Cobb Angle

Review article – Optimisation of exposure parameters for spinal curvature measurements in paediatric radiography

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ABSTRACT

This review aims to identify strategies to optimise radiography practice using digital technologies, for full spine studies on paediatrics focusing particularly on methods used to diagnose and measure severity of spinal curvatures. The literature search was performed on different databases (PubMed, Google Scholar and ScienceDirect) and relevant websites (e.g., American College of Radiology and International Commission on Radiological Protection) to identify guidelines and recent studies focused on dose optimisation in paediatrics using digital technologies. Plain radiography was identified as the most accurate method. The American College of Radiology (ACR) and European Commission (EC) provided two guidelines that were identified as the most relevant to the subject. The ACR guidelines were updated in 2014; however these guidelines do not provide detailed guidance on technical exposure parameters. The EC guidelines are more complete but are dedicated to screen film systems. Other studies provided reviews on the several exposure parameters that should be included for optimisation, such as tube current, tube voltage and source-to-image distance; however, only explored few of these parameters and not all of them together. One publication explored all parameters together but this was for adults only. Due to lack of literature on exposure parameters for paediatrics, more research is required to guide and harmonise practice.

INTRODUCTION

There are several types of spinal deformities that can affect children during their early or late childhood, with scoliosis and kyphosis being the most common[1]. Early diagnosis is important to improve prognosis and life expectancy[2]. Diagnosis and follow-up can be performed using physical examinations and/or imaging (e.g., CT, MRI and plain radiography). Imaging is the most common method because it is accurate and it allows the detection and severity assessment. Despite developments in cross-sectional imaging plain radiography remains the mainstay. Plain radiography can be obtained using analogue or digital systems [computed radiography (CR) or direct radiography (DR)] and is required to measure the degree of spinal curvature, using Centroid, Harrison Posterior Tangent, TRALL and Cobb methods[3-4].

However, plain radiography involves radiation. This can increase stochastic effects, especially for children. Therefore, it should be performed using optimised acquisition parameters to guarantee that Image quality (IQ) is acceptable to analyse the anatomical structures and perform spinal curvature measurements. The European guidelines provided by European Commission (EC)[5] give information about imaging on paediatrics with details on technical parameters but only for analogue systems. Also provides general recommendations for paediatrics although not by age.

Several studies[6-9] provide information about reducing dose to paediatrics but it is not fully explored for digital systems and age groups. This is important because paediatrics are more radiosensitive than adults, due to the rate of cell division[10], increasing the probability of late radiation effects which can affect life expectancy[11]. Therefore, it is important to keep doses As Low As Reasonably Practicable (ALARP)[12].

The aim of this review is to identify strategies to optimise radiography practice using digital technologies for spine curvature examinations on paediatrics and provide an overview of the methods available for measuring the degree of spinal curvatures.

Literature review was performed using different resources including databases (PubMed, Google Scholar and ScienceDirect) and websites and guidelines to obtain a range of information on different methodologies available for assessing spinal curvatures. To search for relevant literature, the following keywords were used: optimisation, effective dose, IQ, paediatrics, phantom and Computed Radiography. Other criteria to select the studies were: year of publication for the selection of exposure parameters (most updated) and use of CR/DR.

Spinal deformities in paediatrics

Spinal conditions include scoliosis (curving of the spine), kyphosis (increasing roundback of the spine), lordosis (increasing inward curvature of the spine), spondylolysis (stress fracture of the spine) and spondylolisthesis (movement of one part of the spine on another part). Scoliosis and kyphosis are the most common. These deformities can affect children during their early or late childhood[1,13]. These may occur due to failure of bone development and are treated depending on the cause. Whilst in adolescence the cause may be unknown, it is more likely to be determined in the early age. To prevent progression of deformity and improve life expectancy early diagnosis is important[2].

Thoracic kyphosis is the increase of the thoracic curvature in the sagittal plane and indication for treatment is based on kyphosis angular measurement. Normal kyphosis ranges from 20-50° when assessed by modified Cobb's method on lateral radiographs[14].

Scoliosis is a structural three-dimensional deformity of the spine defined by a lateral curvature of more than 10°. The development and progression of scoliosis is related to growth. Scoliosis can also be classified by cause, into idiopathic or secondary. Idiopathic scoliosis is further classified into infantile, juvenile (4-10 years) and adolescent types or early and late onset. Scoliosis can also be secondary to congenital disorders, neuromuscular conditions, tumors, trauma or syndromic[2].

Available methodologies to detect spinal curvatures

There are many methods of measuring spinal curvature including: physical examinations (e.g., forward bending) and imaging methods (e.g., CT, MRI and plain radiography). Imaging is the most common and accurate method to determine severity of curvature. Despite the vast development of CT and MRI in terms of cross-sectional imaging, with MRI posing no radiation dose to patient, plain radiography remains the mainstay. It is the most affordable, time efficient, easily accessible (compared to CT and MRI), more patient friendly compared to MRI and provides the least dose when compared to CT[15]. It is used to confirm diagnosis, exclude underlying causes, assess the curves and severity, monitor progression, assess skeletal maturing and determine patient's suitability for surgery[16].

Techniques to measure spinal curvature using imaging methods

Many methods are mentioned in the literature for measuring the degree of spinal curvatures using plain radiography. Centroid method is performed on the lateral view by connecting the intersections of 2, 3 or 4 vertebral bodies. This method is easily performed however has less inter-observer reliability and does not provide accurate angles of hypotension or hyperextension[3-4]. In addition, the Centroid method uses more points and takes more time to conduct. In comparison to the Cobb method and Harrison posterior tangents method, the Centroid method results in smaller angle measurement of the total spinal curvature[3].

In the Harrison posterior tangent method, lines are drawn at two posterior vertebral bodies simultaneously on a lateral radiograph because of the higher density. Despite this method having a smaller standard error compared to other methods, it can only be used on lateral radiographs[3].

The TRALL method requires a vertical line drawn from the posterior-superior apex of the 1st Lumbar vertebra (L1) to Sacrum. The largest perpendicular distance (depth) to the posterior longitudinal ligament is used to find the lumbar curve apex. This method only provides one global angle and does not include segmental angles, limiting its usefulness[2].

The Cobb's method can be used for Antero-posterior (AP)/ Postero-anterior (PA) and lateral radiographs, whereas the posterior tangent method is not widely used for assessing both kyphosis and scoliosis. In the modified Cobb method, four lines are drawn to create the Cobb angle. Two parallel to vertebral bodies at the superior aspect of T1 and the inferior aspect of T12 and two perpendicular to those. This method is the most common and can be created by the computer or drawn manually. In clinical practice there may be instances when the Cobb method is not appropriate (e.g., hypolordosis) due to the lack of convergence of lines on the radiograph. In such cases, posterior tangent method is recommended[4]. Several studies[17-19] showed good reliability with the Cobb method. Furthermore, this method represents the standard means of evaluating clinically, spinal curvature and has been adapted traditionally in clinical practice as the most simple, well known and accurate for diagnosis and follow-up[20].

Optimisation of radiography for the analysis of spine curvature

To satisfy the needs in paediatric imaging, optimisation must be at the forefront of all techniques. The stochastic effects of radiation are a concern in paediatrics because this population is the most sensitive. Imaging may result in a high cumulative dose because serial imaging is often involved[1]. Radiation exposure in the first ten years of life is estimated to cause detrimental effects, with attributable lifetime risk five to seven times greater than exposures between the ages of 50-70[5].

There are two principles of radiation protection of the patient[21]: justification of practice and optimisation of exposure. Justification is particularly important in paediatrics and is related to the relevance of the examination. This means that an exposure is not justifiable without a valid clinical indication. For every examination benefits must outweigh risks[5].

The International Commission on Radiological Protection (ICRP) does not recommend the application of dose limits to patient irradiation, dose reference levels (DRL) should be used as an optimisation tool. However, it is always a challenge to minimize the dose to the patient without compromising IQ required for accurate diagnosis[5,22]. So, during optimisation it is important to considerer IQ, the imaging method and technique, to keep doses ALARP[12]. Generally, optimisation is focused on examinations that are common and/or give significant dose to patients such as skull, pelvis, spine, abdomen and chest[5].

To estimate the radiation dose delivered during an X-ray examination, there are several approaches that can be used such as measurements on phantoms or patients, and also several types of radiation detectors can be used [e.g., Dose-Area product (DAP) dosimeter, thermoluminescent dosimeter (TLD)] and Monte Carlo simulations[23].

The results of the studies can vary according to the methodology that is chosen for dose estimation; however a major overview on dose values can be taken from the literature. A study to optimise lateral thoracic-lumbar images was performed using Monte Carlo simulations. The technical parameters that were used consisted of anode towards the head, broad focus, no Object to Image Distance (OID) or grid, 80kVp, 32mAs and 130cm SID. The estimate effective dose resulted to 0.05 mSv. Yet, this study was performed with adult phantom and patients[24].

In order to achieve the adequate balance between IQ and dose, techniques for evaluating IQ should be focused on the clinical aim[25]. The literature review highlighted many studies on the topic, but this review is focused on more updated studies (after 1990), to have an overview on the strategies for optimisation dedicated to digital technologies.

IQ analysis is difficult to define when there are many aims (e.g., detection only, avoid noise, improve contrast) for different observers, and there are several options to do this. Radiographers and radiologists require images that have quality to ensure a precise diagnosis. Concerning this, observers should share equal standards for visual measures of IQ. IQ is affected by exposure parameters, human characteristics and skills (e.g., eye accuracy, perception and experience) to observe an anatomical region addressing a specific clinical situation. To improve practice, it is desirable that observers have discussions to prevent heterogeneous IQ standards[26].

Concerning IQ assessment, there are many different types of recommended tests and these vary within the literature. There are physical methods [e.g., contrast-to-noise ratio (CNR), signal-to-noise ratio (SNR)] and also visual methods. Visual methods found in the literature tend to use several IQ ratings including: absolute or relative scales [(e.g., five-step scale, 1 (worst) to 5 (best); and two-step scale with 1 (criterion was fulfilled) and 0 (criterion was not fulfilled); four-step scale (perfect, good, moderate and inadequate)]. Software also exists to assist in performing visual IQ assessment, for example ViewDEX, 2 Alternative Forced Choice (2AFC), conspicuity index[25,27].

ViewDEX (Viewer for Digital Evaluation of X-ray images) allows the validation of new imaging systems, techniques and research on IQ using observers. This software is DICOM compatible and the features of the interface (tasks, image handling and functionality) are general and flexible[28]. Also, this software allows observer performance studies with the same fundamental display properties reflected in the clinical reading environment, with less time required to handle the images compared to analogue systems[28-29].

Studies and guidelines often do not include information on observer training for visual IQ assessment. This could be useful to reduce inter and intra observer variability during the assessment. To select the strategies, human resources, material resources and also the available time to perform the tasks must be considered[27].

The literature dedicated to IQ improvement and dose reduction in paediatrics provided general strategies such as raising kVp whilst lowering mAs to reduce dose; and the use of image-processing techniques adapted to the local characteristics, in particular to the noise content, which allows dose reduction. Agfa systems contain MUSICA software that allows different processing methods for 4 different paediatric age/weight groups for a variety of exams[8].

The first examination on a patient should address IQ but for follow up examinations it may not require the same degree of quality, so dose could be reduced. Main methods to optimise provided by Willis[7] were: to select a suitable detector (small, higher sensitivity and efficiency), combination of noisy images, scatter reduction with grid or other technique and limit radiation field to anatomy of interest. The same author also provided other options such as increase kVp or SID to reduce dose, increase mAs to improve contrast, increase image processing adopting the best tools, use AEC or manual technique concerning calibrations[7].

Other studies[7,30-34] focused on one or two parameters (kVp alone, SID alone), apart from the study performed by Qaroot et al[24], which takes into consideration all the above parameters, however relates to adults only. Also, the majority of studies are focused on screen-film systems and measurements accuracy[35-37].

The studies identified as related to digital technologies are mainly reviews and a protocol to optimise paediatric practice could not be found.

CONCLUSION

The two most common spinal deformities in children are kyphosis and scoliosis. Amongst the many methods used for diagnosis, imaging is the most used as it not only provides diagnosis, but also severity of the condition. Between the many imaging methods, plain radiography is most accurate, cost effective and time efficient. From the various techniques available for measuring the degree of spinal curvature, Cobb measurements are most usual, easily performed and can be used for AP/PA and lateral projections. However, in order to carry out these measurements, X-rays are required, which pose radiation risks, especially for paediatrics as they are more radiosensitive. Moreover, with the serial imaging involved, optimisation of dose is critical along with producing imaging that allows accurate Cobb measurements. Due to the lack of current guidelines for paediatrics using digital equipment, it is important to conduct a study which explores different exposure parameters, in order to conclude the most optimum parameters. This will update information provided by the EC and guidelines by ACR.

REFERENCES

1. Bruce Jr R, Fletcher N. Pediatric spinal deformities [Internet]. Emory Health Care; 2014 [updated 2015; cited 2014 Aug 12]. Available from: http://www.emoryhealthcare.org/pediatric-orthopedics/conditions/spinal-deformity.html

2. Rolton D, Nnadi C, Fairbank J. Scoliosis: a review. Paediatr Child Health. 2014;24(5):197-203.

3. Harrison DE, Cailliet R, Harrison DD, Janik TJ, Holland B. Reliability of centroid, Cobb, and Harrison posterior tangent methods: which to choose for analysis of thoracic kyphosis. Spine (Phila Pa 1976). 2001;26(11):E227-34.

4. Harrison DE, Harrison DD, Cailliet R, Janik TJ, Holland B. Radiographic analysis of lumbar lordosis: centroid, Cobb, TRALL, and Harrison posterior tangent methods. Spine (Phila Pa 1976). 2001;26(11):E235-42.

5. Kohn M, Moores B, Schibilla H, Schneider K, Stender H, Stieve F, et al. European guidelines on quality criteria for diagnostic radiographic images in paediatrics. Luxembourg: Office for Official Publications of the European Communities; 1996.

6. Hess R, Neitzel U. Optimizing image quality and dose in digital radiography of pediatric extremities [Internet]. Philips Healthcare; 2011. Available from: http://www.healthcare.philips.com/main/about/events/rsna/pdfs/DR_White_paper_Optimizing_image_quality_and_dose_in_digital_radiography_of_pediatric_extremities.pdf

7. Willis CE. Optimizing digital radiography of children. Eur J Radiol. 2009;72(2):266-73.

8. Schaetzing R. Management of pediatric radiation dose using Agfa computed radiography. Pediatr Radiol. 2004;34 Suppl 3:S207-14

9. Hess R, Neitzel U. Optimizing image quality and dose for digital radiography of distal pediatric extremities using the contrast-to-noise ratio. Rofo. 2012;184(7):643-9.

10. Pearce MS, Salotti JA, Little MP, McHugh K, Lee C, Kim KP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet. 2012;380(9840):499-505.

11. Bone CM, Hsieh GH. The risk of carcinogenesis from radiographs to pediatric orthopaedic patients. J Pediatr Orthop. 2000;20(2):251-4.

12. Health and Safety Executive. ALARP "at a glance" [Internet]. HSE; 2014 [cited 2014 Aug 12]. Available from: http://www.hse.gov.uk/risk/theory/alarpglance.htm

13. SingHealth. Orthopaedic problems in children: spine deformity (scoliosis, kyphosis) and back pain [Internet]. SingHealth Group; 2014 [cited 2014 Aug 12]. Available from: http://www.singhealth.com.sg/PatientCare/ConditionsAndTreatments/Pages/Orthopaedic-Problems-in-Children-Back-Pain-and-Spine-Deformity-in-Children-and-Adolescents.aspx

14. Teixeira FA, Carvalho GA. Confiabilidade e validade das medidas da cifose torácica através do método flexicurva [Reliability and validity of thoracic kyphosis measurements using flexicurve method]. Rev Bras Fisioter. 2007;11(3):199-204. Portuguese

15. Malfair D, Flemming AK, Dvorak MF, Munk PL, Vertinsky AT, Heran MK, et al. Radiographic evaluation of scoliosis: review. AJR Am J Roentgenol. 2010;194(3 Suppl):S8-22.

16. Rajiah P. Idiopathic scoliosis imaging [Internet]. Medscape; 2013 [cited 2014 Aug 7]. Available from: http://emedicine.medscape.com/article/413157-overview

17. Hong JY, Suh SW, Modi HN, Lee JM, Park SY. Centroid method: an alternative method of determining coronal curvature in scoliosis. A comparative study versus Cobb method in the degenerative spine. Spine J. 2013;13(4):421-7.

18. Chen TR, Tyan YS, Yang JJ, Shao CH, Lin JY, Tung CJ. Measurements and applications of dose indices in radiography. Radiat Meas. 2011;46(12):2044-7.

19. Tanure MC, Pinheiro AP, Oliveira AS. Reliability assessment of Cobb angle measurements using manual and digital methods. Spine J. 2010;10(9):769-74.

20. Pearsall DJ, Reid JG, Hedden DM. Comparison of three noninvasive methods for measuring scoliosis. Phys Ther. 1992;72(9):648-57.

21. ICRP. The 2007 recommendations of the International Commission on Radiological Protection [Internet]. Ottawa: ICRP; 2007 [cited 2014 Aug 20]. Available from: http://www.icrp.org/publication.asp?id=ICRP Publication 103

22. Seeram E, Brennan PC. Diagnostic reference levels in radiology. Radiol Technol. 2006;77(5):373-84.

23. International Atomic Energy Agency. Dosimetry in diagnostic radiology: an international code of practice. Vienna: IAEA; 2007. ISBN 9201154062

24. Al Qaroot B, Hogg P, Twiste M, Howard D. A systematic procedure to optimise dose and image quality for the measurement of inter-vertebral angles from lateral spinal projections using Cobb and superimposition methods. J Xray Sci Technol. 2014;22(5):613-25.

25. Martin CJ, Sharp PF, Sutton DG. Measurement of image quality in diagnostic radiology. Appl Radiat Isot. 1999;50(1):21-38.

26. Ween B, Kristoffersen DT, Hamilton GA, Olsen DR. Image quality preferences among radiographers and radiologists: a conjoint analysis. Radiography. 2005;11(3):191-7.

27. Reis C, Pascoal A, Sakellaris T, Koutalonis M. Quality assurance and quality control in mammography: a review of available guidance worldwide. Insights Imaging. 2013;4(5):539-53.

28. Håkansson M, Svensson S, Zachrisson S, Svalkvist A, Båth M, Månsson LG. VIEWDEX: an efficient and easy-to-use software for observer performance studies. Radiat Prot Dosimetry. 2010;139(1-3):42-51.

29. Börjesson S, Håkansson M, Båth M, Kheddache S, Svensson S, Tingberg A, et al. A software tool for increased efficiency in observer performance studies in radiology. Radiat Prot Dosimetry. 2005;114(1-3):45-52.

30. Young KJ. Should plain films of the lumbar spine be taken in the posterior-to-anterior or anterior-to-posterior position? A study using decision analysis. J Manipulative Physiol Ther. 2007;30(3):200-5.

31. Guo H, Liu WY, He XY, Zhou XS, Zeng QL, Li BY. Optimizing imaging quality and radiation dose by the age-dependent setting of tube voltage in pediatric chest digital radiography. Korean J Radiol. 2013;14(1):126-31.

32. Tinsberg A, Sjöström D. Optimisation of image plate radiography with respect to tube voltage. Radiat Prot Dosimetry. 2005;114(1-3):286-93.

33. Saether HK, Lagesen B, Traegde Martinsen AC, Holsen EP, Ovrebo KM. Dose levels from thoracic and pelvic examinations in two pediatric radiological departments in Norway: a comparison study of dose-area product and radiographic technique. Acta Radiol. 2010;51(10):1137-42.

34. Olgar T, Onal E, Bor D, Okumus N, Atalay Y, Turkyilmaz C, et al. Radiation exposure to premature infants in a neonatal intensive care unit in Turkey. Korean J Radiol. 2008;9(5):416-9.

35. Barnes GT. Contrast and scatter in X-ray imaging. Radiographics. 1991;11(2):307-23.

36. Mooney R, Thomas PS. Dose reduction in a paediatric department following optimization of radiographic technique. Br J Rad. 1998;71(848):852-60.

37. Almén AJ, Mattsson S. Dose distribution at radiographic examination of the spine in pediatric radiology. Spine (Phila Pa 1976). 1996;21(6):750-6.