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Barriers to CT Dose Optimization:

The Challenge of Organizational Change

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Keywords: tomography, health resources, radiation dosage, organizational culture

Abstract

Background: The use of diagnostic imaging with computed tomography (CT) has risen significantly, increasing cumulative life-time exposure to ionizing radiation for patients and raising concerns about increased cancer risk. Lowering the doses would reduce concerns about associated cancer risks.

Purpose: To determine organizational leaders' perceptions of barriers to optimizing radiation dose in computed tomography (CT).

Materials and Methods: An observational study using semi-structured interviews conducted with 26 organizational leaders from 19 health care systems in the United States, Europe, and Japan. Interviews focused on approaches the organizations used to optimize radiation dose and barriers encountered. Data were analyzed using a directed content analysis approach.

Results: Analysis identified six primary barriers to dose optimization: 1) resistance to change, 2) limited time and resources, 3) complex organizational structure, 4) lack of leadership support, 5) variations in CT equipment, and 6) variability in CT protocols.

Conclusion: Barriers to optimizing CT dose across diverse health care organizations were described by organizational leaders tasked with implementing and improving CT imaging. They identified six consistent themes that reflected barriers to optimizing radiation dose at the organizational level. These barriers impeded efforts by health care organizations to optimize radiation doses to patients from CT imaging. Identifying barriers early in any improvement process is an important first step in making meaningful and sustained change.

Introduction

Diagnostic imaging with computed tomography (CT) which exposes patients to higher radiation doses than conventional radiographs, has increased significantly .[1,2] The rising use of CT and other advanced imaging has doubled the U.S. average annual exposure to ionizing radiation.[3] Growing evidence links low-dose medical radiation exposure and increased cancer risk.[4-6] This increased patient exposure to ionizing radiation from imaging is fueling discussions on the safety of cumulative exposure to ionizing radiation within healthcare.[4,7,8]

The guiding principle in radiology is that imaging doses should be *as low as reasonably achievable* (ALARA) to minimize potential harm from ionizing radiation exposure. In clinical practice, CT radiation doses vary substantially across patients, hospitals, and countries, even accounting for factors that should help specify doses (e.g., patient size, clinical indication), suggesting ALARA has not led to consistent dosing.[1,9] Variations of more than 10-fold are reported for similar CT procedures across facilities.[1,8]

Meaningful change in CT radiation dose may be difficult to achieve without first understanding organizational barriers to change. Barriers identified to date are number and variation in protocols, which hinders harmonization to a single standard[10]; lack of understanding about doses and risks associated with radiation exposure; and competing priorities.[4,11-17] Information about barriers and challenges to effective, optimal dose setting for CT is scarce. Optimizing the amount of radiation received by patients requires action at the level of care delivery within complex organizational structures. To better understand the barriers to optimizing CT imaging at the organizational level, we interviewed leaders from diverse health care organizations in the United States and abroad about barriers they encountered in their efforts to optimize CT dose within their organizations.

Materials and Methods

This qualitative study was designed to use interview data to explore how organizational leaders perceive barriers to change for CT dose optimization in their organization. Narrative interview data provides a rich opportunity to understand the dynamics in complex problems with a very small sample of unique participants. Data were collected as part of the National Institutes of Health-funded Partnership for Dose Study, a multisite randomized controlled trial of quality improvement interventions to optimize CT radiation dose across 19 health care organizations, including 100 imaging facilities across the United States, four in Europe (Germany, Switzerland, England, Netherlands), and one in Japan. These organizations have diverse organizational structures and include academic teaching systems, community hospitals, and standalone radiology imaging facilities. Interviews for this study were conducted in 2017 and 2018. The study was approved by the Institutional Review Boards of participating health care organizations.

Study Population and Recruitment

Department leaders (lead radiologists or technologists) and medical physicists from the 19 organizations were recruited for semi-structured interviews. The goal was identifying the organizational leaders responsible for CT dose optimization. Participants were identified by their site principal investigator as dose optimization leaders and recruited via introductory email from the study principal investigator, followed by calls to answer questions about the study, obtain informed consent, and then conduct an interview with each participant.

Data Collection

We conducted 21 semi-structured telephone interviews focused on understanding leaders' experiences with CT dose-optimization efforts within organizations. The interview guide contained 13

questions including rating six groups from leaderships to technicians for importance in dose optimization. Other questions were about approaches used to optimize radiation dose, strategies to implement change, and barriers encountered. A set of structured probes explored topics more deeply. A single interviewer trained in research interviewing and knowledgeable about study protocols conducted the phone interviews over 6 months. Interviews averaged 30 minutes (range, 19–40 minutes) and all were audio-recorded and professionally transcribed.

Data Analysis

A directed content analysis approach was used to explore organizational strategies and barriers to change around CT dose optimization.[18] Data were modeled within the theoretical framework of the Practice Improvement Model developed for improving primary care (Figure 1), because no model exists for practice change within radiology. In the Practice Improvement Model, which provides a theoretical structure to assess organizational change within health care organizations,[19] care process improvements depend on an organization's change process capability and care process function . Change process capability is defined as the organizations capacity to use system or workflow-level strategies to alter care processes. Care process function addresses the way patients are care for.

NVivo software (version 11.4.3 for Mac) for qualitative data was used to structure and code data. Three authors experienced in qualitative analysis independently reviewed the data, then met to systematically code and identify emerging patterns, categories, and themes. Analysis employed a constant comparative method using an iterative process with discussion of coding differences until consensus was reached, then applying the final coding scheme to all data.[20] A study codebook and detailed audit trail contained coding structures and decision points to enhance analytic rigor.[21] This paper identifies the main organizational barriers leaders encountered in their efforts to optimize CT dose.

Results

We interviewed individuals with responsibility for overseeing radiation dose optimization from 19 organizations. The 26 participants were 11 radiologists, 8 medical physicists, 5 CT technologists and 2 operational managers/directors with responsibility and oversight for radiology services within their organization. Participants were predominately male (n=17, 65%), and Caucasian (n=20, 77%) and had been with their health care organization for an average of 9.8 years (range 11 months-25 years).

The analysis identified six primary barriers to dose optimization: 1) resistance to change, 2) limited time and resources, 3) complex organizational structures, 4) lack of leadership support, 5) variations in CT equipment, and 6) variability in CT protocols. Four of these barriers were related to change process capability and two were related to the care process (Table 1).

Barriers to Change Process Capability

Resistance to Change

Resistance to change, especially by radiologists, was cited by 88% of respondents as a primary barrier to dose optimization efforts. Respondents described "pushback from radiologists" and noted that "radiologists were pretty resistant" to dose optimization efforts. Radiologists' resistance focused on image quality and were due to two concerns. The first was that lowering doses would reduce image clarity, "images will be too noisy," and that this would inhibit radiologists' ability to make accurate diagnoses. As one respondent noted, "There was only one barrier, that you have to convince your team that you can lower the doses, but you can keep the diagnostic information." The second concern related to personal preferences for higher dose exams. Respondents noted that radiologists have strong personal preferences regarding image quality developed over years of practice and as a result, they can be resistant to any change. In discussing this, a respondent stated, "I think we can lower our dose and

still get optimal images, but…we've had physicians who said, I don't want any radiation dose reduction. I want my scans to look beautiful." Radiologists may resist changes to imaging procedures that they are accustomed to, even when they believe reducing doses won't impede diagnostic accuracy.

Complex Organizational Structure

Organizational structure, including size, how decisions are made (centralized or localized), relationships between subgroups, and overall cohesiveness was noted by 65% of respondents as substantially impacting their ability to institute change. Organizational leaders' desire for standardization as a way to drive changes can be at odds with local units' interests in making their own decisions. A respondent noted, "I think the biggest barrier that we tried to deal with right from the get-go was standardization, because each site is basically its own entity," and "It's a very complex situation because of the difference in culture." One respondent noted, "Some smaller facilities, they're a little too relaxed and to get them to do an extra step is kind of difficult" and "Remote hospitals and the radiologist groups at those hospitals, I think getting them to participate [in optimization efforts] was the hardest thing."

Limited Time and Resources

The challenge of limited time and resources to focus on dose optimization was discussed by 61% of respondents. This included inability to hire appropriate staff including medical physicists. One respondent noted, "I think the one that was the biggest barrier, and probably will remain the biggest barrier, is just not having onsite physicists and not having the degree of expertise." Dose optimization efforts can take considerable time and a respondent noted other priorities: "I would say we're understaffed, chronically understaffed. There are always things that seem like they're more important than making those changes to the protocols" and "Not to say that radiation dose optimization is not

important, it's just that there are so many other pressing needs for day-to-day radiology that just get in the way."

Directing resources for dose optimization efforts was also a challenge. One respondent noted, "I think it just comes down to having a lack of resources," and another said, "I think the barrier was, you have to take the time to look at these things and analyze, and then get back to them and follow through. And that goes back to having manpower and resources." One respondent summed up resources challenges as: "I think the organization would like to support it, but at the same time they are limited as to what they can dedicate for that. So, it's definitely a barrier."

Lack of Leadership Support

Lack of leadership support was identified by 53% of respondents. They spoke of competing priorities that garner more focus and support. One respondent noted, "We have a lot of different competing priorities. And if this was made a priority from our C-suite, change would happen." Another respondent said about leadership, "…they're neither supportive nor not supportive. They're happy that we wanted to do something like that. I think, in general, they're on board with things that will foster patient safety. But on the other hand, things like data security and patient information protection are very, very high on the hospital's list of importance."

In larger, structurally complex organizations, administration awareness of dose optimization efforts was unclear. One respondent noted, "I would say as you get into the upper administration, my guess is they don't know we exist, and I'm not sure they care." Respondents were asked during the interview about their perception of support for optimizing CT dose from various groups within their health care organization. Perceived importance for various groups about the need to optimize CT dose at their health care organization is in Table 2. Administration external to radiology scored lowest,

reflecting concern about broader organizational support for CT dose optimization efforts. Respondents also noted that while organizations may provide initial support, ongoing “material support” or “recognition” for efforts were often lacking.

Barriers in Care Process

Variations in CT Equipment

Over half of respondents (57%) discussed variation in CT equipment as a substantial barrier to dose optimization. Issues included differences in manufacturers, variations in models, and differing ages of CT scanners making optimizing dose difficult. One respondent reflected: “At our site, we had different scanners, they came online at different times, and they all had a differ[ing] technology…it was hard to talk about making changes when everybody had different equipment.” Another respondent noted, “I think we have 12 CT scanners now, and there are 11 different models of scanners, so there's a lot of variability, and because the models are different, they have different performance characteristics. So that was probably the biggest challenge in saying, can we lower the dose." Equipment age was noted as a challenge with older technology providing less opportunity for dose optimization. One respondent noted, “If you have really old machines versus newer ones, you can face differences in regards to the possibilities to reduce dose” and “Until we get newer scanners, some of this stuff, it kind of restricts us.” The costs of investing in newer equipment was itself a substantial barrier given the high capital investment required for newer imaging scanners.

Variability in Protocols

Intertwined with variation in equipment was variation in protocols. This challenge was due to the large number of protocols and the inability to apply a single protocol across different machines. Different manufacturers and even models within manufacturers may employ different technology, and

standardizing protocols across an organization can be hampered by the complexity of available machines. One respondent noted, “The biggest barrier that we've seen is variability in protocols. Not the least of which is because we have so many different types of scanners.” Respondents noted that changing protocols across equipment and sites requires significant knowledge, effort, and time: “The major change would be better protocoling because we are still struggling with that. Getting the protocols correct to begin with” and “I guess the only kind of barriers would be maybe actually deciding on protocol changes.” More protocols meant more challenges in identifying and changing those that need improvements. This can be particularly true in organizations where radiologists develop their own unique protocols. One respondent noted, “If you have multiple radiologists who can actually have their own protocols, there’s no way that you’re getting the standardization…and in some institutions they have dedicated protocols for certain physicians.” Identifying protocols created for an individual physician can be challenging, which as one respondent called “when protocols are going rogue.” Another respondent noted, “A big barrier was figuring out why people had access to protocols and why they were changing them when they really shouldn’t be tinkering with them.” Dose optimization is challenging when organizations have little control over the number of protocols and they increase over time.

Discussion

This study describes the perspective of organizational leaders from diverse health care institutions about barriers to their efforts to implement dose optimization for CT imaging. We revealed six consistent barriers to optimizing dose. Four were related to change process capability: radiologists’ resistance to change; organizational structures including decentralization that makes standardization difficult, limited time and resources for dose optimization (because other topics are considered more important); and lack of leadership support for prioritizing CT dose optimization. Two additional barriers

were related to the care process: variation in CT equipment (with differing technologies), and the large number and variability of CT protocols to optimize. These barriers were seen to impede efforts within health care organizations to optimize CT radiation dose to patients. Identifying barriers early in any improvement process is an important step in making meaningful and sustained change. These barriers suggest the need for different approaches and solutions.

The barriers identified to dose optimization were often overlapping and closely related. Complex or decentralized organizational structure can lead to a lack of leadership support for efforts, and limited resources to engage in change. Efforts at dose optimization, such as standardizing the large number of protocols used for CT imaging requires considerable work, and is made even more difficult with inherent differences across scanner makes and models.[10] That the barriers include personnel, equipment, and institutional factors such as leadership and organizational structure suggest that solutions will have to target many factors. Solutions will be most effective if they influence several factors, reducing the time and resources to adopt them. An example is standardizing technology across scanners, which will facilitate protocol standardization.

Variation in CT protocols is the largest source of dose variation across imaging facilities and is more important than patient factors or machine make and model in explaining this variation.[1,8] This study confirmed that variation in CT protocols within organizations is an important barrier to dose optimization. While variation in manufacturer, model, and age of equipment was frequently cited by respondents as an important barrier to dose optimization, machine make and model are only a modest determinant of dose.[1] This finding suggests that while most machines can be optimized to generate low-dose images, variation in imaging equipment manufacturer and model within an organization create challenges to implementing standardized processes across machines.

Change within any organization is challenging as it impacts organizational culture and accepted norms. This is especially true for people whose day-to-day work is affected, such as radiologists during dose-optimization efforts. Optimizing CT dose impacts image quality and thus potentially diagnostic criteria for radiologists. While diagnostic accuracy must be maintained, at a certain point, higher dose and image quality are not related.[13] Participants in our study noted that radiologists develop strong preferences over time about image quality that they are accustomed to and they can therefore be resistant to change. Efforts to change practice must emphasize what is known about the potential harms associated with doses that are higher than needed.[17,22] Increasing knowledge about radiation risks from medical imaging may impact radiologist perceptions of the importance of CT dose optimization, eventually outweighing resistance to change.

Organizational complexity was also a significant barrier to dose-optimization efforts. The larger and more complex the organization, the more challenging the implementation of change and the greater the required investment in time and resources.[19] Standardization, a typical tool in quality improvement efforts, can prove difficult within larger health care systems with multiple sites and the varying cultures and norms they evolve. Investing in the resources and time for CT dose optimization efforts is also challenged by competing priorities and an ever-evolving focus on lean and efficient staffing and resource use at all levels of health care. In this environment, organizational leadership and support is required for efforts to optimize CT imaging, but as noted by study participants, is often lacking. Organizational leaders are beset by competing priorities and may view these efforts as department-level functions, rather than organizational-level priorities.

Our study identified barriers to dose optimization that require change at the individual level, such as radiologists or technologists changing their practice. We also found that resistance to change, organizational complexity and structure, limited time and resources for improvement, and lack of

leadership support were important barriers. We propose that the greatest challenges are individual resistance to change and organizational complexity, since the other barriers can often be overcome with financial resources and leaders committed to change. We acknowledge that for many organizations, resources are very limited and differing organizational priorities can take prescidence. But individual change at the practice level and the challenge of organizational complexity are difficult to overcome even with financial resources and committed leaders.

This study offers a new perspective on optimizing CT dose from an organizational viewpoint. Limitations to the study include its exploratory nature and small sample size. The study does, however, include data from leaders across a range of health care systems and geographic areas. The significant growth in CT imaging presents a substantial challenge in health care. Imaging growth fueled by wider availability of technology, favorable reimbursement, and increased demand by both physicians and patients, creates a growing problem with the cumulative risks of low-dose ionizing radiation to patients.[7] Broad efforts such as Image Gently and the ALARA principle are important steps to increasing awareness about the risks associated with CT imaging, but do not offer clear frameworks for how to implement change.[12,23,24] Understanding organizational-level barriers to change can assist in developing more robust improvements for CT imaging, leading to sustainable improvements changes in dose optimization within health care organizations.

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Figure 1: Practice Improvement Model for Computed Tomography (CT) Dose Optimization

*Facilitators are not assessed in this report.

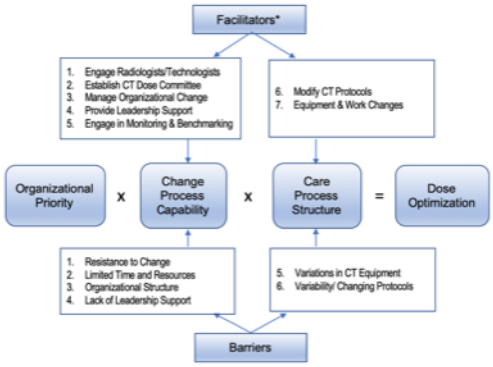
Facilitators*
1. Engage Radiologists/Technologists
2. Establish CT Dose Committee
3. Manage Organizational Change
4. Provide Leadership Support
5. Engage in Monitoring & Benchmarking
6. Modify CT Protocols
7. Equipment & Work Changes
Organizational Priority
x
Change Process Capability
x
Care Process Structure
=
Dose Optimization
1. Resistance to Change
2. Limited Time and Resources
3. Organizational Structure
4. Lack of Leadership Support
5. Variations in CT Equipment
6. Variability/ Changing Protocols
Barriers

Table 1. Barriers to Dose Optimization

Theme	Resistance to Change	Limited Time & Resources	Complex Organizational Structures	Lack of Leadership Support	Variations in CT Equipment	Variability in CT Protocols
% (N=26) Respondents Reported	88% (23)	61% (16)	50% (13)	50% (13)	57% (15)	50% (13)
Thematic Description	Preference for image/ appearance of higher-dose exams Concern about maintaining diagnostic accuracy	Other pressing needs compete for time and resources	Size, decision making (centralized or localized), group relationships within organization impact ability to institute change	Other priorities (e.g., patient safety) compete for leadership time and attention	Challenge to optimize CT dose across differing machines, manufacturers, models	Large number and variability in types of protocols and use of individualized protocols

CT, computed tomography

Table 2. Perceived Importance for Optimizing CT Dose within the Health Care Organizations

Perceived Importance for Optimizing CT Dose by Organizational Group	Mean Score N=19
Administration External to Radiology	5.82
Radiology Leadership	8.37
*Subsites – Radiology Leadership	7.38
Radiologists	7.41
Technologists	7.24

CT, computed tomography. Scale of 1, not important to 10, extremely important. *Of the 19 organizations providing ratings, 13 had subsites with Radiology Leadership.