Patient size and radiation dose: a grid too far?

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Authors: J. Shur, K. Shah, A. Kasoar, J. Kyriou, J. V. Cook; London/UK
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Aims and objectives

Due to the wide variation in patient size with age, dose optimisation in paediatric patients performed with age alone is inadequate [1-4]. Despite recommendations that size should be considered in radiographic optimisation, sparse literature exists describing its routine use in projection radiographic practice.

Size can be used for dose optimisation by measuring height and weight or derived quantities such as cylindrical size or body mass index (BMI) [5,6]. The most direct measure of patient size in projection radiography is the thickness of tissue that the x-ray beam will pass through, usually the anteroposterior (AP) diameter. The first part of this study concerns using calipers to measure this diameter whilst recording patient dose.

Dose optimisation includes anti-scatter grid (referred to thereafter as a "grid") selection, used in larger patients to remove scattered radiation and improve contrast resolution. This comes with a dose penalty as mAs must be increased to maintain acceptable image noise [7]. Guidelines for when to use a grid in paediatric projection radiography are often unclear or even inconsistent. These include patient diameter exceeding 15cm [8], diameter exceeding 12cm [9], unnecessary in "infants and younger children" [10], or with "older and larger" children [11]. The wider latitude and post processing capability of computed radiography (CR) and digital radiography (DR) also allow more flexibility in the choosing of a grid than when they were first designed.

The aim of our study is two-fold:

Firstly we aim to develop a method of direct patient thickness measurement for use in dose optimisation for paediatric projection radiography.

Secondly we assess image quality of radiographs with and without the use of a grid and use this to provide guidance on when grid use is acceptable based on patient size.
**Fig. 2:** Patient measurement performed at the umbilicus.

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Methods and materials

An orthotics foot measuring device (Piedro Ltd, United Kingdom) [12] was modified by attaching two halves of a metal ruler to produce a measuring caliper (figure 1). The umbilicus was chosen as a single anatomical site for all patient measurements as it is quick to find, in most patients does not vary in position and is normally included in the area of irradiation for higher dose abdomino-pelvic radiography. For some patients (such as adolescent females) it is a less sensitive area for measurement than alternative sites (such as the xiphisternum). Patient AP diameter can also be measured at the iliac crest or xiphisternum corresponding to pelvis and chest radiographs.

Measurements were permitted over one layer of light clothing or against skin (see figure 2) and were performed with patients erect or seated if unable to stand. Prior to and following use the calipers were cleaned with a disposable antiseptic towel.

Prior to data collection the measurement error of the calipers was determined. Eight different staff members independently measured three different sized (2 months old, 5 years and 15 years old) children blinded to each other's measurements following the patient's and/or parent's verbal consent. Mean thickness, standard deviation and inter-observer measurement range were calculated.

During data collection 158 patients attending the paediatric radiology department for a trunk radiograph within working hours had their AP thickness, age, examination dose, exposure factors and anti-scatter grid use recorded. Patients were imaged using existing age-based exposure charts and using a GE MPS 50 generator with an Apollo tube and Fujifilm FCR computed radiography (CR) imaging plates and reader. Two anti-scatter grids were used, a focused stationary Pb/Al 8:1 grid and an oscillating Pb/compressed paper/carbon fibre 17:1 grid.

For the second part of the study a 6-point image quality scoring system was adapted from the European Quality Criteria [10]. This was used to score 22 paediatric pelvic radiographs of thickness 130mm-320mm (11 with a grid and 11 without a grid) by two radiologists (one resident and one paediatric radiology consultant).

Scoring involved assessment of the S1 pedicles, femoral neck trabeculae and para-femoral neck fat planes. Each criterion was scored as 0,1 or 2 for not seen, blurred or sharp respectively with a minimum and maximum score of 0 and 6. The mean score, score difference and significance using a t-test were calculated using Microsoft Excel.
Fig. 1: Adapted orthotics foot measuring caliper, with size demonstrated against a toy.

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Fig. 2: Patient measurement performed at the umbilicus.

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Results

Patient thickness measurement is simple and reproducible between operators with a 15mm inter-observer measurement range (see table 1), approximately 10% of actual patient thickness.

DAP plotted against patient thickness for spine, abdomen and pelvis is illustrated in figures 3, 4 and 5 respectively. There is a trend for increasing doses with patient thickness as would be expected.

Doses were significantly higher with the use of a grid, up to 4-6 times for the same thickness of patient. Grid use tended to be primarily in larger thickness patients however there is an overlap of grid use in the intermediate thickness patients as grid use is determined by patient age alone.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean thickness (mm)</th>
<th>SD (mm)</th>
<th>Range (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big (aged 15 years)</td>
<td>168</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Medium (aged 6 years)</td>
<td>130</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Small (aged 2 months)</td>
<td>122</td>
<td>5</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 1. Measurement error. Mean thickness, standard deviation and range of three patients measured by 8 independent staff members for measurement error calculation.

Examples of abdominal radiographs of same-thickness patients (150mm) aged 4.5 and 14 years with and without the use of a grid are shown in figures 6 and 7. Despite the same patient size the older patient "received" a grid based on their age. Field of view (FOV) is 21.8 x 28.9cm and 31.4 x 41.3cm or 630cm² and 1297cm² respectively with a dose of 4.0cGYcm² and 31.3cGYcm². Accounting for the increase in FOV the dose was four times higher with a grid. Vertebral body bony detail in the younger patient remains acceptable despite not using a grid.

Age based anti-scatter grid use results in an increase in image quality (1.5 points, p<0.01), and a 4-fold increase in dose (34.5 vs 8.6cGYcm², p=0.02) (see figures 8 and 9). Examples of radiographs used for image quality assessment are demonstrated in figures 10 and 11.
**Fig. 3:** DAP (cGycm2) vs thickness (mm) for AP spine radiographs with (black squares) and without (grey circles) the use of a grid. N = 43.

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Fig. 4: DAP (cGycm2) vs thickness (mm) for AP abdomen radiographs with (black squares) and without (grey circles) the use of a grid. N= 31.

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**Fig. 5:** DAP (cGycm2) vs thickness (mm) for AP pelvis radiographs with (black squares) and without (grey circles) the use of a grid. N = 57.

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**Fig. 6:** Figures 6 and 7 demonstrate different aged but same-thickness patients. The older patient "received" a grid based on their age. 4.5 year old boy with abdominal pain, found to have intussusception due to a Meckel's diverticulum. 150mm abdominal thickness, DAP of 4.0cGYcm2. No grid. Exposure factors 66/4.

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Fig. 7: Figures 6 and 7 demonstrate different aged but same-thickness patients. The older patient "received" a grid based on their age. 14 year old boy with left loin pain, suspected renal calculus. 150mm thickness. DAP 31.28cGycm2, stationary grid (Pb/Al 8:1 grid ratio). Exposure factors 73/12.5.

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Fig. 8: Boxplot of image quality with and without the use of an anti-scatter grid. There is a statistically significant improvement in image score using a grid (p<0.01). Center lines show the medians, box limits indicate the 25th and 75th percentiles, whiskers extend 1.5 times the interquartile range from the 25th and 75th percentiles, crosses represent sample means.

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**Fig. 9:** Boxplot of dose (DAPcGYcm2) with and without the use of an anti-scatter grid for 22 radiographs used in the image quality assessment. There is a statistically significant increase in dose using a grid (p=0.02). Center lines show the medians, box limits indicate the 25th and 75th percentiles, whiskers extend 1.5 times the interquartile range from the 25th and 75th percentiles, crosses represent sample means.

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Fig. 10: AP pelvic radiograph of a 6 year-old boy of thickness 170mm following treatment of late presentation of developmental dysplasia of the hip (DDH). No anti-scatter grid was used with a DAP of 3.56cGYcm2. Despite the relatively poor bony detail score (just visible femoral neck trabeculae and para-femoral fat planes yielding a score of 2), the radiograph is adequate for the clinical indication and clearly demonstrates the dysplastic acetabulum.

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Fig. 11: AP pelvic radiograph of a 16 year old girl with a thickness of 235mm for chronic right hip pain. Due to her age a grid was used which gives excellent bony detail for her size (score 6) and revealed a well circumscribed lesion in the right femoral neck involving the lesser trochanter. She went on to have cross-sectional imaging of the right hip for further characterisation and the appearances were consistent with fibrous dysplasia (not shown). In this case the use of a grid has not increased diagnostic yield.

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Conclusion

Our experiences are that direct patient thickness measurement is quick and simple to perform. A number of concerns have been raised for the use of thickness measurements using calipers [13] including caliper use causing distress, embarrassment, potential infection risk and increased examination time.

There is no evidence to suggest that this technique poses an infection risk if used correctly. Rarely patients or parents objected to direct thickness measurement and there were no reports of distress or embarrassment. Although measurements add little time to existing radiographic practice we recognise that it may be impractical to perform on every patient and is best used in selected cases.

The technique is reproducible between operators with a small measurement range as a proportion of the actual size of the patients (10%).

The trend of increasing dose with thickness for abdomino-pelvic radiographs is expected and is more pronounced when using a grid. This observed dose difference when using a grid can be explained by the compensatory increase in exposure factors and any increase in FOV. For example in figures 6 and 7, FOV was approximately double in the older patient despite the same patient thickness.

The degree of "overlap" in grid use for intermediate sized patients in figures 3-5 is explained by the use of exposure charts based on patient age alone. This size "overlap" for grid-use varies between 150-250mm dependent on the projection. The higher thickness limit (250mm) is probably an acceptable cut-off for grid-use in most cases and is higher than existing recommendations (120-150mm) [8,9]. Despite the higher quality pelvic bony detail by using a grid, the diagnostic quality of pelvic radiographs for evaluation of paediatric hip pathology in average sized children is not significantly improved and on average increases dose four-fold. The benefit of grid use is likely to further diminish in the future as there is a trend towards ultrasound and MRI replacing projection radiography in paediatric imaging. Rarely would important pathology be missed by not using a grid in average sized children as is demonstrated in figures 10 and 11.

In summary direct patient measurement is simple, reproducible and can be introduced with minimal changes to existing radiographic practice.
Anti-scatter grid use improves image quality but with a 4-6 fold increase in dose. Use of a grid does not always correlate with patient size. Grid use can be avoided in patients less than 250mm in thickness in all but exceptional cases.
**Fig. 3:** DAP (cGycm2) vs thickness (mm) for AP spine radiographs with (black squares) and without (grey circles) the use of a grid. N = 43.

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Personal information

Joshua Shur, MSci(Hons), MBBS.
St George’s Hospital, London
joshshur@doctors.org.uk

Kaye Shah
St Helier’s Hospital, London

Alison Kasoar
St Helier’s Hospital, London

John Kyriou, BSc, MSc.
St George’s Hospital, London

Jane Valmai Cook, MB BCH, MRCP, FRCR.
St Helier’s Hospital, London


12. Piedro Ltd, Castle Donington, United Kingdom. www.piedro-uk.co.uk