Factors Affecting Gonadal Shielding Use Among Technologists in California

Raymond T Ranada, MSRIS, R.T.(R)
Elwin Tilson, EdD, R.T.(R)(M)(QM)(CT), FAEIRS
Kevin Clark, EdD, R.T.(R)(QM), FASRT, FAEIRS

Purpose To assess the patient gonadal shielding practices of radiologic technologists in the state of California.

Methods A survey invitation was sent via email to registered radiologic technologists in California to collect data to determine whether there were significant associations between gonadal shielding practices and various categorical variables, including patient sex, patient age, body part, availability of gonadal shielding protocols, availability of gonadal shields, and supervisor encouragement.

Results There was a significant association between gonadal shielding protocol availability and supervisor encouragement of using gonadal shielding ($P = .005$) and between gonadal shielding availability and supervisor encouragement of using gonadal shielding ($P < .001$). Contrary to other studies in the literature, there was a significant difference between patient sex and the likelihood of gonadal shielding use, with participants indicating that they shield girls and women more often than they shield boys and men ($P < .001$).

Discussion There was a sex-based difference in the frequency of gonadal shielding usage among the sample in this study. Also, supervisors providing accessible protocols and encouraging gonadal shielding can increase technologists' use of gonadal shielding.

Conclusion Gonadal shielding is the current Code of Federal Regulations standard, although most professional and scientific organizations support discontinuing shielding during abdominal and pelvic radiography examinations. Shielding of these areas is more likely to occur with the availability of gonadal shielding, supervisory encouragement, protocols mandating shielding, and state regulations.

Keywords | *radiologic technologists, gonadal shielding, organ shielding, radiation protection, good practice, diagnostic radiography*

The use of gonadal shielding for abdominal and pelvic radiography has been debated in the literature[1] and is addressed explicitly in an article in *Medical Physics* in 2019 by McKenney et al.[2] Based on the consensus of recent research studies on gonadal shielding, in 2021 the National Council on Radiation Protection and Measurements proposed a recommendation for ending routine gonadal shielding during abdominal and pelvic radiography.[3] In the United States, there is no federal requirement to use or not use gonadal shielding. Multiple organizations have made recommendations regarding gonadal shielding usage. Almost all organizations support discontinuation of the recommendation to shield during abdominal and pelvic radiography.[4-9] The Code of Federal Regulations still recommends gonadal shielding for examinations that meet certain requirements, implying use for abdominal and pelvic studies.[10] The regulations state:

> *Such [gonadal] shielding should be provided when the following conditions exist: (a) The gonads will lie within the primary x-ray field, or within close proximity (about 5 centimeters), despite proper beam limitation.*[10]

The literature lists sex, age, length of practice, reproductive status of the patient, and education as some

of the contributing factors in radiation safety decision processes by technologists.[11-16] However, after multiple searches using different parameters, no articles were found in the literature listing the frequency of gonadal shielding in the United States or the practice patterns related to gonadal shielding. Articles found in journals from Europe, Nigeria, Australia, and Oman addressed the factors influencing gonadal shielding.[11-16]

According to the American Registry of Radiologic Technologists (ARRT), as of 2021, there are 252 152 female and 96 215 male registered radiologic technologists (personal communication, April 13, 2021). The technologist's sex has a role in the application of gonadal shielding, according to MacKay et al.[14] In Australia, the scope of practice for staff technologists is like that in the United States. Their study found that female technologists typically will not forgo shielding in difficult situations, such as uncooperative patients or multiple attachments on patient, and that women tend to have more empathetic feelings and conscientiousness in shielding placement than do their male counterparts.[14] MacKay et al also found men are more likely to forgo patient shielding because of challenging situations and emphasize increasing efficiency.[14] According to Miller, empathy has a part in clinical practice in radiologic technology.[17] Studies in other health professions find similar results. In a study on empathy among U.S. medical students, results showed that male empathy is lower on all scales compared with female empathy. The study found that empathy contributes to the difference in approach to patient care between sexes.[18]

Years of professional experience also might influence a technologist's attitude toward patient shielding. Some studies show that experience might hinder adapting to new standards, with the attitude of "it has always been done this way" setting in, and individuals might become complacent with years of experience.[11,14,19,20] However, other studies contradict these findings, showing that more experienced staff have better radiation safety practices than do their younger colleagues. A meta-analysis in 2017 by Karami et al found that years of experience did not adversely affect radiation safety.[21] And, according to the 2018 study by Shaban et al, increasing years of experience and age brings better radiation safety practices.[15]

Educational background has a role in the practices of technologists as well. According to Shanley and Mathews, educators in undergraduate radiography programs strongly agree with the use of gonadal shielding for organs with high radiosensitivity, coinciding with the correlation between education and the attitude toward patient shielding.[1] A study by Tilson found radiation safety behaviors improved with additional education.[20] In addition, MacKay et al stated that technologists with bachelor's and master's degrees emphasize the importance of shielding more often than do other groups, suggesting that higher education degrees positively correlate to the extent of gonadal shielding.[14] Historically, technologists with a collegiate background are more consistent in radiation safety behavior than are certificate-trained technologists.[20]

New recommendations to discontinue gonadal shielding are due, in part, to the International Commission on Radiological Protection studies suggesting that gonads are far less radiosensitive than previously believed[22] and that gonadal dose has been reduced by 95% since the 1950s.[3] Even though this creates contradictions in the use of shielding, gonadal shielding is observed as a best practice by many based on research they conducted.[15,19,23] Few of these discussions include information about current technologists' practices. Therefore, this research focuses on how gonadal shielding is used by technologists in California. The research questions for this study were:

1. What are registered technologists' fetal and gonadal shielding practices?
2. Are gonadal shields and protocols available in technologists' respective departments?
3. Does encouragement by supervisors affect the practice of gonadal shielding?
4. Are there significant associations between the availability of gonadal shielding protocols, supervisors' encouragement, and gonadal shielding?
5. Is there a significant difference between technologists' likelihood of shielding female patients compared with male patients?

Methods

This study followed a nonexperimental survey design. Data collection was through an email invitation

to an electronic survey on the use of gonadal shielding. No suitable survey instrument was located in the literature, so the researchers developed a 25-question survey based on the survey questions used by MacKey et al.[14] The survey included multiple-choice and 4-point scale questions about age, sex, years of experience, education level, likelihood of using gonadal shielding in specific examinations, and rationale if shielding was not typically used. The questionnaire also included questions about perceived support for using gonadal shielding from the department leaders and availability of protection equipment. The survey was reviewed by 1 expert for content and then pretested by administering it to 5 radiographers. After revisions, the survey, study design, and procedures to ensure participants' confidentiality and protection of data collected were approved by the California State University, Dominguez Hills, Institutional Review Board. Informed consent was obtained on the first page of the survey.

The survey was submitted to the ARRT for review, and a simple random sampling of 50% of technologists meeting the inclusion criteria was generated. The inclusion criteria for this study were being currently registered in radiography by the ARRT, listing radiography as primary activity, and having a California permanent address. This generated a list of 1116 email addresses for registered radiologic technologists in the state of California. The survey was distributed in May 2021 with a deadline of 10 calendar days after the initial distribution. A second email was sent 4 days before the deadline as a reminder.

Statistical Analysis

The data collected from each participant were analyzed using SPSS Statistics version 28.0.0.0 (IBM) for descriptive and inferential statistics. Cross-tabulations were used to demonstrate associations between the categorical variables, and a chi-square test was calculated to determine significance. An alpha level of .05 was used for the chi-square calculations to determine whether a significant association existed. Cramér's V was used to determine the strength of those significant associations, with 0.01 as small, 0.03 as medium, and 0.05 as large.

The likelihood to shield responses (1 = never; 2 = rarely; 3 = often; 4 = always) were totaled for the 5 male age groups and the 5 female age groups. A dependent-sample *t* test was calculated to determine whether a significant difference existed between the likelihood of shielding male patients compared with female patients. The significance level was set at .05. For the dependent-sample *t* test, a priori power analysis revealed a minimum sample size of 54 was needed to test for significance at .05 and power of .95.

Results

A total of 1116 email questionnaires were distributed to technologists registered in California. The survey was available for 10 days, and 143 surveys were returned. Of those, 33 were excluded as incomplete. There were 110 valid responses returned, yielding a 9.9% return rate. A sample size of 110 results in a margin of error of ± 9.3% at a 95% confidence level. Not all questions were answered by all 110 participants; statistical values were based on the number of responses instead of the total number of valid returns.

The question regarding sex of participants had 109 respondents, including 60 (55.0%) men, 48 (44.0%) women, and 1 (0.9%) rather not say (see **Table 1**). The education level of 109 respondents was predominantly associate degree (64 respondents [58.7%]), followed by bachelor's degree (29 [26.6%]), with master's degree and certificate program yielding 8 (7.3%) each. Employment was mainly at trauma hospitals (37 respondents [33.6%]) and community hospitals (36 respondents [32.7%]). Outpatient imaging centers represented 28.2% (31) of the total, while 6 (5.5%) were employed at federal government hospitals. Years of experience yielded 39 respondents (35.5%) with 0 to 5 years, followed by 24 (21.8%) with 21 years or more in the profession. Sixteen technologists (14.5%) had 6 to 10 years of experience, 21 (19.1%) had 11 to 15 years, and 10 technologists (9.1%) had 16 to 20 years.

Question 1: Current Fetal and Gonadal Shielding Practices

Research question 1 asked what registered technologists' current fetal and gonadal shielding practices are and received 110 responses. Participants were

Table 1

Demographics of Respondents[a]

Characteristic	n (%)
Sex	
Male	60 (55.0)
Female	48 (44.0)
I'd rather not say	1 (0.9)
Education	
Certificate program	8 (7.3)
Associate degree	64 (58.7)
Bachelor's degree	29 (26.6)
Master's degree	8 (7.3)
Type of facility	
Private or public trauma center hospital	37 (33.6)
Community hospital (nontrauma)	36 (32.7)
Federal government hospital	6 (5.5)
Outpatient imaging	31 (28.2)
Experience, y	
0-5	39 (35.5)
6-10	16 (14.5)
11-15	21 (19.1)
16-20	10 (9.1)
≥ 21	24 (21.8)

[a] *N = 109 for sex and education; N = 110 for type of facility and experience.*

asked to rate their usage of gonadal shielding ranging from always to never for chest, abdomen, pelvis, lumbar spine, and extremities radiography (1 = never; 2 = rarely; 3 = often; 4 = always). Overall, gonadal shielding was most common for chest and extremity radiography and least common for pelvic radiography. **Table 2** summarizes the questionnaire data on the likelihood of gonadal shielding application by body part.

Table 3 summarizes data regarding frequency of shielding for male and female patients of different ages. The frequency data collected exhibited the questionnaires' means and standard deviations. There were no significant findings or outliers reported in the mean. However, the standard deviation indicated a wide variance, from 0.69 at the lowest value to 1.01 at the highest value, indicating a high variation in the survey answers.

Table 2

Frequency of Gonadal Shielding Placement by Body Part

Body part	Mean (SD)
Pelvis	2.11 (0.89)
Abdomen	2.47 (0.97)
Lumbar spine	2.63 (1.02)
Extremities	3.32 (0.90)
Chest	3.27 (0.92)

Table 3

Frequency of Gonadal Shielding Placement by Sex And Age

Patient age, y	Mean (SD)
Female	
0-19	3.70 (0.69)
20-39	3.62 (0.72)
40-59	3.17 (0.88)
60-79	2.37 (0.98)
≥ 80	2.02 (1.00)
Male	
0-19	3.54 (0.77)
20-39	3.42 (0.90)
40-59	2.98 (0.90)
60-79	2.33 (1.01)
≥ 80	2.06 (1.01)

The survey also asked the respondents their rationale for not using gonadal shielding when encountering potential challenges (see **Table 4**). The most common reason for not using gonadal shielding was concern about obscuring parts of interest, which 62 (56.4%) respondents cited. Concerns about infection transfer and uncertainty about shield placement were the next 2 most common reasons cited, by 12% and 9% of respondents, respectively.

Question 2: Availability of Shielding Protocols

Research question 2 asked whether shielding protocols were available in technologists' respective departments. Among 110 responses, 77.3% (85)

Table 4

Frequency of Rationales for Not Using Gonadal Shielding

Rationale	Mean (SD)
Obscuring the potential parts of interest	3.32 (0.92)
Uncooperative patient	2.43 (0.82)
Not confident in shield placement	2.15 (0.93)
Wheelchair patient	1.93 (0.75)
Female patient of childbearing age	2.02 (1.00)
Too busy	1.62 (0.82)
Infectious and isolation patient	2.31 (0.92)
Bed patient	1.95 (0.80)
Embarrassed to palpate anatomy	1.61 (0.87)
Language barrier	1.61 (0.87)

answered yes, 13.6% (15) answered no, and 9.1% (10) of the technologists were unaware. The likelihood of having gonadal shielding in the examination room was also asked. Among respondents, 73.6% (81) answered always, 20% (22) answered often, 2.7% (3) answered rarely, and 3.6% (4) answered never.

Question 3: Supervisor Encouragement

Research question 3 asked whether supervisors' encouragement affects the practice of gonadal shielding. Of 109 respondents, 53.2% (58) answered always, 16.5% (18) often, 16.5% (18) rarely, and 13.8% (15) answered never.

Question 4: Relationship Between Protocols, Encouragement, and Shielding

Research question 4 asked whether there are significant associations between the availability of gonadal shielding protocols, supervisors' encouragement, and gonadal shielding. Results from the chi-square test and cross-tabulations showed a significant association between the availability of gonadal shielding protocols and the supervisor's encouragement of respondents ($\chi^2_6 = 18.3$, $P = .005$). Cramér's V indicated a medium effect size (0.28). A significant association also was shown between gonadal shield availability in the department and supervisor encouragement ($\chi^2_9 = 34.2$, $P < .001$). The strength of this association, assessed by Cramér's V, was 0.38, suggesting a medium effect size.

Question 5: Difference in Shielding by Sex

Research question 5 asked whether there is a significant difference between technologists' likelihood of shielding female patients compared with male patients. A dependent-samples *t* test, or paired-samples *t* test, was calculated to determine whether there was a significant difference between the likelihood of shielding male patients (M = 14.3, SD = 3.7) and the likelihood of shielding female patients (M = 14.8, SD = 3.4). The results were significant ($t_{108} = -3.75$, $P < .001$), indicating participants in this study were more likely to shield female patients compared with male patients, but both groups were shielded frequently, with men and boys being shielded an average of 2.89 and women and girls being shielded 2.97 out of 4.0 (see **Table 5**).

Discussion

Several variables that influenced technologists' practice of gonadal shielding were consistent with past research.[14] The findings demonstrate a higher mean value of technologists shielding patients during chest and extremities radiography, which is consistent with findings from other studies.[14] Technologists report the possibility of shield artifacts during these examinations as a main reason they do not shield; therefore, technologists are more likely to use gonadal shielding if they know the shielding will not interfere with the images.

Table 5

Results of Paired-Samples Test

	Paired differences		95% CI of the difference				
Variable (Pair 1)	Mean (SD)	SEM	Lower	Upper	*t*	*df*	Significance (2-tailed)
MaleSum – FemaleSum	−0.54 (1.5)	0.14	−0.83	−0.26	−3.75	108	< .001

Abbreviations: CI, confidence interval; SEM, standard error of the mean.

That rationale aligns with this study's finding that the highest mean value for reasons to not shield compared with other variables was obscuring parts of interest.

Gonadal shielding is particularly important in female patients of childbearing age, younger male patients, and children because these groups are more sensitive to radiation.[18] The literature suggests the frequency of gonadal shielding on female patients should be lower than on male patients because of potentially obscuring essential structures in the pelvic area for women and girls during radiography.[14] However, the findings of this study did not reflect the literature.[21] Findings demonstrate a higher overall mean in technologists' likelihood of shielding female patients compared with shielding male patients in every age category. This is the opposite of the findings of a meta-analysis done by Karami et al.[21]

Literature related to gonadal shield rates is not from the United States; the contrast might be a result of differences in cultural, educational, or clinical norms. U.S. technologists could be more aware of the female reproductive system's sensitivity to ionizing radiation. This practice rationale is also reflected by a reverse correlation between the patient's age and mean values in shielding. Results from this study indicate that the higher the age of the patient, male or female, the lower the mean value in shielding, demonstrating that technologists are shielding younger patients and are less likely to use shielding for older patients.

A chi-square result showed a significant association between the availability of gonadal shielding protocols and supervisor encouragement of the participants ($P = .02$). This finding suggests that management encouragement and awareness of a gonadal shielding protocol in a department encourages technologists to use patient gonadal shielding. A possible explanation is people tend to look for individuals to follow and lead them. Technologists who have a supervisor that encourages shielding and who are aware of the proper systematic protocol try to use these resources more frequently.

Access to gonadal shielding in each examination room was found to be high, with 93.7% of respondents reporting that shields were always or often available to them. Using resources is easier when technologists are aware of them, and they are visible. A significant relationship was found between gonadal shield availability in the department and supervisor encouragement ($P < .001$). The availability of gonadal shielding in the departments influenced the respondents' intention to use it positively when a supervisor encouraged it. These findings are important because supervisor encouragement affects technologists' attitudes in using patient gonadal shielding. As the current recommendations are to not shield during pelvic or abdominal radiography, supervisors should clarify when the new recommendations call for gonadal shielding and when such shielding is a radiation safety risk.

There was a significant relationship in the likelihood of gonadal shielding application between male and female patients ($P < .001$). The study indicated that participants' shielding of female patients was significantly higher than that of male patients. This finding could be due to the respondents having predominantly 0 to 5 years (35.5%) and 21 or more years of experience (21.85%), which makes up more than 55% of the respondents. One possible reason for this significance is that younger technologists are more aware of the radiosensitivity of the female reproductive system due to having just completed their education, including theories on gonadal shielding. In contrast, studies show senior technologists are more aware of the importance of radiation protection from years of experience and continuing education.

Previous studies of technologists' practice of gonadal shielding emphasized sex, education, years of experience, and geographical location as the main factors that influence shielding application. However, the findings in this research indicate that supervisor encouragement also positively affects technologists' practice. Leadership involvement can cultivate a positive relationship with employees and encourage patient shielding. Rogers noted that people will follow the lead of those they know and trust.[24] Thus, supervisors providing protocols and gonadal shielding in every examination room would give a clear message to the department of the importance of appropriate shielding, potentially increasing the technologist's awareness and subsequent use of these resources. Supervisors emphasizing the importance of gonadal shielding to staff technologists could increase appropriate utilization

and highlight its importance to their practice. These recommendations can lead to consistency in practicing gonadal shielding and reduce overall patient dose from abdominal and pelvic radiography.

Limitations

One limitation of this study is a lack of inclusivity. For example, technologists not registered with the ARRT, such as limited license technicians, are excluded. A second limitation is the low return rate for the survey. Finally, survey research is associated with multiple other limitations, including the use of self-reported data and social desirability bias.

Conclusion

This study investigated the practice of technologists living in California as it relates to gonadal shielding. Leadership involvement can cultivate a positive relationship with employees and encourage appropriate patient shielding. Accessible protocols, gonadal shielding in examination rooms, and supervisors' encouragement deliver a clear message on the importance of shielding to the organization and can increase technologists' awareness of resources, with the expectation of using these assets when appropriate. However, protocols and policies should discourage the use of gonadal shielding during abdominal and pelvic radiography.

Raymond T Ranada, MSRIS, R.T.(R), is associate professor and clinical coordinator for the radiologic technology program at Cypress College in California.

Elwin Tilson, EdD, R.T.(R)(M)(QM)(CT), FAEIRS, is professor and graduate coordinator for the online Master of Science in Radiologic and Imaging Sciences program at California State University, Dominguez Hills, in Carson.

Kevin Clark, EdD, R.T.(R)(QM), FASRT, FAEIRS, is associate professor and associate director for the School of Health Professions at The University of Texas MD Anderson Cancer Center in Houston. He also is founder and CEO of CW Elite, LLC, a professional editing and consulting company.

Received June 28, 2022; accepted after revision July 10, 2023.

Reprint requests may be mailed to the American Society of Radiologic Technologists, Publications Department, 15000 Central Ave SE, Albuquerque, NM 87123-3909, or emailed to publications@asrt.org.

References

1. Shanley C, Matthews K. A questionnaire study of radiography educator opinions about patient lead shielding during digital projection radiography. *Radiography (Lond).* 2018;24(4):328-333. doi:10.1016/j.radi.2018.04.001
2. McKenney S, Gingold E, Zaidi H. Gonadal shielding should be discontinued for most diagnostic imaging exams. *Med Phys.* 2019;46(3):1111-1114. doi:10.1002/mp.13409
3. *NCRP Recommendations for Ending Routine Gonadal Shielding During Abdominal and Pelvic Radiography NCRP Statement No. 13, January 12, 2021.* National Council on Radiation Protection and Measurements [NCRP]; 2021. https://w3.aapm.org/cares/documents/NCRPStatementNo13.pdf
4. AAPM position statements, policies and procedures – details. American Association of Physicists in Medicine. Published April 2, 2019. Accessed March 20, 2023. https://www.aapm.org/org/policies/details.asp?id=468&type=PP&current=true
5. ACR endorses AAPM position on patient gonadal and fetal shielding. American College of Radiology. Published July 6, 2021. Accessed March 20, 2023. https://www.acr.org/Lifelong-Learning-and-CME/Learning-Activities/Gonadal-and-Fetal-Shielding
6. COMP endorses AAPM position on patient gonadal and fetal shielding. Canadian Organization of Medical Physics. Published 2019. Accessed March 20, 2023. https://comp-ocpm.ca/_uploads/5jmw0vk0t.pdf
7. HPS Endorse the AAPM Regarding the Use Gonadal Shielding. Health Physics Society. Published 2019. Accessed March 20, 2023. http://hps.org/physicians/documents/hps_aapm_fetal_gonadal_shielding_10-09-19.pdf
8. AAPM position statement on the use of patient gonadal and fetal shielding. The Australasian College of Physical Scientists and Engineers in Medicine. Published 2019. Accessed April 13, 2021. https://www.acpsem.org.au/Latest-News/2019-2020/AAPM-Position-Statement-on-the-Use-of-Patient-Gonadal-and-Fetal-Shielding
9. Endorsement statement: AAPM gonadal shielding position. Image Gently. Published 2019. Accessed March 25, 2021. https://www.imagegently.org/Portals/6/Endorsement%20Statement.pdf
10. Code of Federal Regulations. 21 C.F.R. §1000.50 (1976). Published 1976. Accessed March 20, 2023. https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=1000.50
11. Borges CF, Reggio E, Vicentini FC, Reis LO, Carnelli GR, Fregonesi A. How are we protecting ourselves from

radiation exposure? A nationwide survey. *Int Urol Nephrol.* 2015;47(2):271-274. doi:10.1007/s11255-014-0882-z

12. Eze CU, Abonyi LC, Njoku J, Irurhe NK, Olowu O. Assessment of radiation protection practices among radiographers in Lagos, Nigeria. *Niger Med J.* 2013;54(6):386-391. doi:10.4103/0300-1652.126290
13. Faggioni L, Paolicchi F, Bastiani L, Guido D, Caramella D. Awareness of radiation protection and dose levels of imaging procedures among medical students, radiography students, and radiology residents at an academic hospital: results of a comprehensive survey. *Eur J Radiol.* 2017;86:135-142. doi:10.1016/j.ejrad.2016.10.033
14. MacKay M, Hancy C, Crowe A, D'Rozario R, Ng C. Attitudes of medical imaging technologists on use of gonad shielding in general radiography. *Radiographer.* 2012;59(2):35-39. doi:10.1002/j.2051-3909.2012.tb00172.x
15. Shabani F, Hasanzadeh H, Emadi A, et al. Radiation Protection Knowledge, Attitude, and Practice (KAP) in Interventional Radiology. *Oman Med J.* 2018;33(2):141-147. doi:10.5001/omj.2018.26
16. Wainwright AM. Shielding reproductive organs of orthopaedic patients during pelvic radiography. *Ann R Coll Surg Engl.* 2000;82(5):318-321.
17. Miller E. *The relationship between emotional intelligence and student success for the radiologic technology and diagnostic medical sonography students at a community college.* Dissertation. University of St. Francis; 2022.
18. Hojat M, Gonnella JS, Mangione S, et al. Empathy in medical students as related to academic performance, clinical competence and gender. *Med Educ.* 2002;36(6):522-527. doi:10.1046/j.1365-2923.2002.01234.x
19. Fauber TL. Gonadal shielding in radiography: a best practice? *Radiol Technol.* 2016;88(2):127-134.
20. Tilson ER. Educational and experiential effects on radiographers' radiation safety behavior. *Radiol Technol.* 1982;53(4):321-325.
21. Karami V, Zabihzadeh M, Shams N, Saki Malehi A. Gonad shielding during pelvic radiography: a systematic review and meta-analysis. *Arch Iran Med.* 2017;20(2):113-123.
22. Thakur Y, Schofield SC, Bjarnason TA, Patlas MN. Discontinuing gonadal and fetal shielding in x-ray. *Can Assoc Radiol J.* 2021;72(4):595-596. doi:10.1177/0846537121993092
23. Somasundaram E, Brady SL, Strauss KJ. Achievable dose reductions with gonadal shielding for children and adults during abdominal/pelvic radiographic examinations: A Monte Carlo simulation. *Med Phys.* 2020;47(11):5514-5522. doi:10.1002/mp.14495
24. Rogers EM. *Diffusion of Innovations.* 5th ed. The Free Press; 2003.