Torsten Kluba
Jürgen Schäfer
Tobias Hahnfeldt
Thomas Niemeyer

Prospective randomized comparison of radiation exposure from full spine radiographs obtained in three different techniques

Received: 15 February 2005
Revised: 18 May 2005
Accepted: 8 July 2005
Published online: 22 April 2006
© Springer-Verlag 2006

T. Kluba (✉) · T. Hahnfeldt · T. Niemeyer
University Tübingen,
Department of Orthopaedics,
Tübingen, Germany
E-mail:
torsten.kluba@med.uni-tuebingen.de
Tel.: +49-70-712986685
Fax: +49-70-71294091

J. Schäfer
University Tübingen,
Department of Radiology,
Tübingen, Germany

Abstract *Problem:* The purpose of the investigation was a comparison of two different digital X-ray techniques with conventional standing full spine films. Evaluation of dose area product, image quality and inter-observer error of Cobb-angle measurement in patients with scoliosis and kyphoscoliosis were studied. *Methods:* A consecutive series of 150 patients were prospectively randomized into three groups. Patients in group 1 ($n=53$) received a conventional standing postero-anterior full spine radiograph. All films were evaluated on the light box. Patients in group 2 ($n=48$) received a X-ray using the digital storage phosphor plate system (CR). For group 3 ($n=49$) digital pulsed fluoroscopy was used. In groups 2 and 3 images were exported to a picture archiving and communicating system (PACS) workstation and viewed on a monitor (Siemens SMM 21140P, Germany). Dose area product measurements were performed in all three groups (Diamentor-M, PTW, Freiburg). Three experienced

investigators independently reviewed all pictures. Pedicles and endplates were counted. Cobb-angles of the main curves were measured. *Results:* The mean dose area product was 97.0 cGy cm^2 ($37.0\text{--}380.0 \text{ cGy cm}^2$) for conventional films, 31.5 cGy cm^2 ($6.0\text{--}66.0 \text{ cGy cm}^2$) for CR imaging and 5.0 cGy cm^2 ($1.0\text{--}29.0 \text{ cGy cm}^2$) for digital fluoroscopy. The differences of Cobb-angle measurements were not significantly different for the three methods. Differences in the count of pedicles and endplates between the investigators were significantly lower for the conventional film as an indicator for the best detail presentation. *Conclusion:* A significant reduction in dose area product is possible with modern digital X-ray methods. The inter-observer error of Cobb-angle measurement is not significantly altered. The detail information is decreased in comparison to conventional films.

Keywords X-ray · AIS · Dose area product · Digital · Exposure

Introduction

Scoliosis radiography was generally performed by using a large film cassette (90 or $60 \times 30 \text{ cm}$) (Fig. 1a). Digital X-ray techniques substitute more and more for conventional film-cassette systems in the clinical routine. Screen imaging becomes routine and hardcopies are no

longer available. However, digital detectors plates are usually not large enough to cover the entire spine of an adult. The use of two detector plates bares the problem of composition artefacts (Fig. 1b). Digital pulsed fluoroscopy technique overcomes the problem of two detector plates and potentially offers a further radiation dose reduction in the long term follow up of patients

Fig. 1 Standard full spine film (a), CR imaging (b) and digital fluoroscopy (c)

with AIS [2]. However, digital fluoroscopy has also limitations, such as horizontal bars and patient motion during exposure with resulting artefacts (Fig. 1c). The diminished image size by screen observation remains a problem.

Patients with AIS are young and repeated radiographs may be necessary especially in the course of brace therapy or surgical treatment. The lifetime risk of cancer from spinal radiographs for patients with AIS cannot be neglected [6, 8]. Progression of deformity is generally expressed by an increased Cobb-angle [7]. Measurements of Cobb-angle bear an intra-observer and inter-observer variability [1, 4]. The aim of this study is to evaluate the dose area product using two different digital X-ray techniques in comparison to standard full spine

films. Further investigation was focused on the inter-observer error of Cobb-angle measurements and detail resolution using the available computer tools for the digital methods. Evaluation of conventional films using pencil and goniometer on the light box served as reference standard for comparison.

Materials and methods

The study was approved by the local ethics committee. The positive votum was given under project number 157/2002. Patients and parents of minors gave their informed consent prior to inclusion in the study. All radiographs were indicated as routine examinations in the course of diagnosis or treatment at the spine deformity outpatients clinics. No patient was exposed to additional study related imaging or radiation.

Patients

Between 1.9.2002 and 31.5.2003 a consecutive series of 150 patients were included in the study. Inclusion criteria consisted of a known or clinically expected scoliotic or kyphoscoliotic deformity, the ability to stand during the examination and a mental status capable of giving an informed consent. The patients were prospectively randomized into three different groups using a computer generated random list. The data from the patients in each group were summarized (Table 1). There was no drop out of included patients.

Radiographic techniques

All film/cassette examinations and CR imaging's were performed with a Bucky Diagnost (Fa. Philips, Netherlands). Screen-film speed class 800 was used for conventional radiographs.

A MultiDiagnost 4 (Fa. Philips, Medical Solution, Netherlands) was used for digital pulsed fluoroscopy. The equipment was operated in the routine setting according to the factory guidelines and adopted to the recommendations of Geijer et al. [2, 3]. With a scanning speed of 4 cm/s 40–60 images were obtained. The tube potential and tube current were adjusted automatically during scanning. A reference ruler was included in the radiograph. All digital images were exported to a PACS. Software Sienet Version VA 42 was used. The images were viewed on a 21 (54 cm) monitor SMM 21140 P (Siemens, Germany). Magic View 1000 software was employed. The monitor parameters were 1280×1600 (number of pixels) for a display area (W×H) of 300×400 mm, luminance up to 800 cd/m² and a deflection angle of 90°. Further parameters and equipment are listed (Table 2).

The patients stood erect facing the film/cassette or digital intensifier (postero-anterior). The image field was reduced to an area from the occiput to the acetabulums in cranio-caudal direction. The lateral degree of coning was adjusted to the severity of scoliosis. The coning was operated identical for all three techniques. Protection of

Table 2 Imaging parameters and equipment

Parameter	Film-imaging	CR imaging	Digital fluoroscopy
Focus-receptor distance (cm)	200	200	112.5
Film/system	Ortho fast curix screens curix HT 1000 G+	ADCC-HR MD 30 Code 15 (AGFA) ADC full body cassette holder ADC compact	–
Tube potential (kV)	74	73–77	56–75
Tube current (mAs)	78	18–32	Automatic

gonades was employed. Lateral views were not included in this study.

Measurements

Area product value (cGy cm²) was measured for every examination by a diamentor (Diametor-M, PTW, Freiburg). Three skilled investigators [senior spine surgeon (T.N.), senior radiologist (J.S.), fellow in spine surgery (T.K.)] evaluated the radiographs independently. Measurement of the main curve was performed according to Cobb [1]. The number of visible endplates and pedicles were counted from Th1 to L5 to estimate image quality. All routinely available image manipulations, such as magnification, measurement, contrast, and brightness were allowed to improve image observation on the monitor.

Statistics

Mean values and standard deviation were determined for each group. The doses were compared using student's *t*-test. Differences in the count of pedicles and endplates between the three investigators (I, II, and III) were determined for each radiograph (I–II, I–III, and II–III). The absolute values of these differences were compared between the three different X-ray techniques using multiple *t*-test. A Bonferroni correction was performed and *p* < 0.005 adjusted for significance.

Results

Dose area product

The measured dose area products for all patients are summarized in a box plot diagram (Fig. 2). The mean dose area product for film imaging was 97.0 cGy cm² (± 73.8, 37.0–380.0 cGy cm²), for CR

Table 1 Patient data by treatment groups

Parameter	Film-imaging	CR imaging	Digital fluoroscopy
N	53	48	49
Male/female	19/34	18/30	11/38
Mean age	17.0	16.0	15.0
(minimum–maximum)	(7.0–69.0)	(8.0–54.0)	(5.0–41.0)
Mean BMI in kg/m ²	19.7	19.4	18.6
(minimum–maximum)	(14.3–38.3)	(12.6–31.4)	(14.3–30.1)
Number of braced pts	3	4	6
Number of fused pts	14	13	11

BMI body mass index, pts patients

imaging 31.5 cGy cm^2 (± 14.1 , $6.0\text{--}66.0 \text{ cGy cm}^2$) and 5.0 cGy cm^2 (± 3.9 , $1.0\text{--}29.0 \text{ cGy cm}^2$) for digital pulsed fluoroscopy, respectively. The results were significantly different ($p < 0.0001$).

Image accuracy

The interobserver error for Cobb-angle measurements were not significantly different for the three groups ($p = 0.15$) (Table 3). The differences of pedicle and endplate counts were significantly lower for the film/cassette combination ($p < 0.0003$) (Table 4).

Discussion

Changes in the film–cassette system can reduce the radiation dose for conventional imaging [5]. We studied the dose area product comparing two digital methods with the conventional film system for three identical groups of patients with deformities. We found that the dose area product could be significantly diminished by the use of CR imaging and digital pulsed fluoroscopy for full spine postero-anterior radiographs to 30.5 and 4.85%, respectively. Effective dose and the dose to specific organs such as the mamma are more practically relevant. To provide for an acceptable feasibility of the experimental set up, we decided to use dose area product measurements for this study. For further investigations the consideration of effective dose is recommended. These parameters would also be less influenced by the degree of coning.

Lateral radiographs were not included in the study. Since most of our patients were referred and had already received radiographs in two planes, we often only repeated the postero-anterior view to assess for curve progression. However, lateral images can be obtained in the same way postero-anterior images were acquired.

Fig. 2 Radiation exposure described as area product value

Table 3 Results of Cobb-angle measurements, number of endplates and pedicles of all investigators by diagnostic technique

Parameter mean (minimum–maximum)	Film-imaging	CR imaging	Digital fluoroscopy
Cobb-angle (°) main curve	23.5 (0–125)	23.5 (0–134)	30 (7–115)
Number of pedicles	31 (2–34)	29 (0–34)	23.5 (2–34)
Number of endplates	26.5 (6–34)	26 (2–34)	25 (6–34)

Table 4 Differences between the investigators for Cobb-angle measurement, number of endplates and pedicles

Parameter absolute value of mean diff. between investigators $\pm$ SD	Film-imaging	CR imaging	Digital fluoroscopy
Cobb-angle (°) main curve	3.60 ± 3.53	4.38 ± 3.86	4.29 ± 5.29
Number of pedicles	2.94 ± 3.48	4.35 ± 4.10	6.26 ± 4.97
Number of endplates	3.92 ± 3.97	5.21 ± 4.21	5.75 ± 4.21

diff. difference, SD standard deviation

Problems may arise in digital pulsed fluoroscopy because of the automatical adjustment of the tube current in patients with large lung volume.

The image quality of conventional film–cassette system was superior to the digital methods. The larger interobserver variability for the digital methods are explained by the diminished detail resolution. Visible noise was a problem in digital fluoroscopy especially when using the magnification function on the screen (Fig. 1c). This point may affect the reproducibility of assessments of Risser grading.

The assessment of spinal curvature is a critical factor in the selection of treatment for scoliosis patients [6]. In our investigation there were no significant differences in the interobserver variance of Cobb-angle measurements between the three methods. The result is in the range of previous investigations for conventional film-systems [1, 4, 7]. In this study we present the results of different techniques of data acquisition and different ways of measurement. Since we compared conventional films, digital images as well as hardcopy measurements with monitor assessments at the same time we were not able to investigate the influence of each method. In our opinion this is never-the-less the preferable approach, since it reflects the actual situation in clinical routine.

Therefore, we consider both digital methods reliable for the measurement of Cobb-angle. For spine surgeons image observation and processing with the computer tools on the monitor has been introduced into clinical practice only recently. To take advantage of lower radiation exposure for our patients provided by digital techniques we stopped using conventional films in our clinical routine. Further optimization of digital fluoroscopy

technique may result in an additional dose reduction for patients with AIS and an improved image quality [3].

Conclusion

Digital radiography offers a significant reduction in dose area product. The inter-observer error of Cobb-

angle measurements were not significantly different between digital images and conventional films. For routine assessment of patients with idiopathic scoliosis the digital image quality is acceptable despite the inferior quality in comparison to conventional films.

References

1. Carman DL, Browne RH, Birch JG (1990) Measurements of scoliosis and kyphosis radiographs: intraobserver and interobserver variation. *J Bone Joint Surg* 72:328–333
2. Geijer H, Beckmann KW, Jonsson B, Andersson T, Persliden J (2001) Digital radiography of scoliosis with a scanning method: initial evaluation. *Radiology* 218:402–410
3. Geijer H, Verdonck B, Beckman KW, Andersson T, Persliden J (2003) Digital radiography of scoliosis with a scanning method: radiation dose optimization. *Eur Radiol* 13:543–551
4. Gross C, Gross M, Kuschner S (1983) Error analysis of scoliosis curvature measurement. *Bull Hosp Joint Dis Orthop Inst* 43:171–177
5. Hellström G, Irstam L, Nachemson A (1983) Reduction of radiation dose in radiologic examination of patients with scoliosis. *Spine* 8:28–30
6. Levy AR, Goldberg MS, Mayo NE, Hanley JA, Poitras B (1996) Reducing the lifetime risk of cancer from spinal radiographs among people with adolescent idiopathic scoliosis. *Spine* 21:1540–1547
7. Lonstein JE, Carlson JM (1984) The prediction of curve progression in untreated idiopathic scoliosis during growth. *J Bone Joint Surg* 66:1061–1071
8. Nash CL Jr, Gregg EC, Brown RH, Pillai K (1979) Risks of exposure to x-rays in patients undergoing long term treatment for scoliosis. *J Bone Joint Surg* 61:371–374