Review article

# Optimisation of pelvic imaging radiography protocols in plain radiology: a scoping review

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## Abstract

**Introduction:** The purpose of this work is to explore which studies have been performed in the field of radiation dose reduction in pelvic x-ray imaging and to determine optimization techniques for dose reduction.
**Materials and methods:** A scoping review was performed by using databases Science Direct, PubMed, EBSCO Host and Springer Link. The keywords used were "radiography", "dose reduction", "pelvis" and "pelvic". Exclusion criteria were the keywords "CT" and "MRI".
**Results:** 15 scientific articles that analyse the current dose impacts in selected institutions or regions were reviewed as a starting point to optimise protocols, to establish diagnostic reference levels, or to suggest different measures for dose reduction. Studies suggest the use of digital image receptor, adaptation of exposure parameters; they also point out the use of air gap instead of radiographic grid and investigate the usefulness of the gonad protection. A difference was noticed in developing countries that focus more on the establishment of DRLs and following the guidelines provided by other countries rather than developing new dose optimisation techniques.
**Conclusion:** A pelvic x-ray must be performed with a low radiation dose impact that still doesn't compromise the diagnostic value of the image, which can be achieved by following the ALARA principle and with certain adjustments, suggested by the considered studies, especially with exposure parameters. The establishment of national and local diagnostic reference levels is also required.
**Keywords:** radiation dose reduction, pelvic imaging, optimization, diagnostic reference levels

## Introduction

Radiation Protection 18 directive lists several indications for pelvic radiography, such as urinary and reproductive system diseases, trauma, or suspicion of a foreign body (1). In general radiography standard anteroposterior image is used to examine the pelvic ring, obturator foramina, sacroiliac joints, symphysis pubis, acetabulum, sacral foramina, and proximal femur. Modified trauma projections can also be performed, such as outlet projection or inlet projection for a better symphysis pubis view (2). There are radiosensitive organs in the X-ray field, such as colon and bone marrow, which have one of the highest tissue weighting factors (wT = 0.12), gonads (wT = 0.08), urinary bladder (wT = 0.04), so the ALARA (as low as reasonably achievable) principle must be carefully followed (3).
The Dose Datamed II study collected dose information for specific radiological procedures in EU countries. Imaging of the pelvis is routinely performed in traumatology, rheumatology, and for evaluation of hip dysplasia. In Slovenia, an average of 37.13 pelvic X-rays is performed per 1000 inhabitants, which is lower than the European average (48.7 per 1000 inhabitants). This means that the dose effect is already optimized, as fewer Slovenians are exposed to radiation from medical examinations. The European average for the effective dose for this type of medical imaging is 0.7 mSv, with only imaging of the abdomen and lumbar spine having a higher effective dose than imaging of



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the pelvis in general radiography. Slovenia has already somewhat optimized protocols in this aspect as well, with an average effective dose of 0.52 mSv for this procedure (4). In the second part of the above study, diagnostic reference levels (DRLs) for specific medical imaging procedures involving ionizing radiation were established for 36 EU countries. For pelvic radiography, the guidelines specify a DRL of 10 mGy of entrance surface dose (ESD) or 3000 mGy*cm$^2$ of DAP (dose area product) (5).

According to the principles of radiation protection, the responsibility for any radiological examination lies with the referring physician or radiologist, who must justify every procedure. They must make sure that the benefit (e.g., obtaining specific information about the patient's condition) is greater than the risk from ionizing radiation. To reduce potential harm, radiology protocols should be optimized to still provide a diagnostically useful image with the lowest possible radiation dose. If a medical examination cannot be performed without the use of ionizing radiation (e.g., an ultrasound), it should be performed in accordance with the ALARA principle. Ionization radiation protection can be described from several points of view and our protocols optimized accordingly. On one hand the justification of the radiological examination must be considered, which is always in the jurisdiction of the referring physician and it is not an aspect that was included in our review of the imaging protocol optimisation. On the other hand, there is optimization of the equipment, technical aspects, and professional use of ionization sources that are in the domain of the radiographer. These aspects were included in the review, as well as the principle of individual dose limit, which defines limits for certain examinations (3).

## Methods

In this work the scoping review method and qualitative data analysis were conducted. After defining the research problem, databases were established and keywords determined to use. Then, documents were selected for review and searched for relevant information and conclusions in texts.

## Article selection

The databases Science Direct, Ebsco Host, PubMed and Springer Link were used to search for documents-articles (6–9). Remote access from Central Medical Library was used to access the databases.

The keywords used were "radiography", "dose reduction", "pelvis" and "pelvic". The adjective "pelvic" was added after noting that it is commonly used in the terms "pelvic series" and "pelvic imaging" and is therefore very useful in determining appropriate texts. Exclusion criteria were the keywords CT and MRI, as the main focus was on plain radiography of the pelvis. For computed tomography, the estimated dose values are not comparable to plain radiography (the CT ones being much higher) and magnetic resonance imaging does not use ionization radiation.

15 original research articles were used in our review. The articles were arranged in a table in alphabetical order and defined according to the observed outcome, study design, anatomical region, measurement tool, country of origin, possible comments to better explain the study, and a brief summary added with the main findings.

The selection of the articles is presented in the section Results.

## Results

After establishing inclusion and exclusion criteria, 1144 articles were extracted from 4 databases. Our search was limited to articles with full open access and only original research articles. After this selection, there were 117 documents. Then articles that did not fit our topic were excluded after reading the titles or abstracts. After this selection, there were 43 texts to read them. 15 of those were included in our review after considering them topic-appropriate. The selection of documents is shown in Fig. 1:



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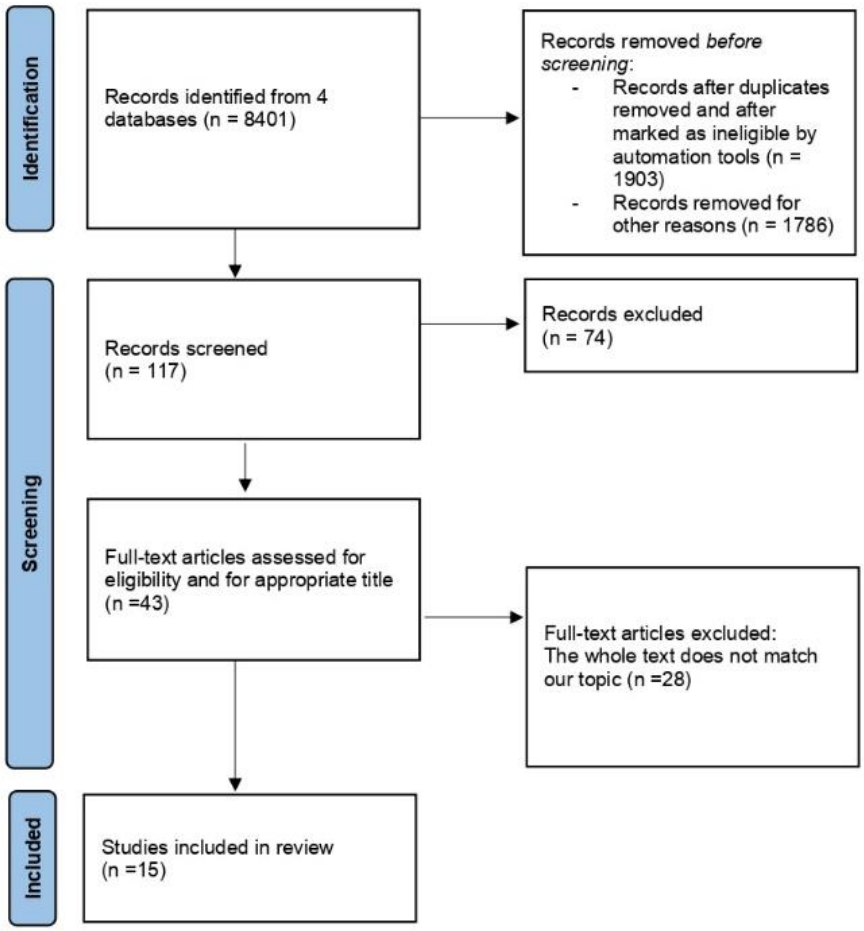
## Figure 1: Article selection process




*The 15 articles analysed are presented in Table 1, arranged in alphabetical order, with country of origin, study design, participating subjects, anatomical region, measurement instrument, comments, and main results defined (10,11,20–24,12–19).*

## Table 1: Study methodology and results

| ARTICLE | COUNTRY OF ORIGIN | STUDY DESIGN | PARTICIPANTS | ANATOMICAL REGION | OBSERVED OUTCOME | MEASUREMENT INSTRUMENT | COMMENTS | RESULTS AND FINDINGS |
|---|---|---|---|---|---|---|---|---|
| Abdelhalim M. 2009. (10) | Saudi Arabia | Cross-sectional study | 200 patients | Pelvis with abdomen AP, also head PA, ankle, foot, sinuses, hips. | To review and compare dose values in 7 diagnostic departments of the hospital KKUH in comparison to other state hospitals and DRL guidelines. | Thermoluminiscent dosimeters (TLD) | | Results vary a lot, some protocols have lower dose values, some have higher than comparable hospitals. The reasons for that can be, as described: different operator abilities, exposure parameters and technical issues. |



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| Aldrich JE et. al., 2006. (11) | Canada | Cross-sectional study | 110 patients | Pelvis AP, also thorax PA and lateral, abdomen AP | To compare entrance skin dose and DAP between different imaging systems (CR, DR, screen-film). | TLD for the screen-film and CR systems, integrated DAP measurement system for the DR | Verifying dose restrictions before moving from screen-film to digital systems in hospital. | There are no statistically significant differences between the 3 systems in pelvic imaging. In other localizations, there are slightly higher dose values in CR system.<br><br>The new digital systems remain inside the frame of proposed DRLs, no protocol changes were implemented. |
| Ali MA et. al. 2019. (17) | Great Britain | Cross-sectional study | Paediatric phantom | Pelvis AP | To optimize exposure parameters and to compare their impact on image quality and dose value. | Solid-state dosimeter on the phantom, ImageJ computer programme to measure SNR (signal-to-noise ratio) and to assess image quality. | The main researcher used Visual<br><br>Grading Analysis (VGA) and binary analysis for image quality assessment as well. | Optimal exposure parameters for pelvic AP x-ray for an appropriate image quality and dose value 178,8 μGy were determined:<br><br>89 kVp, 130 cm SID, filtration 1 mm Al + 0,1 mm Cu, two-outer AEC chamber combination. |
| Chan CTP in Fung KKL. 2015. (18) | China | Cross-sectional study | Phantom | Pelvis AP | To study the possibility of substitution of the radiographic grid with air gap in pelvic imaging to reduce the dose impact on paediatric patients. | TLD dosimeters to measure dose on ovaries and testes. | VGA and Image Quality Score (IQS) for image quality assessment. | A 10 cm air gap was determined as optimal between the object and the image receptor. It can successfully substitute the grid and keeps image quality. It also provides an 81,6 % dose reduction. |
| Haval YY, Hariwan AM, 2017. (19) | Iraq | Cross-sectional study | 409 patients | Pelvis AP, also thorax AP; abdomen, head AP, cervical spine AP and lateral | To evaluate ESD and effective dose for patients in those public hospitals that don't follow the QC (quality control) programme and established protocols. | Calibrated dosimeter. | | Dose values in the observed hospitals are often higher than the recommended DRLs, there is a need for the establishment of a QC program to provide optimal doses. The department of radiology should hire medical physicists that would be responsible for such a program. |
| Jha P. et al.,2013. (20) | USA | Retrospective study | 530 paediatric patients | Pelvis AP and spine lateral | To determine the utility of a routine pelvic and lateral spine radiographs in suspected non-accidental trauma. | Integrated DAP meter. | | Since no fractures were found exclusively on the pelvic or lateral spine radiographs, those imaging protocols are not necessary in the regular protocol of suspected non-accidental trauma. The pelvic radiograph contributes to a higher overall dose; therefore, the benefits don't exceed the risks. |



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| Jibiri NM, Olowookere CJ. 2016. (21) | Nigeria | Cross-sectional study | 640 patients | Pelvis AP, also thorax AP, abdomen AP, lumbar spine AP, skull AP, knee AP, hand AP | Dose measurements for selected radiographs, comparison of the dose values for selected diagnostic centres in two parts of northwest Nigeria, comparison with the published DRLs and establishment of local DRLs. | TLD dosimeters | Big difference in doses between different diagnostical centres. | In most cases the measured doses exceeded guidelines and DRLs of other countries, mostly because of the use of higher mAs. Only in pelvic and lumbar spine radiographs, the dose values are lower compared to some values found in literature, which indicates the possibility for dose optimization in Nigerian diagnostic centres. |
| Kaplan S et al. 2017. (22) | USA | Cross-sectional study, experimental study | 2 phantoms (adult and paediatric (5-year-old patient equivalent) | Pelvis AP | The impact of the female gonadal shielding on DAP and absorbed organ dose when using automatic exposure control in pelvis AP x-ray imaging. | Built-in DAP meter and film dosimetry strips. | The authors mention the restriction of the study to phantom only. With real patients the results could vary because of the differences in gonadal shielding positioning. | When using gonadal shielding and AEC, DAP increases for 63 % in paediatric and 147 % in adult phantom. The absorbed dose on radiosensitive organs, such as colon and sometimes on inadequately shielded ovaries, increases. |
| Kemerink GJ et al. 2019. (23) | Netherlands | Retrospective study with a systematic review, mixed | N/A | Pelvis AP | To re-calculate the outdated exposure data to modern equivalents and to use those in a review of entrance skin doses for pelvic radiographs from 1896–2018. | Computational approach to dose determination from data collected from exposure parameters, chromoradiometers, KAP-meters and TLDs. | Dose reconstruction method was used. | From 1896 to 2018 the dose received from x-ray imaging of the pelvis decreased for a factor of 400. |
| Kloth JK et al. 2016. (24) | Germany | Experimental study | Paediatric patients | Pelvis AP (Rippstein/Dunn projection) | To evaluate the possibility of dose reduction in pelvic x-ray imaging for patients with hip dysplasia. | Dose calculation and exposure parameters adaptation. | For hip dysplasia, two angles are measured and can be assessed even on a radiograph of an otherwise poor diagnostical value. | By changing the S value from 400 to 800 we can achieve lower radiation dose as well as maintain a sufficient diagnostic value of the images of patients with hip dysplasia. |
| Mekiš N, McEntee M, Stegnar P. 2010. (12) | Slovenia | Cross-sectional study | Phantom | Sacroiliac joints (SIJ) AP and PA | To determine possible differences between radiation doses received in SIJ AP or PA imaging. | TLD dosimeters | We included this study for its similarity of the procedure to the pelvic imaging, the positioning, and the same critical organs in both imaging approaches. | The use of lead shielding and PA positioning significantly reduces radiation dose on testicles in SIJ x-ray acquisition. If possible for the patient, PA positioning should be chosen, since it reduces dose on testicles for 93,1 % even without lead shield. |



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| Precht H et al. 2013. (13) | Denmark | Cross-sectional study | Anthropomorphic and technical phantoms | Pelvis AP, also hand and thorax | To explore whether the new detector shape can improve image quality y and/or reduce radiation dose in hand, pelvis and thorax x-ray imaging. | Unfors Xi dosimeter, DAP meter | | The new CXDI-70C proved better than its predecessor in all the examinations because it provides up to 37 % dose reduction while maintaining an appropriate image quality (according to Visual Grading Analysis – VGA). |
| Taha MT et al. 2014. (14) | Saudi Arabia | Cross-sectional study | Patients | Pelvis AP, also thorax PA, head AP, abdomen, cervical spine, foot | To measure ESD in patients, undergoing diagnostic x-ray procedures in King Abdullah Medical City in Makkah, KSA | A calibrated solid-state detector, Ray-safe meter | The authors used the measurements as a basis to write a programme, that can anticipate ESD before the x-ray is even performed. | Measured doses and exposure parameters are similar to those described in literature and to DRLs from the guidelines. |
| Tonkopi E et al. 2012. (15) | Canada | Cross-sectional study | Patients, phantom | Pelvis AP, also thorax PA and lateral, lumbar spine PA and lateral, abdomen | To evaluate and optimize typical radiological procedures in their institution and to establish local DRLs. | Dose calculation from the saved exposure parameters data | The authors mention, there should exist modality specific DRLs; different for CR or DR systems. | Local DRLs in this case were lower than national. There are some differences between different diagnostic technical equipment in the same institution and between CR and DR systems (the latter has lower DRLs). Measures for dose optimization in CR system were proposed. |
| Yvert M et al. 2015. (16) | France | Cross-sectional study, experimental study | Phantom, later 61 paediatric patients | Spine (pelvis is mentioned as a possibility for the use of EOS system which could reduce radiation dose) | To evaluate received radiation dose and image quality in scoliosis diagnostics in two different digital systems: dynamic flat panel detector (DFP) and single slot scanning (SSS or, commercially, EOS). | TLD dosimeters and DAP meter | The EOS system was developed specifically for patients with osteoarthritic issues, especially in the spinal area since they are often exposed to ionizing radiation in medicine during their childhood. | For any spinal or lower limb x-ray imaging the SSS (EOS) system is more appropriate since it allows dose reduction and provides +optimal image quality. It can also be used in other anatomical regions, such as pelvis. |

The studies included in our analysis are mostly cross-sectional and were conducted in different countries. They were performed on phantoms, patients, in two cases on both, such as the study by Yvert M et al. (16), which tested a new imaging system on a phantom and later used the same parameters in clinical imaging for spine imaging in children with scoliosis. This article may not appear entirely appropriate for our review, since it is mainly dedicated to spinal imaging, but it proposes an application to pelvic radiography as well and its findings can be used in pelvimetry and other applications.

The studies often involved the acquisition of pre-existing data (such as DAP, which are often automatically stored by the imaging system without any special settings and the researcher can easily extract the data afterwards). TLD dosimeters have been used in most cases to measure the dose of ionizing radiation. ESD was in some cases calculated from the machine's output. Kemernik et al. (23) had an interesting approach to this issue, as they performed a retrospective study to analyse existing data collected with older dosimetry meters and attempted to convert the values to units of measure (Gy) used today.

All studies discuss the optimisation and reducing dose levels, and 7 of 15 studies also examine image quality (12,13,16,18,22,24). One study by Kloth et al. (24) is somewhat specific, as they attempted to



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reduce exposure parameters and dose as much as possible, even if at the expense of spatial and contrast resolution of the image. In this study, a specific case of pelvic imaging for suspected hip dysplasia and its follow-up is discussed. Since this is a type of paediatric imaging, the dose must be as low as possible, and since the main result of the image is the measurement of two specific angles (AC and CE) between bone surfaces and joints, the diagnostic value of the image is not so important, and the angles can be measured even in a low-quality radiograph.

Dose reduction in pelvic imaging can be achieved by lowering exposure parameters (24), using/not using lead shielding (22), changing imaging system - screen-film/ CR /DR (17), using an air-gap instead of an X-ray grid (18) or positioning the patient differently (12). In 27 % of the documents analysed, researchers focus on establishing DRLs, either by analysing and comparing results with national DRLS or by efforts to establish local DRLs.

## Discussion

In our review, original research articles were analysed discussing various dose optimization techniques in pelvic radiography. Dose optimization is necessary when performing this procedure because many radiosensitive organs are in the primary x-ray beam when a pelvic radiograph is taken. This imaging is also commonly performed in children due to possible trauma or developmental problems. In our analysis a review of studies on various methods to reduce dose without compromising image quality was included, as well as studies to determine if there is even a need for such optimization at their institution. This need can be assessed by measuring dose levels and comparing them to established guidelines regarding DRLs at the national level (or in a comparable country).

Most of the studies analysed have a cross-sectional study design, which is appropriate when planning public health interventions, including protection from ionising radiation. When planning an experimental study in this field, there may be problems when trying to transfer the results of a phantom study to a clinical application, as the ethical point of view must not be neglected.

Geographically, Western countries (Canada, USA, Slovenia, Germany, France (11,12,16,22,24)) focus more on dose optimization through system updates, new techniques, etc., while African and Near-Eastern countries such as Nigeria, Saudi Arabia or Iraq (14,19,21) focus more on collecting dose values for specific facilities and setting national and local DRLs, less on dose-reducing options.

The study by Ali et al. (17) is important and clinically very useful as they give accurate optimal exposure parameters for pelvic imaging in children with a lower dose and with a diagnostically usable image of adequate quality. There is a possibility of improvement by the results of Chan et al.(18), in which the x-ray grid is replaced by an air gap.

## Limitations

There is a language barrier/limitation in our review as only documents in English were analysed. There is also a problem with the word "pelvis", which often occurs in ultrasound procedures in relation to radiology, especially in gynaecology, so it might have been better to use an exclusion criterion “NOT ultrasound” from the beginning. This exclusion criterion was not chosen, so articles on this topic had to be eliminated only after reading. To better review of all dose optimization procedures, more texts should be included in the analysis. The search could also be performed in other databases and perhaps the search terms should be reconsidered.

## The significance of the study

This scoping review could be extended by including more articles in our sample. This could be achieved by adding other databases not included in our review or by using the snowball method.

The before mentioned merger of the results of Chan et al. and Ali et al.(17,18) provides an opportunity for a new study that would combine dose reduction interventions proposed by different researchers. In this way, a phantom study could be designed that could later be expanded into a clinical trial. By combining different methods, optimal exposure and technical parameters could be potentially found as well as patient positioning for pelvic radiography. With a systematic review and with the combination of results from different studies, a similar principle could be used to design studies in other areas of radiology and later implement different factors that contribute to dose reduction without compromising the diagnostic value of the x-ray for other anatomical regions in general radiography.

In Slovenia, similar to other countries, there could be an attempt to identify DRLs at institutional level for a specific diagnostic centre or department. In this way, examples of good practice could be singled out and optimization protocols proposed for other institutions as well.



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## Conclusion

Any work involving ionizing radiation must be done with the awareness that the diagnostic or therapeutic value should be greater than the damage this type of radiation can cause. An x-ray imaging must be performed with low dose exposure to the patient, but still maintain the diagnostic value of the image. Since pelvic radiography is a common examination in which patients receive a rather high radiation dose, among the three highest in conventional radiography, optimization of the imaging protocols seems necessary.

The studies analysed suggest several techniques for dose optimization in pelvic radiographs, such as adjusting exposure parameters, changing the image detector, or even excluding the procedure from a routine protocol when it is not necessary. After reviewing, adjusting exposure parameters seems the most common, appropriate and useful intervention any radiographer can perform to optimize dose exposure for patients undergoing pelvic x-ray imaging. To keep radiological protocols adequate, as studies suggest, a country or institution should also define, comply, and optimize national or local diagnostic reference values, since in literature they prove to be an important tool to which dose values can be compared and any possible need for optimisation can be recognised.

## References

1. European Commision D-G for the environment. Radiation Protection 118: Referral guidelines for imaging. 2000.
2. Hacking, C.; Murphy A. Pelvis series. In: Radiopaedia. Available from: https://radiopaedia.org/articles/pelvis-series?lang=us
3. Jr JDB, Clarke RH, Cousins C, Gonza AJ, Lee J, Lindell B, et al. ICRP Publication 103. 2007. 1–616 p.
4. European Commission. RADIATION PROTECTION N ° 180 Medical Radiation Exposure of the. Eur Union. 2014.
5. Commission E. Diagnostic Reference Levels in Thirty-six European Countries (Part 2/2). 2014;1–73. Available from: http://ddmed.eu/
6. Science Direct. Available from: https://www.sciencedirect.com/
7. EBSCOhost. Available from: https://search.ebscohost.com/login.aspx?authtype=ip,uid&group=CMK&profile=ehost&defaultdb=c8h
8. PubMed. Available from: https://pubmed.ncbi.nlm.nih.gov/
9. Springer Link. Available from: https://rd.springer.com/search?facet-content-type=%22Journal%22
10. Abdelhalim MAK. Patient dose levels for seven different radiographic examination types. Saudi J Biol Sci. 2010;17(2):115–8.
11. Aldrich JE, Duran E, Dunlop P, Mayo JR. Optimization of dose and image quality for computed radiography and digital radiography. J Digit Imaging. 2006;19(2):126–31.
12. Mekiš N, Mc Entee MF, Stegnar P. PA positioning significantly reduces testicular dose during sacroiliac joint radiography. Radiography. 2010;16(4):333–8.
13. Precht H, Tingberg A, Waaler D, Outzen CB. New developed DR detector performs radiographs of hand, pelvic and premature chest anatomies at a lower radiation dose and/or a higher image quality. J Digit Imaging. 2014;27(1):68–76.
14. Taha MT, Al-Ghorabie FH, Kutbi RA, Saib WK. Assessment of entrance skin doses for patients undergoing diagnostic X-ray examinations in King Abdullah Medical City, Makkah, KSA. J Radiat Res Appl Sci. 2015;8(1):100–3. A
15. Tonkopi E, Daniels C, Gale MJ, Schofield SC, Sorhaindo VA, Vanlarkin JL. Local diagnostic reference levels for typical radiographic procedures. Can Assoc Radiol J. 2012;63(4):237–41.
16. Yvert M, Diallo A, Bessou P, Rehel JL, Lhomme E, Chateil JF. Radiography of scoliosis: Comparative dose levels and image quality between a dynamic flat-panel detector and a slot-scanning device (EOS system). Diagn Interv Imaging. 2015;96(11):1177–88.
17. Mohammed Ali A, Hogg P, England A. Dose optimisation in paediatric radiography – Using regression models to investigate the relative impact of acquisition factors on image quality and radiation dose. Phys Medica. 2019;68(November):61–8.
18. Chan CTP, Fung KKL. Dose optimization in pelvic radiography by air gap method on



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Online: ISSN 2637-3297

CR and DR systems - A phantom study. Radiography. 2015;21(3):214–23.
19. Yacoob HY, Mohammed HA. Assessment of patients X-ray doses at three government hospitals in Duhok city lacking requirements of effective quality control. J Radiat Res Appl Sci. 2017;10(3):183–7.
20. Jha P, Stein-Wexler R, Coulter K, Seibert A, Li CS, Wootton-Gorges SL. Optimizing bone surveys performed for suspected non-accidental trauma with attention to maximizing diagnostic yield while minimizing radiation exposure: Utility of pelvic and lateral radiographs. Pediatr Radiol. 2013;43(6):668–72.
21. Jibiri NN, Olowookere CJ. Patient dose audit of the most frequent radiographic examinations and the proposed local diagnostic reference levels in southwestern Nigeria: Imperative for dose optimisation. J Radiat Res Appl Sci. 2016;9(3):274–81.
22. Kaplan SL, Magill D, Felice MA, Xiao R, Ali S, Zhu X. Female gonadal shielding with automatic exposure control increases radiation risks. Pediatr Radiol. 2018;48(2):227–34.
23. Kemerink GJ, Kütterer G, Kicken PJ, van Engelshoven JMA, Simon KJ, Wildberger JE. The skin dose of pelvic radiographs since 1896. Insights Imaging. 2019;10(1):1–12.
24. Kloth JK, Neumann R, Von Stillfried E, Stiller W, Burkholder I, Kauczor HU, et al. Quality-controlled dose-reduction of pelvic X-ray examinations in infants with hip dysplasia. Eur J Radiol. 2016;85(1):233–8.



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