Perceptions of Radiation Safety Culture Among Radiography, Computed Tomography, And Mammography Technologists

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Purpose To investigate determinants of radiation safety culture among radiologic technologists to determine whether factors related to the primary imaging modality affect the perception of workplace radiation safety.

Methods A secondary analysis was performed on deidentified data from 425 radiologic technologists collected with the Radiation Actions and Dimensions of Radiation Safety (RADS) questionnaire, a 35-item survey with valid and reliable psychometric properties. The data included radiologic technologists working in radiography, computed tomography (CT), and mammography. Descriptive statistics were used to report RADS determinant outcomes by imaging discipline, and 1-way analysis of variance and Games-Howell post hoc tests were conducted to analyze the hypothesis.

Results Mean differences in the radiologic technologists' perceptions of teamwork across imaging stakeholders pertaining to radiation safety were found ($P < .001$). Mammographers had the most favorable perceptions of teamwork compared with radiographers and CT technologists.

Discussion Collaboration in mammography between imaging stakeholders is dictated by professional practice standards and federal law. The resultant engagement might influence mammographers' perceptions of radiation safety. Additional research is warranted to determine if perception differences exist among technologists in other modalities and whether intentional collaboration drives improved perceptions of radiation safety culture.

Conclusion An analysis of the collaborative actions in the mammography department is needed, and the findings could be applied in radiography and CT to improve perceptions of radiation safety–related teamwork.

Keywords | *radiographer, radiologic technologist, radiation safety culture, computed tomography, mammography*

Foundational tenants of radiation safety often guide radiation safety actions in medical imaging,[1] along with the as low as reasonably achievable (ALARA) principle, state and federal requirements, and department policies. Although rules and guidance are in place, calls have been made to strengthen radiation safety culture in medical imaging.[2-6] The International Radiation Protection Association advocates that embedding radiation safety at a cultural level in an organization is the most effective way of advancing safety performance.[3] The correct culture will support safety initiatives and create accountability in medical imaging,[7] empowering personnel to lead continual quality improvement efforts that support optimized radiation safety practices in the field.

Although establishing and maintaining a positive organizational radiation safety culture is critical to bring about meaningful change, specific actions to optimize radiation safety are inherently unique to each imaging modality. A study by Moore et al found that a radiologic technologist's primary imaging discipline had a small effect on their overall perception of radiation safety ($P < .001$). Radiologic technologists working in computed tomography (CT) had a lower overall perception of radiation safety compared with those working in radiography and mammography.[8] As a result, this study examines additional determinants of radiation safety culture to determine whether other mean differences exist among radiologic technologists working in the various imaging modalities.

Methods

The dataset used for this secondary analysis came from a quantitative cross-sectional study conducted in 2019 where respondents were recruited through the American Society of Radiologic Technologists (ASRT) membership database. The ASRT Research Department generated a simple randomized sample of 10 000 radiologic technologists for the study, and there was a 7.8% response rate.[6,9,10]

The original research study was exempted by the Northern Illinois University Institutional Review Board (HS20-0031). The present research study was a secondary data analysis of deidentified data that did not require institutional review board approval.

Study Design

Data were collected using the Radiation Actions and Dimensions of Radiation of Safety (RADS) questionnaire, a 35-item survey with valid and reliable psychometric properties.[9] This study used data from 9 of the 11 determinant scales in the questionnaire[9]:

- error reporting (3 items; scale $\alpha = .71$)
- feedback loops (3 items; scale $\alpha = .84$)
- leadership actions (3 items; scale $\alpha = .70$)
- nonpunitive response (3 items; scale $\alpha = .79$)
- organizational learning (3 items; scale $\alpha = .76$)
- questioning attitude (3 items; scale $\alpha = .72$)
- radiation policy (4 items; scale $\alpha = .81$)
- teamwork across imaging stakeholders (3 items; scale $\alpha = .74$)
- teamwork in imaging (3 items; scale $\alpha = .81$)

Determinant definitions should be interpreted in the context of radiation safety (see **Box**).[9] The personal accountability scale was not analyzed in this study based on its scale reliability ($\alpha < .70$). Also, the overall perception of the radiation safety scale was not used because data were already examined with professional role.[8]

The dataset included 425 radiologic technologists working in radiography, CT, mammography, and hospital radiology management. Radiology directors, managers, and leads included in the dataset also were registered radiologic technologists. Participants identified their primary employed discipline ($\geq$ 51% of their time) as radiography (265, 62.4%), CT (97, 22.8%), and mammography (63, 14.8%). Other participant characteristics were not analyzed in this study, but categorical majorities are reported for transparency. Radiologic technologists primarily worked as staff technologists (328, 77.2%), were employed full-time (342, 80.5%), and worked 8- to 9-hour shifts (267, 62.8%). Participants also held an associate degree (222, 52.2%) and 1 medical imaging credential (196, 46.1%), were aged 55 to 64 years (117, 27.5%), and had 25 or more years of experience (124, 29.2%). Optional demographic questions were included in the dataset, with most items having 408 to 409 responses. Data indicated that most respondents were women (329 out of 408, 80.6%) who worked the first shift (308 out of 409, 75.3%) in hospitals (239 out of 409, 58.4%) that served adult and pediatric patients (317 out of 409, 77.5%) in a suburban setting (174 out of 408, 42.6%). Data also showed that respondents were from 49 of 50 states in the United States.

Box

Definitions of the Study Determinants[9]

Error reporting – Radiation safety protocol mistakes are reported.

Feedback loops – Radiologic technologists are informed about radiation safety concerns, receive feedback about changes implemented, and discuss ways to prevent errors.

Leadership actions – Leaders' commitment to radiation safety through decisions and behaviors.

Nonpunitive response – Radiation safety mistakes are not personally held against the individual.

Organizational learning – Opportunities to improve radiation safety are sought out, implemented, and evaluated.

Questioning attitude – Radiologic technologists speak up if they see something that might negatively affect radiation safety.

Radiation policy – Policies, regulatory requirements, and guidelines intended to control, support, or enhance the use of ionizing radiation in medicine.[11-13]

Teamwork across imaging stakeholders – Teamwork between radiation-related stakeholders in the different disciplines (radiologic technologists, radiologists, and medical physicists).

Teamwork in imaging – Teamwork between radiologic technologists.

Data Analyses

SPSS version 26.0 (IBM) was used for all data analyses. Descriptive statistics included means and standard deviations for continuous data. A series of 1-way analysis of variance tests were performed to evaluate whether mean differences were present for a variety of dependent radiation safety culture determinant variables based on primary employed imaging discipline (independent variable; 3 levels: radiography, mammography, CT). Hypotheses (H_{null}: $\mu 1 = \mu 2 = \mu 3$, H_{alt}: $\mu 1 \neq \mu 2 \neq \mu 3$) were evaluated with each dependent variable:

- H_1 – teamwork in imaging
- H_2 – teamwork across imaging stakeholders
- H_3 – questioning attitude
- H_4 – feedback loops
- H_5 – organizational learning
- H_6 – leadership actions
- H_7 – nonpunitive response
- H_8 – error reporting
- H_9 – radiation policy

The *F* ratio and its associated probability value (*P* value) were calculated. *P* values of .05 or less resulted in H_{null} being rejected, meaning that groups with the given variable differed in significance. Post hoc tests were carried out to determine the specific groups that differed for each significant *F* test value. The Games-Howell post hoc test was used in this study because of the unequal sizes between groups. Adjusted R^2 was interpreted to evaluate the effect size for each significant variable as a method to describe the importance of each significant mean difference. Per Cohen, values of .01, .06, and .14 were used to report small, moderate, and large effect sizes, respectively.[14] Post hoc power also was considered at the threshold of 0.80 or higher to determine the control for type II error to detect an actual difference.

Results

Among the determinants of radiation safety culture and regardless of primary imaging modality, radiologic technologists rated teamwork in imaging most favorably (see **Table 1**). Radiologic technologists working in mammography had the most favorable perceptions of radiation safety of the groups in the study, with 4 of the 9 determinants exceeding a mean score of 4.0. These included teamwork in imaging, teamwork across imaging stakeholders, leadership actions, and radiation policy. Those working radiography had lower perceptions of radiation safety than did mammographers, but teamwork in imaging and leadership actions exceeded a mean determinant score of 4.0. Radiologic technologists working in CT rated teamwork in imaging with a mean score above 4.0. Descriptive statistics consistently demonstrated that CT technologists had lower perceptions of radiation safety among the study determinants,

Table 1

Rank Order of Determinant Favorability by Primary Imaging Discipline

Rank	Radiography	Mammography	Computed tomography
1	Teamwork in imaging (M = 4.26)	Teamwork in imaging (M = 4.33)	Teamwork in imaging (M = 4.02)
2	Leadership actions (M = 4.02)	Teamwork across imaging stakeholders (M = 4.28)	Radiation policy (M = 3.82)
3	Questioning attitude (M = 3.96)	Leadership actions (M = 4.10)	Questioning attitudes (M = 3.77)
4	Teamwork across imaging stakeholders (M = 3.88)	Radiation policy (M = 4.16)	Leadership actions (M = 3.76)
5	Radiation policy (M = 3.88)	Questioning attitude (M = 3.96)	Teamwork across imaging stakeholders (M = 3.64)
6	Organizational learning (M = 3.70)	Feedback loops (M = 3.75)	Organizational learning (M = 3.60)
7	Feedback loops (M = 3.69)	Organizational learning (M = 3.71)	Feedback loops (M = 3.56)
8	Nonpunitive response (M = 3.43)	Nonpunitive response (M = 3.45)	Error reporting (M = 3.38)
9	Error reporting (M = 3.23)	Error reporting (M = 3.40)	Nonpunitive response (M = 3.30)

apart from error reporting, whereas mammographers consistently had the most favorable perceptions of radiation safety in the workplace (see **Table 2**).

Hypothesis Evaluation

One-way analysis of variance test results demonstrated that primary employed imaging discipline groups had a mean difference between 4 of the 9 dependent variables (see **Table 3**). However, only the teamwork across imaging stakeholders' determinant ($F_{2,424} = 12.87, P < .001$) met the power requirements for the study (≥ 0.80). Mean differences in leadership actions ($P = .009$), teamwork in imaging ($P = .01$), and radiation policy ($P = .02$) were significant but did not meet the study's power requirements, although some researchers might interpret the results as having adequate power (> 0.70). Mean differences in questioning attitude, feedback loops, organizational learning, nonpunitive response, and error reporting were not observed in primary employed imaging discipline groups at the level of $P \leq .05$. Effect size is also reported in **Table 3**, with primary employed imaging discipline having a small effect on the perception of teamwork across imaging stakeholders.

Games-Howell post hoc tests were conducted to determine which groups differed for each significant *F* test value (see **Table 4**). Post hoc tests revealed significant differences in teamwork across imaging stakeholders scores between radiologic technologists working in mammography (M = 4.28, SD = 0.66) and those working in radiography (M = 3.88, SD = 0.74); in addition, differences were found between radiologic technologists working in mammography and those in CT (M = 3.64, SD = 0.94).

Discussion

This study demonstrates that perceptions of radiation safety differ among imaging modalities, specifically for the determinant teamwork across imaging stakeholders. The results show that mammographers perceive greater collaboration between imaging stakeholders (radiologic technologists, radiologists, and medical physicists) than do radiographers and CT technologists. Although radiologic technologists, regardless of imaging discipline, are

Table 2

Descriptive Statistics for Radiation Safety Culture Determinants by Primary Discipline

Determinant[a]	Discipline	Mean (SD)	SE	95% CI
Teamwork in imaging	Radiography	4.26 (0.72)	0.04	4.18 - 4.35
	Mammography	4.33 (0.68)	0.09	4.16 - 4.50
	CT	4.02 (0.91)	0.09	3.84 - 4.21
	Total	4.22 (0.76)	0.04	4.15 - 4.29
Teamwork across imaging stakeholders	Radiography	3.88 (0.74)	0.05	3.79 - 3.97
	Mammography	4.28 (0.66)	0.08	4.11 - 4.44
	CT	3.64 (0.94)	0.10	3.45 - 3.83
	Total	3.88 (0.80)	0.04	3.81 - 3.96
Questioning attitude	Radiography	3.96 (0.75)	0.05	3.87 - 4.05
	Mammography	3.96 (0.80)	0.10	3.76 - 4.16
	CT	3.77 (0.90)	0.09	3.59 - 3.95
	Total	3.92 (0.79)	0.04	3.84 - 3.99
Feedback loops	Radiography	3.69 (1.06)	0.07	3.56 - 3.81
	Mammography	3.75 (1.08)	0.14	3.48 - 4.02
	CT	3.56 (1.16)	0.12	3.33 - 3.80
	Total	3.67 (1.08)	0.05	3.56 - 3.77
Organizational learning	Radiography	3.70 (0.76)	0.05	3.61 - 3.80
	Mammography	3.71 (0.75)	0.09	3.52 - 3.90
	CT	3.60 (0.82)	0.08	3.43 - 3.76
	Total	3.68 (0.77)	0.04	3.61 - 3.75
Leadership actions	Radiography	4.02 (0.78)	0.05	3.93 - 4.11
	Mammography	4.10 (0.72)	0.09	3.92 - 4.28
	CT	3.76 (0.91)	0.09	3.57 - 3.94
	Total	3.97 (0.81)	0.04	3.89 - 4.05
Nonpunitive response	Radiography	3.43 (0.83)	0.05	3.33 - 3.53
	Mammography	3.45 (0.96)	0.12	3.21 - 3.69
	CT	3.30 (0.91)	0.09	3.12 - 3.49
	Total	3.41 (0.87)	0.04	3.32 - 3.49
Error reporting	Radiography	3.23 (1.07)	0.07	3.10 - 3.36
	Mammography	3.40 (0.96)	0.12	3.16 - 3.64
	CT	3.38 (1.02)	0.10	3.17 - 3.58
	Total	3.29 (1.04)	0.05	3.19 - 3.39
Radiation policy	Radiography	3.88 (0.74)	0.05	3.79 - 3.97
	Mammography	4.16 (0.68)	0.09	3.99 - 4.33
	CT	3.83 (0.81)	0.08	3.67 - 4.00
	Total	3.91 (0.76)	0.04	3.84 - 3.98

[a] *Radiography, n = 265; mammography, n = 63; CT, n = 97; total, N = 425.*
Abbreviations: CI, confidence interval; CT, computed tomography.

Table 3

One-way Analysis of Variance Results

Dependent variable	$F_{2,424}$	*P* value	Outcome	Adjusted R^2	Effect size	Observed power
Teamwork in imaging	4.34	.01	Reject null	0.016	Small	0.752[a]
Teamwork across imaging stakeholders	12.87	< .001	Reject null	0.053	Small	0.997[b]
Questioning attitude	2.26	.11	Fail to reject	0.006	-	0.459
Feedback loops	0.66	.52	Fail to reject	−0.002	-	0.161
Organizational learning	0.76	.47	Fail to reject	−0.001	-	0.179
Leadership actions	4.78	.009	Reject null	0.018	Small	0.793[a]
Nonpunitive response	0.90	.41	Fail to reject	0	-	0.206
Error reporting	1.10	.33	Fail to reject	0	-	0.243
Radiation policy	4.19	.02	Reject null	0.015	Small	0.735[a]

[a] *Significant finding with low statistical power (< 0.80).*

[b] *Significant finding with required statistical power (≥ 0.80).*

expected to enhance quality and efficiency by developing and maintaining partnerships,[15] the mammography department was found to be a more collaborative imaging environment than were radiography and CT.

ASRT practice standards document potential reasons for this by indicating specific criteria for higher-level collaborative functions. For example, mammography's standards for assessment, evaluation, and outcomes indicate that mammographers are expected to[15]:

- Assist in setting policy and procedures in the facility to meet certification and accreditation standards specific to breast imaging.
- Collaborate with the lead interpreting physician and medical physicist to maintain equipment and comply with federal and state regulations and guidelines.
- Prepare annual medical outcomes audit and provide results to the lead interpreting physician.

These 3 practices, while collaborative, are rooted primarily in maintaining compliance with federal Mammography Quality Standards Act requirements[16] and resultant inspections. Thus, these findings might signify that advanced safety requirements could lead to enhanced radiation safety–related teamwork among imaging stakeholders in mammography and that other imaging modalities could benefit from policy-embedded collaborative conditions. Likewise, although the test's power was beneath the study's defined threshold, mammographers perceived that radiation policy fostered higher levels of radiation safety compared with radiologic technologists representing other imaging modalities.

Although policy can have a role in bringing imaging stakeholders together, the results suggest that simply placing emphasis on the formation of high-functioning collaborative teams might improve radiation safety perceptions among imaging modalities, notably with nearly every mean determinant score in mammography exceeding those of the other modalities in this study. ASRT best practices also indicate that it is up to radiologic technologists to "personally emphasize a culture of safety and professionalism and to pursue open discussions … to learn from and support radiologists and other interpreting practitioners, as well as fellow technologists."[17] Therefore, radiologic technologists need to feel empowered to have conversations regarding direct team collaboration that advances radiation safety practices in radiography, CT, and mammography.

Collaborative Radiation Safety Teams

Research by Taplin et al indicates that teams must "interact dynamically, interdependently, and adaptatively to achieve a common goal."[18] In medical imaging, multidisciplinary imaging stakeholders often work parallel to one another but carry out most functions

Table 4

Games-Howell Post Hoc Test Results

Primary discipline (≥ 51% of work time)		Mean difference	SE	*P* value[a]	95% CI
Teamwork in imaging					
Radiography	Mammography	−0.06	0.10	.79	−0.29 - 0.17
	CT	0.24	0.10	.051	0 - 0.48
Mammography	Radiography	0.06	0.10	.79	−0.17 - 0.29
	CT	0.30[a]	0.13	.04	0.01 - 0.60
CT	Radiography	−0.24	0.10	.051	−0.48 - 0
	Mammography	−0.30[a]	0.13	.04	−0.60 - −0.01
Teamwork across imaging stakeholders					
Radiography	Mammography	−0.40[a]	0.09	< .001	−0.63 - −0.18
	CT	0.24	0.11	.07	−0.01 - 0.49
Mammography	Radiography	0.40[a]	0.09	< .001	0.18 - 0.63
	CT	0.64[a]	0.13	< .001	0.34 - 0.94
CT	Radiography	−0.24	0.11	.07	−0.49 - 0.01
	Mammography	−0.64[a]	0.13	< .001	−0.94 - −0.34
Leadership actions					
Radiography	Mammography	−0.08	0.10	.71	−0.32 - 0.16
	CT	0.26[a]	0.10	.03	0.02 - 0.51
Mammography	Radiography	0.08	0.10	.71	−0.16 - 0.32
	CT	0.34[a]	0.13	.02	0.04 - 0.65
CT	Radiography	−0.26[a]	0.10	.03	−0.51 - −0.02
	Mammography	−0.34[a]	0.13	.02	−0.65 - −0.04
Radiation policy					
Radiography	Mammography	−0.28[a]	0.10	.01	−0.51 - −0.05
	CT	0.05	0.09	.86	−0.17 - 0.27
Mammography	Radiography	0.28[a]	0.10	.01	0.05 - 0.51
	CT	0.33[a]	0.12	.02	0.04 - 0.61
CT	Radiography	−0.05	0.09	.86	−0.27 - 0.17
	Mammography	−0.33[a]	0.12	.02	−0.61 - −0.04

[a] *Mean difference is significant at the P ≤ .05 level.*

independently. A multidisciplinary team differs from an interdisciplinary team in which stakeholders collaborate and routinely consider the input of the other team members to maximize the clinical outcome.[19] Execution of a plan in an interdisciplinary manner requires not only shared responsibility but also shared mental models and continuous analysis of shared information.[20] To execute this plan, imaging stakeholders must collaboratively establish clear goals and roles to manage the interdependent tasks[18] as they pertain to radiation safety.

According to Mahmoud et al, an integrated radiology team can accomplish tasks more safely and efficiently, and team members should be encouraged to cross boundaries.[21] This integration is not suggested to infringe on another discipline's scope of practice but to ensure completion of all radiation safety–related tasks, particularly those abutting discipline boundaries. There is minimal published guidance that defines the roles and responsibilities of each staff member involved in this type of integrated setup in medical imaging.[22] However, Bartal et al noted that decisive leadership and coordination of every procedure is critical and can improve radiation safety by reducing fluoroscopy times.[22] This also aligns with Mahmoud et al's notion that having a designated facilitator can substantially and positively affect examination flow.[21] Each modality has its unique complexities regarding radiation safety; therefore, clear directives should be established to support intentional team integration that optimizes modality-specific practices.

Team Barriers and Opportunities

Several barriers have been associated with the establishment of effective teams[23]:

- communication failures
- inadequate participant execution
- inefficient leadership
- lack of organizational support
- personal conflict
- personnel turnover
- time constraints

Evidence demonstrates that the speed to progress through team formation barriers will differ based on skills, the task at hand, and the available leadership.[24] Keeping these team barriers in mind when assembling stakeholders from different disciplines is essential, as cohesion will take time.

Structured frameworks that can improve team performance are available. For example, the Team Strategies and Tools to Enhance Performance and Patient Safety (TeamSTEPPS) curriculum, developed by the U.S. Department of Defense in collaboration with the Agency for Healthcare Research and Quality, can be applied to any health care environment to assist with team performance, communication, patient safety, and clinical outcomes.[23,25,26] The TeamSTEPPS approach uses various resources, such as checklists, Situation-Background-Assessment-Recommendation technique[27] and structured communication tools to facilitate improvements.[28] The curriculum promotes using 3 critical events—brief, huddle, and debrief—for role clarity and simulation to reinforce applying the TeamSTEPPS tools.[23] Ghodadra and Bartoletti have used this structure, suggesting the importance of devising radiation dose reduction strategies before beginning a procedure (brief) and providing continual feedback during the examination (huddle).[29] The authors found that pairing radiation dose feedback with dose reduction education can reduce fluoroscopy radiation exposure by nearly 50%.[29] In addition, Rinehart initiated a process to allow technologists to inform the physician when certain dose thresholds were reached (huddle), allowing the operator to make more informed radiation dose decisions regarding proceeding with the examination.[30] Teamwork across imaging stakeholders is necessary, and taking steps to learn and apply TeamSTEPPS approaches might be a practical approach to enhancing the perception of radiation safety across imaging modalities.

Limitations

The teamwork in imaging, leadership actions, and radiation policy variables presented with significance but had low power (0.735-0.793). Power can be improved in several ways such as increasing the sample size of the groups. Although this was not possible in the static dataset, greater power would help to demonstrate the spectrum of radiation safety–related challenges and opportunities to inform on mechanisms needed to foster a positive radiation safety culture in each imaging discipline.

Future Research

The state of teamwork in medical imaging and underlying drivers for optimized teamwork across imaging stakeholders need to be explored, with lessons learned from the mammography clinical environment being applied. The current research also demonstrates a need to consider radiation safety perceptions among radiologic technologists working in other ionizing radiation–based diagnostic imaging disciplines such as nuclear medicine, vascular interventional radiography, and cardiac interventional radiography. Data from the increasingly collaborative interventional imaging environments would inform and advance these findings. Finally, discipline-related disparities should be evaluated at the organizational level using the RADS questionnaire before and after initiatives are implemented to consider the state of radiation safety and whether actions, requirements, or initiatives, including those pertaining to teamwork and policy, foster positive radiation safety practices in medical imaging departments.

Conclusion

Perceptions of radiation safety differ for the teamwork across imaging stakeholder variable among the imaging disciplines, with mammographers indicating an enhanced perception of teamwork to improve radiation safety. An analysis of collaborative actions occurring in the mammography department is needed, with relevant findings applied in radiography and CT to enhance radiation safety perceptions. Exploring opportunities to engage intentionally in an interdisciplinary manner also needs to be considered to advance modality-specific radiation safety actions.

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