Poor Utility of Gonadal Shielding for Pediatric Pelvic Radiographs

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abstract

Plain pelvic radiographs are commonly used for a variety of pediatric orthopedic disorders. Lead shielding is typically placed over the gonads to minimize radiation exposure to these sensitive tissues. However, misplaced shielding can sabotage efforts to protect patients from excessive radiation exposure either by not covering radiosensitive tissues or by obscuring anatomic areas of interest, prompting repeat radiographic examinations. The goal of this study was to determine the incidence of misplaced shielding for pelvic radiographs obtained for pediatric orthopedic evaluation. Children 8 to 16 years old who had an anteroposterior or frog lateral pelvic radiograph between 2008 and 2014 were included. A total of 3400 patients met the inclusion criteria, and 84 boys and 84 girls were randomly selected for review. For both boys and girls, the percentage of incorrectly positioned or missing shields was calculated. Chi-square testing was used to compare the frequency of missing or incorrectly placed shields between sexes and age groups. Pelvic shields were misplaced in 49% of anteroposterior and 63% of frog lateral radiographs. Shielding was misplaced more frequently for girls than for boys on frog lateral radiographs (76% vs 51%; $P<.05$). Pelvic bony landmarks were often obscured by pelvic shielding, with a frequency of 7% to 43%, depending on the specific landmark. The femoral head and acetabulum were obscured by shielding in up to 2% of all images. The findings suggest that accepted pelvic shielding protocols are ineffective. Consideration should be given to alternative protocols or abandonment of this practice. [*Orthopedics.* 2017; 40(4):e623-e627.]

Pelvic radiographs are standard diagnostic tools used to assess the anatomy of the hips and pelvis in pediatric patients with a range of orthopedic pathologies. Lead shielding is typically used with pelvic radiographs to decrease radiation exposure to the gonads, a practice prompted by earlier studies that showed a significant cancer risk for patients exposed to large quantities of ionizing radiation from plain radiographs.[1-4] Specific best practice guidelines have been developed for the appropriate placement of gonadal shielding to protect the gonads and minimize interference in visualization of bony landmarks.[5]

However, several studies have shown that gonad shielding is misplaced or missing in 50% to 78% of pediatric pelvic radiographs.[1,6,7] Although these studies identified malposition of shielding among a high percentage of patients, it is not clear whether the study institutions had rigorous shielding protocols in place, and there is no analysis of the frequency at which shields covered bony landmarks in the pelvis, potentially compromising the value of the study.

The goal of the current study was to determine the incidence of missing or misplaced gonad shields in pediatric orthopedic practice with a rigorous shielding pro-

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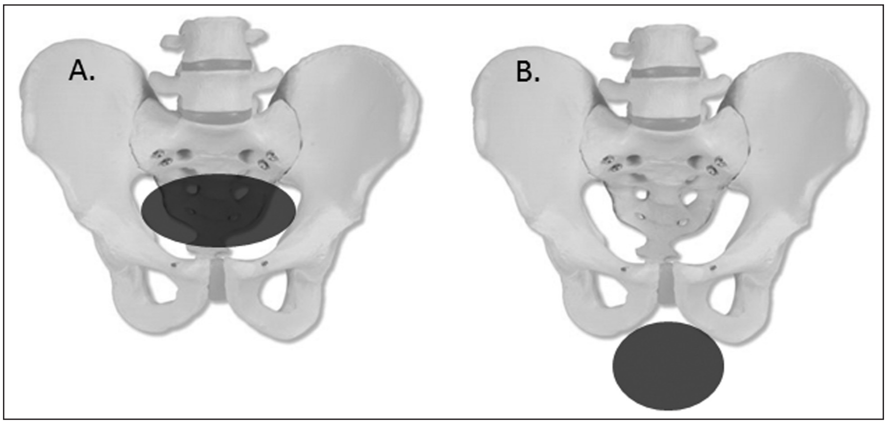

Figure 1: Correct placement of gonadal shields. For female patients, placement is considered correct if the shield covers the pelvic basin from the symphysis pubis to the sacrum without obscuring bony landmarks (A). In male patients, placement is considered correct if the shield is placed as close to the pubic arch as possible without covering bony landmarks and if both testicles are completely covered (B).

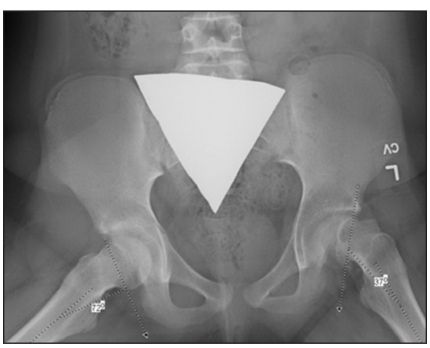

Figure 2: Incorrect placement of a gonadal shield in a girl with a left slipped capital femoral epiphysis. The sacrum and sacroiliac joint are obscured.

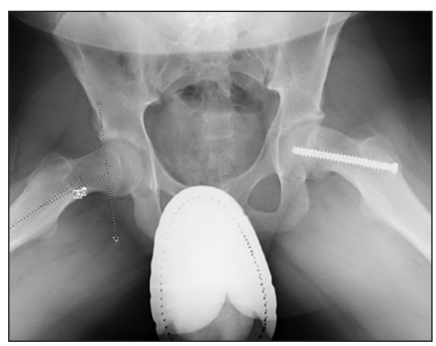

Figure 3: Incorrect placement of a gonadal shield in a boy with a treated left slipped capital femoral epiphysis. The shield obscures the pubic symphysis and rami.

tocol and to determine the frequency with which visualization of bony landmarks is compromised by pelvic shielding.

Materials and Methods

A retrospective evaluation was performed of patients examined between 2008 and 2014 at a single institution in which a pelvic shielding protocol was in place. Charts and pelvic radiographs of patients were examined. Patients were included if they were between the ages of 8 and 16 years, had either anteroposterior or frog lateral projections of the pelvis performed, and had images available for review on the institutional picture archiving and communication system. Patients were excluded if they had congenital absence or abnormality of the pelvis or sacrum, developmental or acquired abnormality of the pelvis or sacrum (eg, multiple exostoses or pelvic resection), or skeletal dysplasia. A total of 3400 patients met the initial inclusion criteria. From this set, 84 boys and 84 girls were randomly selected for inclusion in the study to reach 80% statistical power. For randomization, the patient group was divided into boys and girls. These sets were then imported into an Excel spreadsheet (Microsoft Corp, Redmond, Washington), and a random number generator was used to assign each patient a numeric value. The patient lists were arranged in order of this randomly assigned numeric value, and the first 84 boys and 84 girls were selected for inclusion.

All available anteroposterior and frog lateral images for each patient were reviewed to determine the position of the pelvic shielding. For boys, the gonadal shield was considered correctly placed if it was as close to the pubic arch as possible and covered both testicles without obscuring bony landmarks. For girls, the gonadal shield was considered correctly placed if it covered the pelvic basin from the symphysis pubis to the sacrum without obscuring bony landmarks (**Figure 1**).[8] Shields were identified as present or absent and correctly or incorrectly positioned (**Figures 2-3**). Further, if the shield was incorrectly positioned, bony landmarks that were completely or partially obscured were noted. Specific bony landmarks that were examined included the sacroiliac joint, iliac crest, acetabulum, ilium, pubic symphysis, and ischium.

The total number of missing shields was determined for the cohort. Because institutional policy required the first diagnostic pelvic images to be performed without shielding, the first radiographic evaluation for each patient, as determined by the patient medical record and confirmed by the digital radiographic record, was excluded from analysis for missing shields.

Subgroup analysis was used to determine whether patient sex or age affected the incidence of misplaced or missing shields. Chi-square testing was used to identify statistically significant differences between the sexes and between the 2 age-based subgroups, separated according to mean age of the cohort. $P<.05$ was considered significant.

Results

A total of 168 patients were analyzed, and a total of 668 anteroposterior pelvic images and 448 frog lateral pelvic images were reviewed. Average patient age was 12.2±2.3 years, and each patient on average had a total of 4 anteroposterior studies and 3 frog lateral studies over the course of the evaluation.

On the anteroposterior images for all included patients, gonad shields were misplaced in 49% of images and missing in 4% of images. On the frog lateral images, the incidence of misplaced shields for all patients increased to 63% and the incidence of missing shields decreased to 1% (**Table 1**). Gonad shields were misplaced in 47% of anteroposterior images for boys and 51% for girls. No statistically significant difference was noted between groups. However, on frog lateral images, gonad shielding was misplaced in 51% of images for boys and 76% of images for girls, showing a significant difference between groups (*P*<.002). No difference was noted between the number of misplaced shields for patients 12 years or younger compared with those older than 12 years when both anteroposterior and frog lateral images were examined (*P*=.951 and *P*=.061, respectively).

Pelvic shielding partly or completely covered bony pelvic landmarks in anteroposterior and frog lateral images with a variable frequency (**Table 2**). On anteroposterior images, for girls, a shield was significantly more likely to block visualization of the ilium, iliac crest, and sacroiliac joint, with a frequency of 7% to 43%; for boys, a shield was significantly more likely to block visualization of the ischium and pubis, with a frequency of 10% to 16%. On frog lateral images, for girls, a shield was significantly more likely to block visualization of the sacroiliac joint (51%); for boys, a shield was significantly more likely to block the pubic symphysis or ischium (20% and 27%, respectively). For all views, the acetabulum and femoral head were obscured by pelvic shielding in 0.3% to 2% of images, with no significant difference between sexes. In 5 images, gonad shields blocked complete visualization of pelvic or proximal femoral fixation during early postoperative evaluation (<2 weeks).

Table 1

Absent Shielding in Anteroposterior and Frog Lateral Pelvic Radiographs

Variable	All Patients	Boys	Girls
Age, mean±SD, y	12.1±2.1	12.1±2.3	12.2±2.0
Total radiographs, No.			
Anteroposterior	668	382	286
Frog lateral	488	289	199
Missing shield			
Anteroposterior	4%	4%	4%
Frog lateral	2%	2%	2%
Misplaced shield			
Anteroposterior	49%	47%	51%
Frog lateral	63%	51%	76%[a]

[a]*Statistically significant difference between boys and girls (*P*<.05).*

Table 2

Pelvic Anatomy Obscured by Shielding for Pelvic Radiographs

	Anteroposterior Radiographs		Frog Lateral Radiographs	
Pelvic Anatomy	Boys	Girls	Boys	Girls
Sacroiliac joint	2%	43%[a]	3%	51%[a]
Iliac crest	1%	9%[a]	1%	4%
Acetabulum/femoral head	0.3%	0.4%	2%	1%
Ilium	1%	7%[a]	2%	3%
Ischium	16%	7%[a]	27%	1%[a]
Pubic symphysis	10%	3%[a]	20%	1%[a]

[a]*Statistically significant difference between boys and girls (*P*<.05).*

Discussion

Pelvic radiographs are performed in children to diagnose pelvic ring or hip pathology. With an understanding of the importance of protecting radiosensitive tissues such as the gonads, especially in a pediatric population, best practice guidelines have been developed that emphasize the use of pelvic shielding during these procedures. However, the overall efficacy of pelvic shielding is questionable.

The current study showed that adherence to a strict shielding protocol in a single institution can maintain the rate of missing pelvic shielding at 1% to 4%, depending on the view. This finding differs markedly from previous reports that showed up to 30% absence of shielding.[1,9] The data suggest that adherence to a strict systems-based guideline can decrease overt absence of pelvic shielding for a pediatric population. The protocol used at the study institution requires that all radiology technicians palpate the patient to determine the location of the iliac crests. The shield is then placed beneath and medial to the crests, essentially over the estimated location of the bladder. As mentioned previously, the institutional policy is to perform the first pelvic radiograph without shielding to ensure that the entire pelvis is visualized for better diagnostic accuracy.

However, in agreement with previous studies, the current findings showed that 49% to 63% of pelvic shields were misplaced on standard pelvic radiographs, especially for girls. In the current study, for girls, shielding was misplaced on almost half of all anteroposterior images and 76% of frog lateral images.

In addition, misplaced pelvic shields often obscured relevant pelvic or hip anatomy and potentially diminished the diagnostic value of the study. The incidence of obscured bony landmarks ranged from 0.3% to 51%. The frequency of anatomy that was blocked by shielding showed a general sex-specific pattern of misplacement of pelvic shielding. For girls, the pelvic shield often was placed superior to the pelvic basin, blocking the sacroiliac joint and ilium. For boys, the shield often was placed superior and eccentric to the inferior pubic arch, obscuring the pubic symphysis and ischium. In 0.3% to 2% of cases, the hip joint itself was blocked by shielding, and in 5 images obtained during the early postoperative period, pelvic or proximal femoral fixation was obscured. Although the retrospective data provided no record of repeat imaging for obscured anatomy, mostly because such instances are not recorded in the picture archiving system, misplaced pelvic shielding could contribute to a significant number of radiographic retakes and likely preclude its intended role to protect the patient from additional ionizing radiation.

Although several studies conducted during the past 3 decades[2,3,6] suggested a high error rate in the use of pelvic shielding, the findings of this study and others[1,7,8] showed no apparent improvement in the positioning of pelvic shielding over time, despite a strict institutional shielding program. The persistently high error rate illustrates the difficulty of using surface anatomy to guide localization of gonads, particularly in a variably cooperative pediatric population. Further, the ovaries can be outside of the true pelvis or pelvic basin in 18% of the population, and ovary position can vary depending on bladder filling.[8,10] Therefore, even if a pelvic shield is placed on a female patient within the confines of the true pelvis according to surface anatomy guidelines, the ovaries may not be shielded effectively.

The current best practice guidelines for pelvic shielding were based on radiation data from the 1950s.[2] With advances in technology, patient radiation doses have decreased decade by decade. Frantzen et al[11] reported that the effective dose of radiation to the gonads with current imaging technology is approximately 0.008 to 0.098 millisievert (mSv). This dose compares favorably with the 0.008 mSv received from background radiation sources daily. Further, Frantzen et al[11] reported that, because of the identified errors in misplacement of pelvic shielding and the potential need for retakes, pelvic shielding does not reduce the risk of radiation exposure for boys and potentially increases the risk of radiation exposure for girls.

Given the current study data and the available literature, the use of pelvic shielding for radiographs in pediatric patients requires reevaluation. Ultimately, in terms of radiation exposure and medical economics, it might be preferable to perform these studies without a shielding protocol. Because advances in technology have reduced radiation exposure, it may be safer to perform pelvic studies without shielding. However, there is still a risk associated with radiation exposure to the sensitive tissue. A prospective study of different shielding algorithms is needed to obtain evidence for the increased efficiency and safety associated with removing the shielding requirement.

Limitations

This study had several limitations. Its retrospective nature limited the ability to evaluate the number of repeat radiographs obtained because of erroneous shielding position and therefore prevented an acceptable estimate of overall radiation exposure. Further, the results can be extrapolated only to anteroposterior and frog lateral images of the pelvis taken for diagnostic purposes in a pediatric orthopedic setting and cannot be applied to adult populations or other diagnostic imaging modalities.

Conclusion

In children undergoing diagnostic imaging of the pelvis for orthopedic pathology, pelvic shields are rarely absent but are often misplaced. Up to 76% of gonadal shields are improperly placed on pelvic radiographs, and bony landmarks are obscured by gonadal shielding in up to 51% of pelvic radiographs. Consideration should be given to abandoning current gonad shielding methods, especially for girls, because of the inconsistent placement of pelvic shields and the increased risk of repeat imaging from interference with relevant bony anatomy.

References

1. Gul A, Zafar M, Maffulli N. Gonadal shields in pelvic radiographs in pediatric patients. *Bull Hosp Jt Dis.* 2005; 63(1-2):13-14.
2. Abram E, Wilkinson DM, Hodson CJ. Gonadal protection from X radiation for the female. *Br J Radiol.* 1958; 31(366):335-336.
3. Ardran GM, Kemp FH. Protection of the male gonads in diagnostic procedures. *Br J Radiol.* 1957; 30(353):280.
4. Osborn SB. The genetically significant radiation received from diagnostic radiology. In: Medical Research Council, eds. *The Hazards to Man of Nuclear and Allied Radiations.* London, England: Her Majesty's Stationery Office; 1956:117.
5. US Food & Drug Administration. CFR-code of Federal Regulations Title 21. https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm. Accessed August 16, 2015.
6. Kenny N, Hill J. Gonad protection in young orthopaedic patients. *BMJ.* 1992; 304(6839):1411-1413.
7. Masud S, Mehra A, Clothier JC. Study on the use of gonadal shields in paediatric pelvic x-rays. *J Bone Joint Surg Br.* 2008; 90(suppl II):338.
8. Fawcett SL, Barter SJ. The use of gonad

shielding in paediatric hip and pelvis radiographs. *Br J Radiol.* 2009; 82(977):363-370.

9. 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(6):422-425.

10. Counsell R, Bain G, Williams MV, Dixon AK. Artificial radiation menopause: where are the ovaries? *Clin Oncol (R Coll Radiol).* 1996; 8(4):250-253.

11. Frantzen MJ, Robben S, Postma AA, Zoetelief J, Wildberger JE, Kemerink GJ. Gonad shielding in paediatric pelvic radiography: disadvantages prevail over benefit. *Insights Imaging.* 2012; 3(1):23-32.