would increase the usefulness of such information to clinicians, as would the development of clinical decision aids and support tools to guide clinicians' and patients' decision-making.

This is the first study to explore how clinicians who provide adult outpatient care view the significance of radiation exposure from advanced medical imaging,

Table 3 Suggestions to make radiation exposure information more useful in clinical practice

Theme	Illustrative quote
Provide test characteristics for each imaging test	"…it would just be nice to insert in a conversation with the patient…to be able to say here's the likelihood we'll find something and here's the quantifiable amount of radiation in this study."
Add clinical indications	" [Providers are] just going to still order [the imaging test] despite the…radiation exposure, but if they find out there are these other options and this one [has] less radiation for the patients, they may go with that one."
Provide cumulative radiation exposure for each patient and by body part	"What I would love would be if patients' cumulative exposure…got tracked. If you are talking [about] serial CTs for someone with a malignant brain tumour, okay, [but] if you're talking about another imaging study on someone who has had dozens of imaging studies all of which are negative, that is a well person… [Providers might]…say, 'What am I doing?'"
	"I pretty much never look at the CT abdomen [at] Chest Clinic—I think pulling together the necessary studies that our patients are getting would be helpful [for] outpatient, inpatient, and ER [clinicians]."
	"I have no idea if they've had their abdomen scanned 50 times within the last year when I make the decision to order my CT chest."
Develop more clinical guidelines related to imaging tests	"One of the places I think that it comes up is screening for hepato-cellular carcinoma if you have Hep C cirrhosis. There have been various recommendations…about whether to get ultrasound, CT, or MRI where this actually may make a difference in terms of what people order."
Patient hand-out regarding radiation exposure	"I mean one idea is 'Why aren't we doing this for patients?' Are they getting something at the point of care or when the test is scheduled?"
Provide formal decision-making aids	"The radiation adds up, but if I were going to have any way of using that information I'd have to do some cost benefit analysis. I think having a way of doing that would be helpful."
Include patient education component	"I think when you're scheduling an exam, either with the [protocol] or the piece of paper that the patient gets, there are some streamlined ways to alert [the patients]. [For example, a notification to patients that reads,] 'It's important that we know about prior imaging from other sources' or a very small amount of information that people will actually read about cumulative dose of radiation. That may empower some of the patients who are likely to talk to us."

and their attitudes towards displaying radiation exposure information at clinician order entry. Prior work has focused on whether informed consent or informed decision-making should be required for CT scans to improve physician and patient awareness of the risks of radiation exposure,[31 32] especially among paediatric populations.[33 34] The American College of Radiology's Image Wisely[35] campaign reflects an awareness of the potential harms of unnecessary imaging. Our study aims to build on this literature to better understand how clinicians would want radiation exposure information presented to them, and what the barriers would be to using such information to inform clinical decision-making and patient–clinician communication.

In 2010 California passed the Medical Radiation Safety Act (SB 1237) which requires all hospitals and clinics to record the radiation dose of each CT scan in the radiologist report sent to the referring physician for a given patient.[36] This law focuses on providing referring clinicians with the radiation dose a patient receives from a given imaging study. Our study suggests that this information alone may not be adequate. While it is an important step to improve clinicians' awareness of the risks of radiation exposure from advanced medical imaging, a more nuanced approach or the provision of information about the relevant clinical impact may be more useful to inform clinical decisions. The cancer risk associated with cumulative radiation exposure from multiple imaging tests is not well understood by the radiology and medical community.[37 38] Whether cumulative radiation exposure information would be clinically relevant warrants further investigation. Attempting to track patients' radiation exposure from imaging tests over time would be challenging currently, as many patients receive care in multiple settings including clinics, emergency rooms and hospitals. This may been an attainable goal in the future aided by the expansion of electronic medical records,[39] the development of personal health records,[40] the integration of health information exchanges[41 42] and the establishment of a national dose registry.[43]

Recent efforts to increase the awareness of radiation exposure from medical imaging have focused on populations where the risk of the exposure may likely outweigh the benefit. Campaigns such as 'Image Gently' advocate for conservative use of imaging and stronger imaging safety precautions among paediatric populations.[11] Our study suggests clinicians' perceptions of the risk–benefit ratio for patients at high risk for poor outcomes or those at high risk for being lost to follow-up may differ, and the cancer risks from radiation exposure should be interpreted on a case-by-case basis.[44]

Our findings suggest that diagnostic imaging ordering represents an important opportunity for shared medical decision-making, particularly under circumstances where there is more than one reasonable clinical approach.[45] Shared decision-making is a

collaborative process that allows patients and clinicians to make healthcare decisions together, taking into account evidence and the patient's values and preferences. Shared decision-making supports patients in making the best individualised care decisions, as patient factors affect the risk–benefit ratio of medical decisions. Clinicians in our study believed that having radiation exposure information more readily available would assist them in making imaging ordering decisions. Clinical guidelines for diagnostic imaging that integrate principles of shared decision-making may facilitate patient engagement in this process.[46]

Clinicians noted that limited health literacy presented a barrier to communication regarding risks of radiation exposure, and by extension, shared decision-making. Our finding that clinicians reported many of their patients did not raise concerns about radiation exposure in their patient–clinician discussions highlights an important opportunity to increase communication about clinically relevant risks. Prior research suggests that patient understanding of cancer risks related to imaging is low,[47 48] even in higher literacy populations. Developing tools to assist clinicians in discussing the risks and benefits of radiation exposure with patients may be helpful,[49] such as literacy-appropriate patient education information to help patients make informed decisions about their care. Recent studies have sought to create patient education information regarding the radiation risks of mammography and cancer treatment for low-literacy populations,[50–52] and the Image Gently campaign has created materials to improve parents' health literacy regarding radiation exposure in children.[53 54] It may be useful to build on these existing educational tools to provide information about higher radiation exposure from CT scans for low-literacy adult patient populations. Patient preferences regarding the presentation of this information have been studied in paediatrics,[55] but not among adult patient populations. This represents an area for future study in order to effectively engage adult patients in decision-making about radiation exposure.

Clinicians' attitudes towards using radiation exposure information in clinical practice were generally positive. These attitudes supported their intention to use the radiation exposure information if it was available in a clinically useful presentation under circumstances where the risk–benefit ratio to the patient was uncertain or there was more than one feasible, clinically appropriate approach. The suggestion of providing clinical guidance tools to help clinicians weigh the risks and benefits of particular tests supports the notion that clinicians believed they would use the information if available. Barriers to using this information in the safety-net, such as longer wait times for tests with less radiation, would need to be addressed for the information to be actionable. Clinicians' perceptions that the availability of more clinically useful information, such as cumulative radiation exposure and the development of clinical guidelines to help clinicians use radiation exposure information, are key steps to assist the translation of clinician interest in incorporating radiation exposure information into practice.

This study has several limitations. Participation in the focus groups was voluntary, and the attitudes and practices of respondents may differ from non-participants. The researchers who conducted the focus groups also participated in the analyses of the transcripts. We attempted to limit inherent biases by having a third researcher who compared their independently coded transcripts to verify the consensus. We collected limited demographic information about our participants. Our findings may not be generalisable to clinicians practising in other regions and market settings. This qualitative research is exploratory by nature. Therefore, the findings will need confirmation in future studies.

Posting radiation exposure information at the site of clinician order entry may improve clinician knowledge and inform patient–clinician discussions regarding the risks and benefits of various imaging tests. Interventions designed to improve the appropriateness of diagnostic imaging ordering may need to be tailored to practice setting and patient population served. Safety-net health systems should consider additional factors that challenge clinicians' use of radiation exposure in decision-making, including limited access to care and longer wait times for tests with less radiation exposure, patient vulnerability and low health literacy.

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