AJR FOCUS ON:

Patient Shielding in Diagnostic Imaging: Discontinuing a Legacy Practice

Rebecca M. Marsh[1]
Michael Silosky

OBJECTIVE. Patient shielding is standard practice in diagnostic imaging, despite growing evidence that it provides negligible or no benefit and carries a substantial risk of increasing patient dose and compromising the diagnostic efficacy of an image. The historical rationale for patient shielding is described, and the folly of its continued use is discussed.

CONCLUSION. Although change is difficult, it is incumbent on radiologic technologists, medical physicists, and radiologists to abandon the practice of patient shielding in radiology.

Patient shielding is an integral part of radiology. Its practice and importance are so deeply ingrained that when a group of radiologic technologists was recently asked what they would do if their institution adopted a policy to not provide patient shielding, 86% of respondents stated that they would shield patients anyway. (One percent of respondents said that such a policy change would cause them to quit their job [1].) This raises an important question: why do we shield patients? The assumption is that shielding improves patient safety [2–6]. This belief is often regarded as fact, with little consideration given to its veracity. However, a review of the history of patient shielding and the current role of patient shielding in radiology provides evidence that the associated risks are substantial, whereas the benefits are negligible or nonexistent.

Patient Shielding Was Intended to Alleviate Hereditary Risks

Patient shielding was first introduced into the U.S. Code of Federal Regulations in 1976 [7]. Around this time, it was recognized that radiation exposure from diagnostic examinations was too low to affect fertility, because even temporary decreases in sperm count do not occur at doses of less than 250 mGy, and because female fertility is not affected at doses of less than 3000 mGy [8]. Consequently, the regulation cited only a concern regarding hereditary risks (i.e., mutations in germ cells that may affect future generations) and addressed gonadal shielding only. The wording in the April 2018 version of title 21 of the U.S. Code of Federal Regulations has not changed from the initial wording found in the 1976 version [9]. Patient shielding was—and is—justified as a matter of protection from hereditary risks, not as an overall reduction in stochastic risk. Of importance, 42 years later, no hereditary effects from radiation have ever been observed in humans [10].

Patient Shielding Provides Negligible (or No) Benefit

In addition to increased data about radiation effects, any risk that may exist would be much lower now than it was in the 1970s simply because of the drastic decrease in the amount of radiation used in radiography. In 1959, the radiation dose to the testes of a 4-year-old male patient undergoing anteroposterior examination of the pelvis was approximately 2.5 mGy. The radiation dose to the ovaries of a female patient undergoing the same examination was 1.2 mGy [11]. By 2012, those doses had been reduced to approximately 0.06 mGy and 0.01 mGy to the testes and ovaries, respectively [12], for a reduction of more than 96%. Even data about fetal dose suggest that at radiation doses of less than 100 mGy, the risk to an embryo or fetus is either small or nonexistent [13]. Multiple studies have shown that fetal doses from radiographic and CT examinations are well below this amount. In radiography, even when the fetus is in the primary x-ray beam, the fetal dose is less than 4 mGy [6]. During CT examination for pulmonary embolism in the mother, the fetal dose is approximately 1.5 mGy; CT examinations of the abdomen and pelvis result in a fetal dose

Keywords: gonadal shielding, patient safety, patient shielding, radiation, shielding

doi.org/10.2214/AJR.18.20508

Received August 6, 2018; accepted without revision August 28, 2018.

[1]Both authors: University of Colorado School of Medicine, 12700 E. 19th Ave, Mail Stop C278, Aurora, CO 80045. Address correspondence to R. M. Marsh (rebecca.marsh@ucdenver.edu).

AJR 2019; 212:1–3

0361–803X/19/2124–1

ranging from 15 to 20 mGy (depending on the scanner type) [14]. To our knowledge, no evidence exists to indicate that a single imaging study poses any risk to a fetus [15, 16].

Although stochastic radiation effects still are not fully understood, the data that do exist are commonly misrepresented. For example, cumulative effects of radiation are used to defend current patient shielding practices. It is convenient to assume that the risk to a neonate who undergoes 20 radiographic examinations in the neonatal ICU is the same as if the same total amount of radiation is delivered during a single examination; however, this assumption completely ignores abundant evidence to the contrary. The effects of varying the rate at which radiation is delivered is well documented and is even exploited by radiation oncologists, who use treatment fractionation to minimize damage to healthy tissues [17]. A thorough analysis of the linear no-threshold model is beyond the scope of this article, but there are two highly relevant key points. First, epidemiologic studies do not support the linear no-threshold model at doses less than 100 mSv [18]. Second, most data show that the biologic effects of radiation delivered at low dose rates vary substantially from those of acute doses of radiation [19]. The Biologic Effects of Ionizing Radiation VII report contains a large discussion of dose-rate dependence and includes a correction factor to account for how it affects the linear no-threshold model [10]. Some groups, including the French Académie Nationale de Médicine, even suggest that small amounts of radiation delivered at low dose rates may have a protective effect [18, 20]. In other words, the assumption that the risk from 20 imaging studies, each with an effective dose of 10 mSv, is the same as that from a single imaging study with an effective dose of 200 mSv is unfounded. This point is even more important when one considers the very low doses encountered in planar radiography and the risks associated with not shielding patients.

One must also consider the amount of protection that shielding provides to a patient. This varies based on whether anatomy is located outside the imaging FOV (i.e., not in the path of the primary x-ray beam) or inside the imaging FOV. For anatomy outside the imaging FOV, radiation exposure results almost entirely from internal scatter generated within a patient [21]. Because contact shielding cannot protect against internal scatter, shielding anatomy outside the imaging FOV provides negligible protection to the patient. This holds true for all examinations, including those of pediatric and pregnant patients [13, 15, 22–25]. For anatomy that is within the imaging FOV, the use of patient shielding may reduce patient dose, but this potential dose savings comes at the risk of inadvertently increasing patient dose or adversely affecting the diagnostic efficacy of the examination.

Since gonadal shielding was introduced in the U.S. Code of Federal Regulations, substantial changes in imaging technology, from x-ray generation to detection and image formation, have further reduced any benefit from shielding. Collimation in modern radiographic systems has drastically improved; the requirements for minimum amounts of beam filtration have increased [26]. Shorter examination times have expanded the applicability of automatic exposure control to a wider range of pediatric patients [27]. The increased dynamic range of digital image receptors and advances in digital image processing have allowed further reductions in the amount of radiation needed to produce a diagnostic-quality image. In addition, radiology has moved from a field using conventional radiographs only to one that is heavily dominated by digital image receptors, digital image processing, and automatic exposure techniques.

Patient Shielding Introduces Significant Risks

Although these developments can reduce patient dose and improve image quality and consistency, the efficacy of patient shielding must be reconsidered with these technologies in mind. For example, most modern x-ray–based imaging systems have some sort of automatic exposure control. In radiography, photocells are built into the image receptor to sense when the detector has received a target dose, allowing the automatic exposure control algorithm to determine an optimal tube current–exposure time product. In fluoroscopy, automatic brightness control algorithms work as a feedback loop between the image receptor and the x-ray tube so that the tube output is constantly adjusted to ensure consistent image quality. In CT, automatic tube current modulation and automatic tube voltage modulation use localizer images to determine what tube current and tube voltage are needed to create diagnostic quality images. The details regarding how these systems work are beyond the scope of this article, but the takeaway is that each of these techniques depends on the system optimizing image quality by adjusting the radiation output based on what is in the imaging FOV. Although this greatly improves the consistency of image quality (signal intensity, noise properties, and other factors), the consequence of introducing a highly attenuating material into the imaging area is significant. If a lead shield, which is meant to protect the patient, enters the imaging FOV, the radiographic system will drastically increase the tube output to try to penetrate the shield. This results in an increased dose to the patient and a marked degradation in image quality.

In addition to the risks posed by automatic exposure control, several clinical studies have shown that gonadal shields are often positioned incorrectly, obscuring relevant anatomy and increasing repeat rates [12, 28, 29]. A study by Frantzen et al. [12] found that gonadal shields were incorrectly placed for 91% of pelvic radiographic examinations of girls and 66% of those of boys. Another group of investigators found that pelvic shields were misplaced in 49% of anteroposterior radiographs and 63% of frog lateral radiographs and that pelvic bony landmarks were obscured by shielding in up to 43% of images [30]. The investigators concluded that "consideration should be given to alternative protocols or abandonment of this practice." Of even more concern is the fact that the study also found that retakes were warranted in many cases but were not performed. This forces the radiologist to fill in the gaps with information from previous images, negating much of the benefit from the current examination.

It is important to recognize that the practice of shielding patients is largely supported by a skewed perception of radiation risk. This is also the most difficult aspect to address through rational discussion. The challenges associated with gaining public trust in health care are substantial and have been previously discussed elsewhere [31, 32]. In a discussion of the public perception of radiation risk, Hendee [31] placed the onus on medical professionals to use their topical expertise to become involved in such issues: "If the sources of reason and wisdom in the community are silent, only irrational and foolish voices will be heard." He concluded by stating, "Enough examples of these effects exist today in our society to suggest that reasonable voices have been silent long enough" [31].

Practical Implementation of a No-Shielding Practice

Discontinuing the use of patient shielding will be a significant departure from how radiology has been practiced for decades. Although

the need to abandon this practice is clear, it is incumbent on health care professionals to help patients feel confident about the care they receive. This is especially important regarding issues of radiation risk, for which misinformation is rampant. Consequently, how to address patient concerns as facilities stop providing patient shielding should be considered.

First, it may be beneficial to address patient concerns before the examination begins. For example, when greeting a patient, the technologist typically introduces himself or herself, verifies the patient's identity, and describes the examination to the patient. At this time, it may be appropriate to inform the patient that the facility does not provide patient shielding for imaging examinations because evidence indicates that shielding increases the risk to the patient and provides negligible or no benefit. This gives the patient the opportunity to ask questions and express any concerns he or she may have. In addition, information in the form of posters or brochures can provide information to patients before an appointment, either online or in a waiting room. The concerns of many patients may be alleviated if the patients know that someone is paying attention to their safety and that the lack of shielding is intentional rather than negligent.

Last, it is important to give technologists discretion to provide shielding in certain circumstances. Patients who are extremely anxious about the lack of shielding should be advised of the potential risks. If the technologist still determines that shielding would provide a substantial psychologic benefit to the patient, he or she should be allowed to make this professional judgment. However, it is important to emphasize to medical staff that shielding should be avoided whenever possible.

Conclusion

Patient shielding persists despite growing evidence that the practice should be abandoned. Although change is difficult, it is incumbent on radiologic technologists, medical physicists, and radiologists to finally step up as reasonable voices on the subject. Until then, training programs, health care facilities, and accreditation and regulatory bodies will continue to encourage and engage in a legacy practice that presents substantial risk but negligible (or no) benefit to patient health.

References

1. Advanced Health Education Center. What would you do? Stop shielding your patients? Advanced Health Education Center Online website. ahecblog.com/2018/01/15/what-would-you-do-stop-shielding-your-patients. Published January 15, 2018. Accessed July 18, 2018
2. Gomes M, Matias A, Macedo F. Risks to the fetus from diagnostic imaging during pregnancy: review and proposal of a clinical protocol. *Pediatr Radiol* 2015; 45:1916–1929
3. Pahade JK, Litmanovich D, Pedrosa I, et al. Quality initiatives: imaging pregnant patients with suspected pulmonary embolism: what the radiologist needs to know. *RadioGraphics* 2009; 29:639–654
4. Ratnapalan S, Bentur Y, Koren G. Doctor, will that x-ray harm my unborn child? *CMAJ* 2008; 179:1293–1296 [Erratum in *CMAJ* 2009; 280:952]
5. Sikand M, Stinchcombe S, Livesley PJ. Study on the use of gonadal protection shields during paediatric pelvic x-rays. *Ann R Coll Surg Engl* 2003; 85:422–425
6. Ursprung WM, Howe JW, Yochum TR, Kettner NW. Plain film radiography, pregnancy, and therapeutic abortion revisited. *J Manipulative Physiol Ther* 2006; 29:83–87
7. 21 C.F.R. §1000.50 (1976)
8. International Commission on Radiological Protection (ICRP). Recommendations of the International Commission on Radiological Protection: ICRP publication 26. *Ann ICRP* 1977; 1(3)
9. 21 C.F.R. §1000.50 (2018)
10. National Research Council. *Health risks from exposure to low levels of ionizing radiation: BEIR VII phase 2*. Washington: DC: The National Academies Press, 2006
11. Bishop HA, Webber M, O'Loughlin BJ. Reducing gonad irradiation in pediatric diagnosis. *Calif Med* 1959; 90:20–25
12. Frantzen MJ, Robben S, Postma AA, et al. Gonad shielding in paediatric pelvic radiography: disadvantages prevail over benefit. *Insights Imaging* 2012; 3:23–32
13. National Council on Radiation Protection and Measurements (NCRP). Preconception and prenatal radiation exposure: health effects and protective guidance. Report 174. Bethesda, MD: NCRP Publications, 2013
14. Gilet AG, Dunkin JM, Fernandez TJ, et al. Fetal radiation dose during gestation estimated on an anthropomorphic phantom for three generations of CT scanners. *AJR* 2011; 196:1133–1137
15. Colletti PM, Lee KH, Elkayam U. Cardiovascular imaging of the pregnant patient. *AJR* 2013; 200:515–521
16. Wieseler KM, Bhargava P, Kanal KM, et al. Imaging in pregnant patients: examination appropriateness. *RadioGraphics* 2010; 30:1215–1229
17. Arnold KM, Flynn NJ, Raben A, et al. The impact of radiation on the tumor microenvironment: effect of dose and fractionation schedules. *Cancer Growth Metastasis* 2018; 11:1179064418761639
18. Tubiana M. Dose-effect relationship and estimation of the carcinogenic effects of low doses of ionizing radiation: the joint report of the Académie des Sciences (Paris) and of The Académie Nationale de Médicine. *Int J Radiat Oncol Biol Phys* 2005; 63:317–319
19. Brooks AL, Hoel DG, Preston RJ. The role of dose rate in radiation cancer risk: evaluating the effect of dose rate at the molecular, cellular and tissue levels using key events in critical pathways following exposure to low LET radiation. *Int J Radiat Biol* 2016; 92:405–426
20. Moghissi AA, Calderone R, Azam F, et al. Regulating ionizing radiation based on metrics for evaluation of regulatory science claims. *Dose Response* 2018; 16:1559325817749413
21. American College of Radiology (ACR). ACR–AAPM–SIIM–SPR practice parameter for digital radiography. ACR website. www.acr.org/-/media/ACR/Files/Practice-Parameters/Rad-Digital.pdf. Accessed July 23, 2018
22. Patel SJ, Reede DL, Katz DS, et al. Imaging the pregnant patient for nonobstetric conditions: algorithms and radiation dose considerations. *RadioGraphics* 2007; 27:1705–1722
23. Ryckx N, Sans-Merce M, Schmidt S, et al. The use of out-of-plane high Z patient shielding for fetal dose reduction in computed tomography: literature review and comparison with Monte-Carlo calculations of an alternative optimization technique. *Phys Med* 2018; 48:156–161
24. Sadro C, Bernstein MP, Kanal KM. Imaging of trauma. Part 2. Abdominal trauma and pregnancy: a radiologist's guide to doing what is best for the mother and baby. *AJR* 2012; 199:1207–1219
25. Sidhu M, Strauss K, Connolly B, et al. Radiation safety in pediatric interventional radiology. *Tech Vasc Interv Radiol* 2010; 13:158–166
26. 21 C.F.R. § 1020.30 (2017)
27. National Council on Radiation Protection and Measurements (NCRP). Radiation protection in pediatric radiology. Report 68. Bethesda, MD: NCRP Publications, 1978
28. Fawcett SL, Barter SJ. The use of gonad shielding in paediatric hip and pelvis radiographs. *Br J Radiol* 2009; 82:363–370
29. Winfeld M, Strubel N, Pinkney L, et al. Relative distribution of pertinent findings on portable neonatal abdominal radiographs: can we shield the gonads? *Pediatr Radiol* 2013; 43:1295–1302
30. Lee MC, Lloyd J, Solomito MJ. Poor utility of gonadal shielding for pediatric pelvic radiographs. *Orthopedics* 2017; 40:e623–e627
31. Hendee WR. Personal and public perceptions of radiation risks. *RadioGraphics* 1991; 11:1109–1119
32. Freudenberg LS, Beyer T. Subjective perception of radiation risk. *J Nucl Med* 2011; 52(Suppl 2):29S–35S