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More harm than good? The anatomy of misguided shielding of the ovaries

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Objective: Popular gonad shield designs aim to provide coverage of the true pelvis, which is presumed to be the probable location of the ovaries. Shields are frequently placed inaccurately, especially in children, obscuring important orthopaedic landmarks on pelvic radiographs. We aimed to identify the position of the ovaries and asses how this may vary with age and the degree of bladder filling. We aimed to identify the position of the ovaries and asses how this may vary with age and the degree of bladder filling.
Methods: Using MRI examinations of the pelvis in women and children, we located 594 ovaries in 306 female patients aged from birth to 59 years.
Results: This study provides new evidence that bladder filling affects ovary position. A lower than expected number of patients had both ovaries within the pelvis if the bladder contained more than a moderate volume of urine. Bladder emptying should be achieved wherever practical if a shield is used. In children under the age of 7 years, more than half (19/37) had at least one ovary outside the true pelvis. There was a significant association between age and ovary position, with the percentage of patients with one or both ovaries outside the true pelvis decreasing with age (χ^2, $p<0.0001$).
Conclusion: The embryological descent of the ovaries into the pelvis would appear to continue after birth, well into childhood. Current popular shield designs are therefore inappropriate for use in young children. Given the high risk of obscuring critical landmarks, coupled with the new evidence that even accurate placement will not necessarily protect the ovaries, the use of pelvic shields in girls should be reconsidered.

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Radiation protection for patients during imaging, especially for children, remains a subject of great importance, attracting much attention in recent medical literature [1–6].

The intentional exposure of the ovaries to radiation may be desirable as part of the radio-ablation treatment for oestrogen-dependent tumours such as breast cancer. Accurate localisation of the ovaries is required for this technique. In this context, the variable position of the ovaries in adult women has been the subject of investigation using ultrasound and CT [7, 8].

On the other hand, protecting the ovaries from radiation, especially in children undergoing diagnostic procedures such as pelvic radiography, also requires knowledge of ovary position. Ovarian localisation in children has been less well investigated, and the International Commission on Radiological Protection (ICRP) based their recommendations on limited data from the 1960s using hysterosalpingography and surgery [9–11].

Since the original description (in this journal in 1958) of a lead shield for gonadal protection in female patients undergoing pelvic radiography, the design and use of such shields has been the subject of numerous publications [12–18]. Most often the reports are of ineffective gonad protection. The popular Kings Lynn shield, in contrast to the original design, offers no protection to the sacral or paralumbar regions (Figure 1) [17].

This is perhaps surprising given that the studies in children from the 1960s, albeit limited, suggested that ovaries are not infrequently located in these areas [10, 11]. A relatively cranial ovarian location in infants would be consistent with embryological development of the gonads [19, 20].

We used MRI of the pelvis in female children and adults to localise the ovaries. Our aim was to assess whether age or the degree of bladder filling influences ovarian position. Are the ovaries truly most often located under the shielded area illustrated in Figure 1?

Methods and materials

Using radiology information systems, we identified all pelvis MRI examinations performed between May 2005 and April 2008 in women aged from 16 to 59 years, and in children aged from birth to 15 years.

The examinations were performed using 1.5 T whole-body MR systems (Signa® HDx, GE Healthcare,

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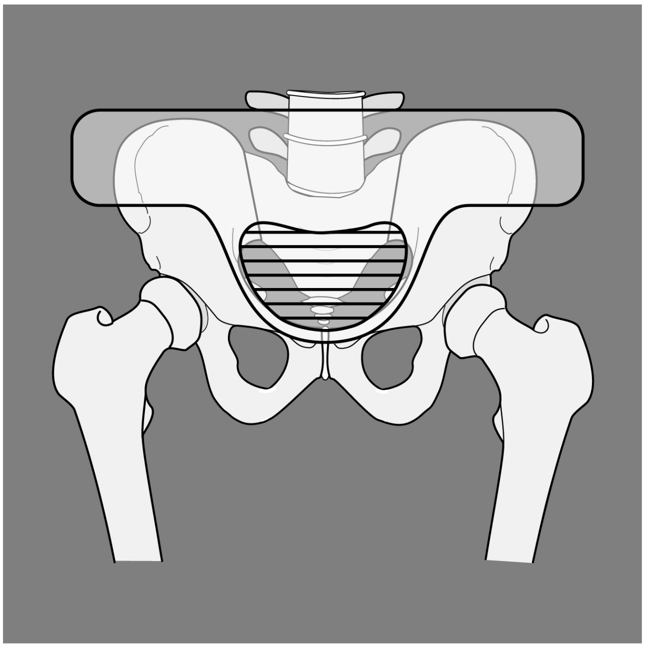

Figure 1. Illustration of ideal positioning of a Kings Lynn-style gonad shield in a female patient.

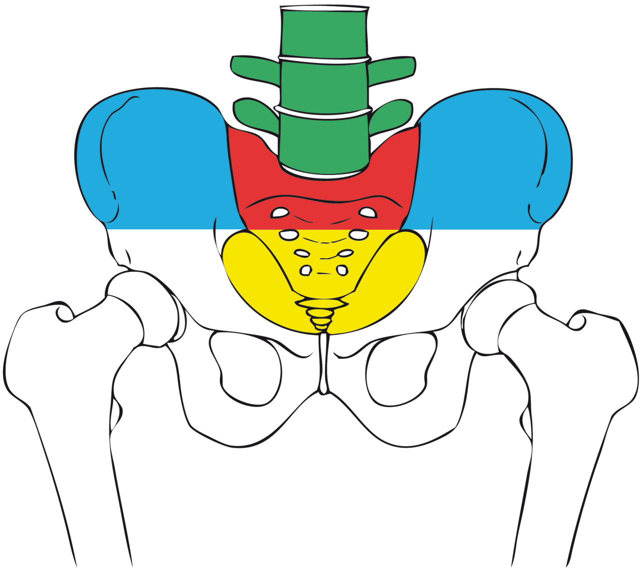

Figure 2. Illustration of the zones used to classify ovary position. Zone 1—in yellow. Regarded as the true pelvis and corresponding to the area targeted for shielding using the Kings Lynn system. The ovary is located caudal to the lower limit of the sacroiliac joints, within the ring defined by the lower limits of the sacroiliac joints, the bony side wall of the pelvis and the symphysis pubis (8). Zone 2—out medial (red)—the ovary is seen lying medial to the visualised sacroiliac joint. Zone 3—out lateral (blue)—the ovary is seen lying lateral to the visualised sacroiliac joint. Zone 4—lumbar (green)—the ovary is seen lying cranial to the lumbosacral junction.

Waukesha, WI; or Avanto TIM, Siemens, Erlangen, Germany) and images were reviewed using GE PACS (GE, Milwaukee, WI) or Fuji PACS (Fuji, Tokyo, Japan).

Repeat studies were excluded to ensure that each patient was represented only once. Owing to the potential of a pelvic mass, enlarged uterus or pregnancy to displace the ovaries, any such case was excluded from this series. Owing to the association between ovarian maldescent and congenital Müllerian anomalies, these cases were also excluded [21, 22]. In addition, owing to the risk of associated genitourinary malformations, plus the complication of skeletal distortion, cases with congenital spine abnormalities were excluded [23]. Patients with a history of pelvic radiotherapy, hysterectomy and/or oophorectomy were also removed from the data series. Mislabelled orthopaedic examinations that were of a different region and did not include the ovaries within the field of view were similarly removed.

In each case the position of the ovaries was identified in at least two different planes and recorded according to the four zones, as illustrated in Figure 2.

In addition to ovary position, an estimate of the extent of bladder filling was also recorded by approximation into one of the following five categories on sagittal cross section:

1. *Empty:* collapsed empty bladder or with minimal urine.
2. *Concave:* small amount of urine present with concave cranial bladder surface.
3. *Flat:* small to moderate amount of urine with flat cranial bladder surface.
4. *Convex:* moderate to large amount of urine present, which just achieves a convex cranial bladder surface.
5. *Full:* large volume of urine in large bladder with convex cranial surface.

The data were analysed using PASW Statistics version 17. The χ^2 test was used for the assessment of association between ovary position and both age and bladder filling. A p-value of <0.05 was regarded as statistically significant. Ethical approval for this retrospective study was sought and granted, or waived, as required in each institution.

Results

The data set contained information on 306 patients, including 154 female children (50.3%) under the age of 16 years and 152 women (49.7%) who were aged 16 years and above. In the children's age group, the mean age in the data set was 10.1 years (standard deviation 4.8) and the median age was 11.9 years, with an interquartile range from 7.3 to 15.0 years. In the women, years the ages ranged from 16 to 62 years; the mean age was 36.5 years (standard deviation 11.02) and the median age was 36 years, with an interquartile range from 29 to 44 years.

Among the children's age group, 152 left ovaries and 154 right ovaries were included. In two studies only the right ovary could be seen. Among adults, 144 left ovaries and 144 right ovaries were included. In eight studies, only the left ovary could be seen and in eight studies only the right ovary could be seen.

For the children and women in whom both ovaries could be observed (288 patients), the overall number of patients with at least 1 ovary outside the true pelvis was 73 (25.3%). For females under the age of 16 years, 1 or

Table 1. Number of patients with one, both or neither ovary within the true pelvis for both children and adults

	Age group		
Position of both ovaries	**Child (<16 years)**	**Adult (≥16 years)**	**Total**
Both in true pelvis	97 (63.8)	118 (86.8)	215 (74.7)
One ovary in true pelvis	25 (16.4)	8 (5.9)	33 (11.5)
Both ovaries outside true pelvis	30 (19.7)	10 (7.4)	40 (13.9)
Total	152 (100.0)	136 (100.0)	288 (100.0)

Data are number (percentage).

both ovaries were outside the true pelvis in 55 cases (36.2%; Table 1).

Table 2 shows the number of patients with at least one ovary outside the true pelvis by 8 age group categories (each age group category containing roughly 12.5% of the data).

The positions for all 594 visualised ovaries according to the 4 zones (described in Figure 2) are given in Table 3. A lumbar position (Zone 4) was only observed in two cases, both in children.

A χ^2 test for trend showed a significant association between age group and the position of the ovaries, with the percentage of patients with at least one ovary outside the true pelvis decreasing as age increases ($p<0.001$).

The ovary position with respect the degree of bladder filling is given in Table 4. In children, if the bladder was full, in 65.2% (15/23) of cases 1 or more ovaries were found outside the true pelvis, compared with 27.8% (5/18) if the bladder was empty. In adults, the corresponding figures are 30.8% (4/13) and 12.8% (5/39), respectively.

There was a significant association between the extent of bladder filling and both ovaries being positioned inside the pelvis when all patients are considered as one group (χ^2, $p<0.001$). When children are considered as a separate group, the same analysis also confirms this association ($p<0.001$). When the adult group is considered separately, the association is not statistically significant ($p=0.47$).

Table 2. Position of the ovaries by age group

	Both ovaries inside true pelvis		
Age groups (years)	**No**	**Yes**	**Total**
<7	19 (51.4)	18 (48.6)	37
7–11	11 (35.5)	20 (64.5)	31
11–14	12 (27.9)	31 (72.1)	43
14–16	14 (33.3)	28 (66.7)	42
16–29	5 (13.9)	31 (86.1)	36
29–36	4 (11.1)	32 (88.9)	36
36–44	3 (9.1)	30 (90.9)	33
>44	5 (16.7)	25 (83.3)	30
Total	73 (25.3)	215 (74.7)	288

Data are number (percentage) or number.

Discussion

Radiation protection and the ALARA (as low as reasonably achievable) principle, especially for children, rightly continue to attract considerable attention in the medical literature [1–6]. These issues have also been highlighted recently by the Image Gently Campaign from the Alliance of Radiation Safety in Pediatric Imaging [24].

The use of lead shielding for the ovary during radiography of the pelvis in female patients was described in this journal more than half a century ago. The described shield included extension to the level of the lower lumbar spine, thus affording protection to the sacral and paralumbar regions [17]. Since the description of this shield, new modern designs have emerged, and popular models such as the King Lynn shield have evolved. As illustrated in Figure 1, these shields are designed only to protect the contents of the true pelvis, in a ring defined by the sacroiliac joints, the bony side wall of the pelvis and the symphysis pubis [8].

The placement of such modern shields is often inaccurate, and an unfortunate consequence of misplacement is obscuration of critical orthopaedic landmarks [12–16, 18]. The application of shields can be especially difficult in children. The audit process and radiographer training reportedly have an inconsistent and disappointing impact on the degree of accuracy, perhaps reflecting, in part, the training challenges faced in large departments with significant staff turnover [13, 18].

The 1982 recommendations for ovary protection from the ICRP were based on two studies of ovary position, mostly composed of adult data [9, 11]. The smaller of the 2 series contained information from just 13 patients under the age of 12 years [10]. Even with this limited information, a cranial position for the ovaries, outside the true pelvis, could be appreciated as a relatively common occurrence in children. In addition, two studies in the

Table 3. Ovary position by zone and age group

	Age group		
Ovary position	**Child (<16 years)**	**Adult (≥16 years)**	**Total**
Zone 1: in	221 (72.2)	257 (89.2)	478 (80.1)
Zone 2: out medial	79 (25.8)	26 (9.0)	105 (17.7)
Zone 3: out lateral	4 (1.3)	5 (1.7)	9 (1.5)
Zone 4: lumbar	2 (0.6)	0 (0)	2 (0.3)
Total	306 (100.0)	288 (100.0)	594 (100.0)

Data are number (percentage).

Table 4. Position of both by bladder filling and age group

	Bladder filling					
Age group (years)	Empty	Concave	Flat	Convex	Full	Total
Child (<16)						
Both ovaries in true pelvis	13 (72.2)	32 (74.4)	34 (87.2)	10 (34.5)	8 (34.8)	97 (63.8)
One ovary in true pelvis	3 (16.7)	7 (16.3)	3 (7.7)	8 (27.6)	4 (17.4)	25 (16.4)
Both ovaries outside true pelvis	2 (11.1)	4 (9.3)	2 (5.1)	11 (37.9)	11 (47.8)	30 (19.7)
Total	18 (100.0)	43 (100.0)	39 (100.0)	29 (100.0)	23 (100.0)	152 (100.0)
Adult (≥16)						
Both ovaries in true pelvis	34 (87.2)	12 (92.3)	52 (88.1)	11 (91.7)	9 (69.2)	118 (86.8)
One ovary in true pelvis	3 (7.7)	1 (7.7)	3 (5.1)	0	1 (7.7)	8 (5.9)
Both ovaries outside true pelvis	2 (5.1)	0 (0.0)	4 (6.8)	1 (8.3)	3 (23.1)	10 (7.4)
Total	39 (100.0)	13 (100.0)	59 (100.0)	12 (100.0)	13 (100.0)	136 (100.0)

Data are number (percentage).

1990s, in the context of radiation-induced ovarian ablation, also indicated that ovaries are not infrequently outside the true pelvis even in adults [7, 8]. The relatively frequent cranial location in children has also been most recently confirmed using MRI [25].

Our data are consistent with observations from previous studies. In children under the age of 7 years, more than half of our patients had at least one ovary outside the area intended for protection by the accurate placement of a Kings Lynn shield. This study also shows a progressive trend to a more caudal ovarian position with age. This suggests that the descent of the ovaries into the pelvis is incomplete at birth and continues well into childhood. Even in adults with normal uterine size, just over a quarter (77/288) of our series had at least 1 ovary outside the pelvic ring. An example is given in Figure 3.

A more cranial ovarian position in children, and even in adults, also carries important implications when considering abdominal CT. The dose to the gonads during an unshielded abdominal CT is significantly higher than plain radiography at ~2.4 mSv, compared with 0.3–1.4 mSv [26, 27]. These data would argue strongly for more care in limiting the field of view in upper abdominal CT to avoid unnecessary exposure of the lower abdomen, unless truly indicated.

It would seem logical that the presence of a pelvic mass could adversely affect the position of the ovaries, with the potential to displace them out of the confines of the shielded pelvis. For this reason, as described, we excluded from our series all patients with a pelvic mass or enlarged uterus. An example is given in Figure 4.

With this in mind, it is surprising that the degree of bladder filling has previously been reported not to affect ovary position [8]. This is in contrast to our findings, which demonstrate that, in the presence of a full bladder, only 34.8% of children would have both ovaries within the true pelvis, compared with 72.2% if the bladder was empty. Although the association between the degree of bladder filling and ovary position in adults did not reach statistical significance, a larger proportion of those with a full bladder had both ovaries outside the true pelvis (23.1%) than those with an empty bladder (5.1%). An example of the effect of a full bladder is given in Figure 5.

Although this effect is more pronounced in children, this would suggest that a policy of routine bladder emptying in continent patients, where practical, may be advisable. Certainly, it would seem that ensuring an empty bladder is only likely to increase the chances of both ovaries being located within the pelvis, and is most unlikely to have a detrimental effect.

If we now accept that an accurately placed shield will fail to protect the ovaries in over one-third of children, and given the high reported incidence of interference with essential landmarks by a poorly placed shield, it is perhaps time to reconsider the routine application of the current shields to girls undergoing radiography of the pelvis. Obscuration of landmarks resulting in repeated exposures may well mean that the placement of a shield, despite the best intentions, causes more harm than good. In addition, if a shield is used, the bladder should be empty wherever possible.

The idea that ''one size does not fit all'' is not a new concept in radiation protection [2]. In light of the

Figure 3. Axial weighted T_2 images in an adult female patient. The uterus is normal in size. The ovaries were located lateral to the sacroiliac joint (arrowhead) and would thus not be protected by a correctly positioned Kings Lynn shield. The right ovary, containing follicles, is marked with an arrow.

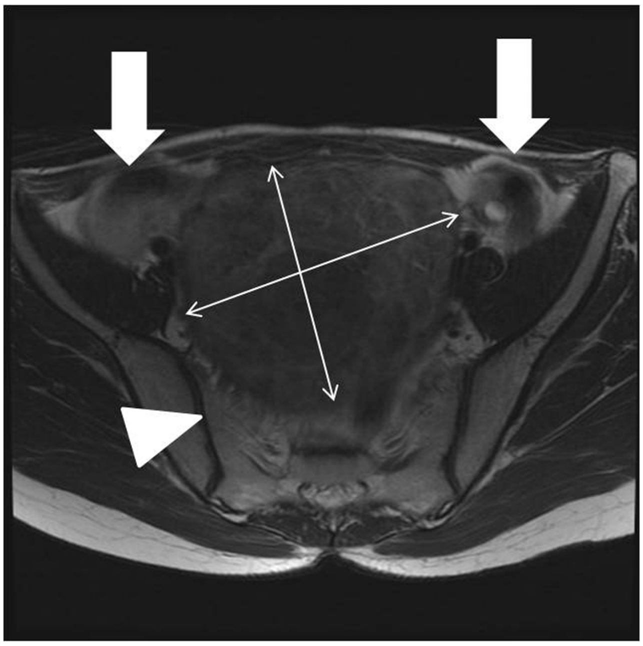

Figure 4. Axial T_2 weighted image in a 26-year-old female patient, excluded from this data series. The fibroid uterus is enlarged (marked with crossed double-headed thin arrows). The ovaries (thick arrows) can be seen lateral to the sacroiliac joint (arrowhead).

reduction in the tissue-weighting factor for the gonads (from 0.2 to 0.08), in addition to this new data on bladder emptying, a multidisciplinary review of this topic is perhaps long overdue [28, 29]. There is now sufficient evidence for shield design and recommendations for their use to be revisited with a view to the publication of clear national guidelines.

Figure 5. Sagittal T_2 weighted image of an adult female patient. The right ovary (arrow), containing follicles, can be seen at the level of the convex bladder dome, cranial to the level of the umbilicus (arrowhead).

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