

Effects of Work Shift or Shift Length on Radiation Safety Perception

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Purpose This study investigated several determinants of radiation safety culture among radiologic technologists to determine whether factors related to work shifts or workday length affect the perception of workplace radiation safety.

Methods The secondary analysis used de-identified 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. Respondents included radiologic technologists working in radiography, computed tomography (CT), mammography, and hospital radiology administration. Descriptive statistics were used to report RADS survey item outcomes, and analysis of variance (ANOVA) tests with Games-Howell post hoc tests were conducted to analyze the hypotheses.

Results Mean differences in perception of teamwork across imaging stakeholders ($P < .001$) and leadership actions ($P = .001$) were found across shift-length groups. In addition, mean differences in perception of teamwork across imaging stakeholders ($P = .007$) were found across work-shift groups.

Discussion Longer shifts (≥ 12 hours) and night shifts are related to a diminished perception of the importance of radiation safety among radiologic technologists. The study showed a significant effect of these shift factors on the perception of teamwork and leadership actions concerning radiation safety.

Conclusion These results underscore the importance of leadership actions and messaging, teamwork-building, and in-service training on radiation safety for technologists who frequently work long, after-hours shifts.

Keywords | work shift, shift length, safety perceptions, radiation safety, leadership

As the demand for after-hours imaging continues to escalate in hospitals, especially in the emergency setting,¹ there is an increasing need for greater numbers of radiologic technologists to work extended shifts and overnight shifts. These shifts often are hectic and demanding. Concerns have been raised that in these situations, radiologic technologists might be disposed culturally to bypass radiation safety best practices as a result of reduced staffing and increased throughput expectations. Therefore, this study investigated whether long and after-hours shifts affect radiologic technologists' perceptions and attitudes regarding radiation safety.

In previous work, Moore et al found that shift length ($P < .001$) and work shift ($P = .007$) had moderate and

small effects, respectively, on the overall perception of radiation safety among radiologic technologists.² The findings showed that radiologic technologists working shifts of 12 hours or longer and night shifts had a lower overall perception of radiation safety than those working shorter and day shifts.³ The present study was conceived to further examine the determinants of radiation safety culture to show whether other mean differences exist between radiologic technologists working various shifts or shift lengths.

Methods

This study is a secondary analysis that used de-identified data from a 2019 survey of 425 U.S. radiologic technologists.

Ethical Considerations

The present research study was a secondary data analysis of de-identified data, which did not require an institutional review board evaluation. The original data were collected under protocol number HS20-0031, a research study exempted by the Northern Illinois University Institutional Review Board.

Instrumentation and Data Usage

Data were collected in a quantitative, cross-sectional study that used the Radiation Actions and Dimensions of Radiation Safety (RADS) questionnaire, a 35-item survey with valid and reliable psychometric properties.³ This study used data from 9 of the 11 determinant scales in the questionnaire³:

- 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 $\alpha = .81$)

The personal accountability scale was not analyzed in this study based on its scale reliability ($\alpha < .70$). Also, the overall perception of radiation safety scale was not used because the data were already examined for work shift and shift length.² The data collection process, which occurred in 2019, and response rate (7.8%) were reported previously.^{3,5} Determinant definitions are available in the previous research report.³

Subjects

The dataset included U.S. radiologic technologists working in radiography, computed tomography (CT), mammography, and hospital radiology management. The total dataset included 425 participants, with all 425 reporting their primary shift length: less than 8-hour shifts (4.9%, $n = 21$), 8- to 9-hour shifts (62.8%, $n = 267$), 10- to 11-hour shifts (13.9%, $n = 59$), or 12 hours or more shifts (18.4% $n = 78$). Also, 409 of the 425 respondents (96.2%) reported their work shift; participants reported working first shift or 12-hour day shift (75.3%, $n = 308$), second shift (7.8%, $n = 32$),

third shift or 12-hour night shift (9.0%, $n = 37$), or float shift (7.8%; $n = 32$).

Other participant characteristics in this dataset were not analyzed in this study, but categorical majorities are reported for transparency. Out of 425 participants, radiologic technologists primarily worked in radiography (62.4%, $n = 265$) as staff technologists ($n = 328$; 77.2%), were employed full time (80.5%, $n = 342$), held an associate degree (52.2%, $n = 222$) and 1 medical imaging credential (46.1%, $n = 196$), were 55 to 64 years old (27.5%, $n = 117$), and had 25 or more years of experience (29.2%, $n = 124$). There also were optional demographic questions included in the dataset, with most items having 408 or 409 responses. The data indicate that most respondents were women (80.6%, $n = 329$ of 408) who worked in hospitals (58.4%, $n = 239$ of 409) and served adult and pediatric patients (77.5%, $n = 317$ of 409) in a suburban setting (42.6%, $n = 174$ of 408). Data also showed that respondents were from 49 of 50 U.S. states.

Data Analyses

SPSS Statistics (IBM, version 26.0) was used for all data analyses. Descriptive statistics included means and standard deviations for continuous data. A series of 1-way analysis of variance (ANOVA) tests were performed to evaluate whether mean differences were present for a variety of dependent radiation safety culture-determinant variables based on shift length (H1 independent variable; 4 levels: < 8 hours; 8-9 hours, 10-11 hours, or ≥ 12 hours) or work shift (H2 independent variable; 4 levels: first shift or 12-hour days, second shift, third shift or 12-hour nights, or float). Hypothesis ($H_{null}: \mu_1 = \mu_2 = \mu_3 = \mu_4$, $H_{alt}: \mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4$) were evaluated with each dependent variable:

- H_{1a} and H_{2a} – Teamwork in imaging
- H_{1b} and H_{2b} – Teamwork across imaging
- H_{1c} and H_{2c} – Questioning attitude
- H_{1d} and H_{2d} – Feedback loops
- H_{1e} and H_{2e} – Organization learning
- H_{1f} and H_{2f} – Leadership actions
- H_{1g} and H_{2g} – Nonpunitive response
- H_{1h} and H_{2h} – Error reporting
- H_{1i} and H_{2i} – Radiation policy

The F ratio and its associated probability value (P value) were calculated. P values less than or equal to .05 resulted in the null hypothesis (H_0) being rejected, meaning that groups with the given variable differed with significance. Post hoc tests were carried out to determine the specific groups that differed for each significant F test result. The Games-Howell post hoc test was used in this study because of 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 as thresholds to report small, moderate, and large effects, respectively.⁶ Post hoc power also was considered at the threshold of .80 to determine the control for type II (false negative) error to detect a true difference.

Results

Mean differences in perception of teamwork across imaging stakeholders ($P < .001$) and leadership actions

($P = .001$) were found across shift-length groups. Mean differences in perception of teamwork across imaging stakeholders ($P = .007$) were found across work-shift groups.

Descriptive Statistics

Across the determinants of radiation safety culture, regardless of shift length, radiologic technologists rated teamwork in imaging most favorably (see **Table 1**). Radiologic technologists working less than 8-hour shifts had the most favorable perceptions of radiation safety culture, with 5 of the 9 determinants exceeding a mean score of 4.0. Those working 8- to 9-hour shifts had lower perceptions of radiation safety, with teamwork in imaging and leadership actions exceeding a mean determinant score of 4.0; those working 10- to 11-hour shifts and 12-hour or longer shifts rated teamwork in imaging with a mean score above 4.0. All 4 shift-length groups rated the categories of error reporting and nonpunitive response as least favorable. **Table 2** reports complete descriptive data for shift length.

Table 1

Rank Order of Determinant Favorability by Shift Length

Rank	< 8 hours	8-9 hours	10-11 hours	≥ 12 hours
1	Teamwork in imaging (M = 4.37)	Teamwork in imaging (M = 4.25)	Teamwork in imaging (M = 4.12)	Teamwork in imaging (M = 4.13)
2	Questioning attitude (M = 4.17)	Leadership actions (M = 4.08)	Radiation policy (M = 3.84)	Questioning attitude (M = 3.75)
3	Leadership actions (M = 4.14)	Teamwork across imaging stakeholders (M = 3.98)	Questioning attitude (M = 3.82)	Radiation policy (M = 3.74)
4	Radiation policy (M = 4.14)	Questioning attitude (M = 3.96)	Teamwork across imaging stakeholders (M = 3.76)	Leadership actions (M = 3.72)
5	Teamwork across imaging stakeholders (M = 4.12)	Radiation policy (M = 3.96)	Leadership actions (M = 3.76)	Teamwork across imaging stakeholders (M = 3.57)
6	Organizational learning (M = 3.89)	Feedback loops (M = 3.72)	Organizational learning (M = 3.60)	Organizational learning (M = 3.55)
7	Feedback loops (M = 3.85)	Organizational learning (M = 3.72)	Feedback loops (M = 3.54)	Feedback loops (M = 3.55)
8	Error reporting (M = 3.61)	Nonpunitive response (M = 3.49)	Nonpunitive response (M = 3.28)	Nonpunitive response (M = 3.24)
9	Nonpunitive response (M = 3.38)	Error reporting (M = 3.30)	Error reporting (M = 3.22)	Error reporting (M = 3.23)

Table 2

Descriptive Statistics for Radiation Safety Culture Determinants by Shift length

Shift length, h ^a	M (SD)	SE	95% CI
Teamwork in imaging			
< 8	4.37 (0.53)	0.11	4.13 - 4.60
8-9	4.25 (0.76)	0.05	4.16 - 4.35
10-11	4.12 (0.67)	0.09	3.95 - 4.30
≥ 12	4.13 (0.90)	0.10	3.93 - 4.34
Total	4.22 (0.76)	0.04	4.15 - 4.29
Teamwork across imaging stakeholders			
< 8	4.12 (0.59)	0.13	3.85 - 4.39
8-9	3.98 (0.76)	0.05	3.80 - 4.07
10-11	3.76 (0.79)	0.10	3.56 - 3.97
≥ 12	3.57 (0.91)	0.10	3.37 - 3.78
Total	3.88 (0.80)	0.04	3.81 - 3.96
Questioning attitude			
< 8	4.17 (0.68)	0.15	3.87 - 4.48
8-9	3.96 (0.74)	0.05	3.87 - 4.05
10-11	3.82 (0.80)	0.10	3.62 - 4.03
≥ 12	3.75 (0.94)	0.11	3.54 - 3.96
Total	3.92 (0.79)	0.04	3.84 - 3.99
Feedback loops			
< 8	3.85 (0.99)	0.22	3.40 - 4.31
8-9	3.72 (1.08)	0.07	3.59 - 3.85
10-11	3.54 (1.03)	0.13	3.27 - 3.81
≥ 12	3.55 (1.17)	0.13	3.29 - 3.82
Total	3.67 (1.08)	0.05	3.56 - 3.77
Organizational learning			
< 8	3.89 (0.55)	0.12	3.64 - 4.14
8-9	3.72 (0.75)	0.05	3.63 - 3.81
10-11	3.60 (0.75)	0.10	3.40 - 3.79
≥ 12	3.55 (0.89)	0.10	3.35 - 3.75
Total	3.68 (0.77)	0.04	3.61 - 3.75

Similar outcomes were observed in the descriptive statistics from work-shift groups, with teamwork in imaging having the highest mean score and

Shift length, h ^a	M (SD)	SE	95% CI
Leadership actions			
< 8	4.14 (0.63)	0.14	3.86 - 4.43
8-9	4.08 (0.74)	0.05	3.99 - 4.17
10-11	3.76 (0.83)	0.11	3.54 - 3.97
≥ 12	3.72 (0.99)	0.11	3.50 - 3.95
Total	3.97 (0.81)	0.04	3.89 - 4.05
Nonpunitive response			
< 8	3.38 (1.01)	0.22	2.92 - 3.84
8-9	3.49 (0.83)	0.05	3.39 - 3.59
10-11	3.28 (0.97)	0.13	3.03 - 3.53
≥ 12	3.24 (0.88)	0.10	3.04 - 3.44
Total	3.41 (0.87)	0.04	3.32 - 3.49
Error reporting			
< 8	3.61 (1.02)	0.22	3.15 - 4.08
8-9	3.30 (1.06)	0.06	3.17 - 3.42
10-11	3.22 (1.00)	0.13	2.96 - 3.48
≥ 12	3.23 (1.03)	0.12	2.99 - 3.46
Total	3.29 (1.04)	0.05	3.19 - 3.39
Radiation policy			
< 8	4.14 (0.58)	0.13	3.88 - 4.40
8-9	3.96 (0.74)	0.05	3.87 - 4.05
10-11	3.84 (0.74)	0.10	3.65 - 4.03
≥ 12	3.74 (0.84)	0.10	3.55 - 3.93
Total	3.91 (0.76)	0.04	3.84 - 3.98

^a Less than 8 h, n = 21; 8-9 h, n = 267; 10-11 h, n = 59; ≥ 12 h, n = 78; total, N = 425.

Abbreviation: CI, confidence interval.

error reporting and nonpunitive response having the lowest mean scores across work-shift groups (see Tables 3 and 4).

Radiation Safety Culture Based on Shift Length

One-way ANOVA test results demonstrate that shift length groups had a mean difference in the means for 2 of the 9 dependent variables (see Table 5). The significant variables included teamwork across

Table 3

Rank Order of Determinant Favorability by Work Shift

Rank	First shift or days on 12-hour shift	Second shift	Third shift or nights on 12-hour shift	Float or no defined primary shift
1	Teamwork in imaging (M = 4.24)	Teamwork in imaging (M = 4.03)	Teamwork in imaging (M = 4.09)	Teamwork in imaging (M = 4.39)
2	Leadership actions (M = 4.00)	Questioning attitude (M = 3.88)	Radiation policy (M = 3.84)	Radiation policy (M = 4.23)
3	Teamwork across imaging stakeholders (M = 3.95)	Leadership actions (M = 3.84)	Questioning attitude (M = 3.73)	Leadership actions (M = 4.05)
4	Questioning attitude (M = 3.94)	Radiation policy (M = 3.79)	Leadership actions (M = 3.71)	Feedback loops (M = 3.92)
5	Radiation policy (M = 3.90)	Feedback loops (M = 3.68)	Teamwork across imaging stakeholders (M = 3.55)	Organizational learning (M = 3.92)
6	Organizational learning (M = 3.69)	Teamwork across imaging stakeholders (M = 3.64)	Organizational learning (M = 3.52)	Teamwork across imaging stakeholders (M = 3.89)
7	Feedback loops (M = 3.67)	Organizational learning (M = 3.54)	Feedback loops (M = 3.44)	Questioning attitude (M = 3.88)
8	Nonpunitive response (M = 3.46)	Nonpunitive response (M = 3.38)	Error reporting (M = 3.20)	Error reporting (M = 3.54)
9	Error reporting (M = 3.29)	Error reporting (M = 3.14)	Nonpunitive response (M = 3.08)	Nonpunitive response (M = 3.38)

imaging stakeholders ($F_{3,424} = 6.49, P < .001$) and leadership actions ($F_{3,424} = 5.87, P = .001$). Mean differences in teamwork in imaging, questioning attitude, feedback loops, organizational learning, nonpunitive response, error response, and radiation policy were not observed in shift-length groups at the level of $P \leq .05$. Effect size also is reported in Table 5, with shift length having a small effect on the perception of teamwork across imaging stakeholders and leadership actions. The observed power for both variables was deemed acceptable ($> .80$).

Games-Howell post hoc tests were conducted to determine which groups differed for each significant F test result (see Table 6). Post hoc tests revealed significant differences in teamwork across imaging stakeholder scores between radiologic technologists working less than 8-hour shifts ($M = 4.37, SD = .53$) and those working 12-hour shifts or longer ($M = 4.13, SD = .90$), along with radiologic technologists working 8- to 9-hour shifts ($M = 4.25, SD = .76$) and those

working 12-hour shifts or longer. Post hoc tests also revealed significant differences in leadership action scores between radiologic technologists working 8- to 9-hour shifts ($M = 4.08, SD = .74$) and those working 10- to 11-hour shifts ($M = 3.76, SD = .83$), along with significant differences between those working 8- to 9-hour shifts and radiologic technologists working 12-hour shifts or longer ($M = 3.72, SD = .99$).

Radiation Safety Culture Based on Work Shift

One-way ANOVA test results demonstrate that work-shift groups had a mean difference between them in 1 of the 9 dependent variables: teamwork across imaging stakeholders ($F_{3,408} = 4.07, P = .007$). The data, including effect size, are reported in Table 7. Work shift had a small effect on teamwork across imaging stakeholders. Further, the observed power for the teamwork across imaging stakeholder variable was also deemed acceptable (0.84). Mean differences in teamwork in imaging, questioning attitude, feedback

Table 6

Games-Howell Post Hoc Test Results for Shift Length

Shift length, h	Mean difference	SE	P value	95% CI	
Teamwork across imaging stakeholders					
< 8	8-9	0.14	0.14	.722	-0.23 - 0.52
	10-11	0.36	0.17	.142	-0.08 - 0.80
	≥ 12	0.55 ^a	0.17	.009	0.11 - 0.99
8-9	< 8	-0.14	0.14	.722	-0.52 - 0.23
	10-11	0.22	0.11	.226	-0.08 - 0.51
	≥ 12	0.41 ^a	0.11	.003	0.11 - 0.70
10-11	< 8	-0.36	0.17	.142	-0.80 - 0.08
	8-9	-0.22	0.11	.226	-0.51 - 0.08
	≥ 12	0.19	0.15	.561	-0.19 - 0.57
≥ 12	< 8	-0.55 ^a	0.17	.009	-0.99 - -0.11
	8-9	-0.41 ^a	0.11	.003	-0.70 - -0.11
	10-11	-0.19	0.15	.561	-0.57 - 0.19
Leadership actions					
< 8	8-9	0.06	0.14	.970	-0.33 - 0.46
	10-11	0.39	0.18	.137	-0.08 - 0.85
	≥ 12	0.42	0.18	.097	-0.05 - 0.89
8-9	< 8	-0.06	0.14	.970	-0.46 - 0.33
	10-11	0.32 ^a	0.12	.038	0.01 - 0.63
	≥ 12	0.36 ^a	0.12	.021	0.04 - 0.67
10-11	< 8	-0.39	0.18	.137	-0.85 - 0.08
	8-9	-0.32 ^a	0.12	.038	-0.63 - -0.01
	≥ 12	0.03	0.16	.996	-0.37 - 0.44
≥ 12	< 8	-0.42	0.18	.097	-0.89 - 0.05
	8-9	-0.36 ^a	0.12	.021	-0.67 - -0.04
	10-11	-0.03	0.16	.996	-0.44 - 0.37

^a The mean difference is significant at the P = .05 level.

and teaching is being emphasized,¹³ widespread efforts to apply collaborative interdisciplinary teaching and learning practices are needed to enhance radiation safety in the clinical setting.

Similarly, the actions and expectations of leaders are well known to influence the behavior of their subordinates, so a relatively lax attitude from leadership—perhaps in the service of doing more with less under conditions of marginal or inadequate levels of

staffing—might contribute to undesirable downstream effects. Leaders often establish cultural norms in an organization, and their actions can serve to enhance adherence to best practices in radiation safety. This study demonstrates that enhanced leadership is needed to support radiologic technologists who work longer shifts and night shifts to improve perceptions of radiation safety practices in the workplace.

Four T's of Leadership

The World Health Organization indicates that the 4 T's of leadership (truth, trust, teamwork, and training) can be used to improve radiation safety culture.¹⁴ That framework aligns with the findings in this study that suggest positive perceptions of teamwork across imaging stakeholders and leadership actions are diminished with longer shift lengths, and, likewise, teamwork across imaging stakeholders across work shifts. Leader presence, engagement, and collaborative actions are critical elements for achieving a positive and effective radiation safety culture. Radiologic technologists must be able to bring forward challenges and concerns and trust that leaders will follow through with appropriate actions. Teams must collaborate to analyze radiation safety challenges and formulate quality improvement action plans. Fostering a radiation safety culture necessitates that leaders develop and facilitate trust, collaborate, provide positive and critical appraisal, and communicate between imaging stakeholder groups. Day shift staffing models naturally allow for better collaboration because of the physical presence of leaders and various imaging stakeholders, but presence alone does not equal intentionality. Leaders must be deliberate in their actions and prioritize efforts to improve radiation safety. It is understood that distancing of imaging stakeholders has occurred throughout the digital imaging era,¹⁵ but this study confirms that shorter shifts and day shifts perceive the collaboration to be more acceptable than those working outside of usual business hours.

Although this study focused on work shifts, findings demonstrate the importance of the 4 T's described by the World Health Organization. Of course, every environment and clinical situation is different, but collaboration, ongoing training and development, and truth-driven improvement strategies are necessary to foster optimal radiation safety cultures.

Table 7

One-way ANOVA Results for Work Shift

Dependent Variable	F _{3,408}	P value	Outcome	Adjusted R ²	Effect size	Observed power
Teamwork in imaging	1.52	.208	Fail to reject	0.004	-	0.40
Teamwork across imaging stakeholders	4.07	.007	Reject null	0.022	Small	0.84
Questioning attitude	0.87	.457	Fail to reject	-0.001	-	0.24
Feedback loops	1.09	.352	Fail to reject	0.001	-	0.30
Organizational learning	1.87	.135	Fail to reject	0.006	-	0.48
Leadership actions	1.79	.149	Fail to reject	0.006	-	0.47
Nonpunitive response	2.14	.095	Fail to reject	0.008	-	0.54
Error reporting	0.91	.438	Fail to reject	-0.001	-	0.25
Radiation policy	2.37	.070	Fail to reject	0.010	-	0.59

Table 8

Games-Howell Post Hoc Test Results for Work Shift

Shift	Mean difference	SE	P value	95% CI	
Teamwork across imaging stakeholders					
First shift or days on 12-hour shift	Second shift	0.31	0.18	.330	-0.18 - 0.80
	Third shift or nights on 12-hour shift	0.40 ^a	0.14	.035	0.02 - 0.79
	Float or I do not have a defined primary shift	0.07	0.18	.981	-0.42 - 0.55
Second shift	First shift or days on 12-hour shift	-0.31	0.18	.330	-0.80 - 0.18
	Third shift or nights on 12-hour shift	0.09	0.22	.975	-0.49 - 0.68
	Float or I do not have a defined primary shift	-0.24	0.25	.763	-0.90 - 0.41
Third shift or nights on 12-hour shift	First shift or days on 12-hour shift	-0.40 ^a	0.14	.035	-0.79 - -0.02
	Second shift	-0.09	0.22	.975	-0.68 - 0.49
	Float or I do not have a defined primary shift	-0.33	0.22	.437	-0.92 - 0.25
Float or I do not have a defined primary shift	First shift or days on 12-hour shift	-0.07	0.18	.981	-0.55 - 0.42
	Second shift	0.24	0.25	.763	-0.41 - 0.90
	Third shift or nights on 12-hour shift	0.34	0.22	.437	-0.25 - 0.92

^a The mean difference is significant at the P = .05 level.**Limitations**

It is impossible to control for all variables that might affect the study population and tend to affect the study's population means. Thus, caution must be taken when attributing causes to the effects the authors report. In addition, all data were self-reported, making recall bias and social-desirability bias possible.

Future Research

There are many aspects to the after-hours working environment that might have a role in the observed results. For example, workers who are tasked with covering shifts occasionally outside of their usual diurnal rhythm might experience greater fatigue and disorientation than will those who work after-hours shifts

regularly.^{16,17} Effects of fatigue on performance are greater for less-experienced workers.^{18,19} Correlating the perception of how well staffing levels meet demand also might be a factor. In future work, these factors can be assessed separately.

Conclusion

Intentional engagement by leaders and stakeholder teams across work shifts and various shift lengths is likely critical to improving radiation safety practices in settings where radiologic technologists work long and after-hours shifts. The authors' results show a decline in the perception of teamwork and leadership actions during such times. Although further work is needed to tease out the specific issues that underlie these results, it seems clear that managers and institutional leaders must place a greater emphasis on cultivating and maintaining the safety culture in their organizations for after-hours workers, especially those who work extended shifts. In addition to consistent messaging from leadership, specific efforts toward teamwork-building and in-service education on radiation safety best practices are needed.

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References

- Smith-Bindman R, Kwan ML, Marlow EC, et al. Trends in use of medical imaging in US health care systems and in Ontario, Canada, 2000-2016. *JAMA*. 2019;322(9):843-856. doi:10.1001/jama.2019.11456
- Moore QT, Walker DA, Frush DP, Daniel M, Pavkov TW. Intrapersonal and institutional influences on overall perception of radiation safety among radiologic technologists. *Radiol Technol*. 2022;93(3):255-267.
- Moore QT. Validity and reliability of a radiation safety culture survey instrument for radiologic technologists. *Radiol Technol*. 2021;92(6):547-560.
- Moore QT. Determinants of overall perception of radiation safety among Radiologic Technologists. *Radiol Technol*. 2021;93(1):8-24.
- Moore QT. *Radiation Actions and Dimensions of Radiation Safety Among US Radiologic Technologists*. Dissertation. Northern Illinois University; 2020.
- Cohen J. *Statistical power analysis for the behavioral sciences*. 2nd ed. Routledge; 1988.
- Moore Q. TeamSTEPPS: addressing imaging procedure appropriateness. *Radiol Technol*. 2017;88(5):550-555.
- Gupta RT, Sexton JB, Milne J, Frush DP. Practice and quality improvement: successful implementation of TeamSTEPPS tools into an academic interventional ultrasound practice. *AJR Am J Roentgenol*. 2015;204(1):105-110. doi:10.2214/AJR.14.12775
- Rosen MA, DiazGranados D, Dietz AS, et al. Teamwork in healthcare: key discoveries enabling safer, high-quality care. *Am Psychol*. 2018;73(4):433-450. doi:10.1037/amp0000298
- Lacerenza CN, Marlow SL, Tannenbaum SI, Salas E. Team development interventions: evidence-based approaches for improving teamwork. *Am Psychol*. 2018;73(4):517-531. doi:10.1037/amp0000295
- Nancarrow SA, Booth A, Ariss S, Smith T, Enderby P, Roots A. Ten principles of good interdisciplinary team work. *Hum Resour Health*. 2013;11(19). doi:10.1186/1478-4491-11-19
- Burns J, Agarwal V, Jordan SG, Dallaghan GLB, Byerley JS. Interprofessional education - a mandate for today's radiology curriculum. *Acad Radiol*. 2022;29(suppl 5):S89-S93. doi:10.1016/j.acra.2021.05.019
- Saul D. What it means 'to teach' as a radiologist in the modern era: a personal perspective. *Pediatr Radiol*. 2018;48(10):1381-1387. doi:10.1007/s00247-018-4201-1
- World Health Organization. Radiation risk communication in paediatric imaging. Global Initiative on Radiation Safety in Health Care Settings Workshop Report; Dec. 2 2012; Bonn, Germany.
- DeMaio DN, Herrmann T, Noble LB, et al. *Best Practices in Digital Radiography*. American Society of Radiologic Technologists; 2019.
- Bruno MA. Radiology errors across the diurnal cycle. *Radiology*. 2020;297(2):380-381. doi:10.1148/radiol.2020202902
- Patel AG, Pizzitola VJ, Johnson CD, Zhang N, Patel MD. Radiologists make more errors interpreting off-hours body CT studies during overnight assignments as compared with daytime assignments. *Radiology*. 2020;297(2):374-379. doi:10.1148/radiol.2020201558
- Stec N, Arje D, Moody AR, Krupinski EA, Tyrrell PN. A systematic review of fatigue in radiology: is it a problem? *AJR Am J Roentgenol*. 2018;210(4):799-806. doi:10.2214/AJR.17.18613
- Hanna TN, Zygmunt ME, Peterson R, et al. The effects of fatigue from overnight shifts on radiology search patterns and diagnostic performance. *J Am Coll Radiol*. 2018;15(12):1709-1716. doi:10.1016/j.jacr.2017.12.019