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Original Article

Radiation exposure during scoliosis surgery: a prospective study

Nicholas McArthur, MD, MRCS[a,b,*], David P. Conlan, BSc, MB ChB, FRCS[a,b], John R. Crawford, BSc, MB BS, FRCS, FRCS(Orth)[a,b]

[a]Department of Orthopaedic Surgery, Addenbrooke's Hospital, Hills Rd., Cambridge, CB2 0QQ, United Kingdom
[b]Department of Neurosurgery, Addenbrooke's Hospital, Hills Rd., Cambridge, CB2 0QQ, United Kingdom

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Abstract

BACKGROUND CONTEXT: The present literature on the cancer risks related to radiation exposure in patients and surgeons during scoliosis surgery is sparse.

PURPOSE: To assess the radiation exposure in patients and surgeons during scoliosis surgery and estimate the increased cancer risk of both groups.

STUDY DESIGN: Over a 6-month period, we conducted a prospective study to monitor the intraoperative radiation dose received by both patients and surgeons during scoliosis cases.

PATIENT SAMPLE: It included 30 consecutive patients undergoing scoliosis surgery by a team of two surgeons (S1 and S2).

OUTCOME MEASURES: We measured the radiation exposure to the eyes, thyroid, and hands for each surgeon; measured the difference of radiation exposure between the two surgeons; the difference in radiation exposure with respect to the proximity of the surgeon to the X-ray tube, and the radiation exposure for each patient.

METHODS: An electronic dosimeter was attached over the thyroid guard and a thermoluminescent dosimeter ring on both hands of each surgeon. The patients were monitored using the dose area product (DAP) measurements from the image intensifier, and their radiation exposure was calculated with the Monte Carlo calculation.

RESULTS: The mean eye dose per procedure for the two surgeons S1 and S2 was 0.8 μSv and 1.3 μSv, respectively. The mean thyroid dose for S2 and S1 was 1.2 μSv and 1.4 μSv, respectively. The dose recorded by the surgeon on the same side of the patient as the X-ray tube was significantly higher than for the surgeon on the far side ($p<.05$). Mean DAP per procedure was 91.3 cGycm^2 and the mean radiation dose for patients was 252.9 μSv. The increase in cancer risk for patients and surgeons was 0.001% and 0.0005%, respectively, for each year of exposure.

CONCLUSIONS: A significantly higher dose of radiation during scoliosis surgery was received by the surgeon standing on the same side as the X-ray tube. However, both surgeons received a total radiation dose of less than 1% of the recommended dose limit per year and, therefore, the total radiation exposure in both surgeons and patients was well within the recommended safe limits. © 2015 Elsevier Inc. All rights reserved.

Keywords: Scoliosis surgery; Radiation exposure; Children; Surgeon; Cancer risk; Radiation protection

Introduction

Advances in scoliosis surgery over the last 50 years have allowed for improved correction of spinal curves. In 1984, Cotrel and Dubousset [1] revolutionized scoliosis surgery by introducing the modern posterior instrumentation techniques that allow for distraction, compression, and derotation of the scoliotic deformity [2–4]. Approximately 38,000 patients undergo surgery for scoliosis each year in the United States [5].

Several studies have examined the radiation exposure during the assessment of scoliosis patients [6–12]; however, we could identify only one previous study examining the intraoperative radiation exposure in children with

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* Corresponding author. 3 Brothers Place, Cambridge, CB1 8BN, United Kingdom. Tel.: (44) 757-007-5524.

E-mail address: nicholasmcarthur@gmail.com (N. McArthur)

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scoliosis [13]. There are also few studies examining the radiation exposure in surgeons performing spinal procedures [14,15].

Children are more susceptible to radiation exposure than adults as their organs are more sensitive to the effects of radiation and their longer life expectancy allows more time for cancers to manifest [16]. Mathews et al. [17] analyzed the effects of radiation from computed tomography scans in childhood and adolescence in 680,000 patients and demonstrated an increased cancer risk for these patients. Mastrangelo et al. [18] showed a significant increase in tumors among orthopedic surgeons over a 14-year-period. A larger study by Chou et al. [19] of breast cancer prevalence among female orthopedic surgeons surveyed female members of the American Academy of Orthopaedic Surgeons and discovered that they had breast cancer prevalence 85% higher than in the general population.

We conducted a study to measure the intraoperative radiation exposure in both pediatric patients and orthopedic surgeons during scoliosis surgery to establish the cancer risk after radiation exposure.

Patients and methods

We conducted a 6-month prospective study between 1st June, 2011 and 31st December, 2011 to monitor the radiation dose received by both patients and surgeons in all scoliosis cases. The two senior authors Surgeon 1 (S1) and Surgeon 2 (S2) operated on all the patients together during the study period.

All the scoliosis corrections in the study involved posterior instrumentation of the thoracolumbar spine using a pedicle screw construct. A single hook was used at the proximal end of the construct on the convex side, as is our usual practice. The instrumentation used was either the Expedium 5.5 (Depuy Zuchwil, Switzerland) system or the Colorado (Medtronic, Minneapolis, MN, USA) system for all cases.

Eye, thyroid, and hand radiation exposure were measured for both surgeons. We calculated the overall difference in radiation exposure between the two surgeons and also compared the difference in the surgeons' radiation exposure depending on if they were standing next to or opposite to the X-ray tube.

Each surgeon wore an electronic dosimeter over the thyroid guard and a thermoluminescent dosimeter ring on each hand. Image intensifier screening was performed during the insertion of pedicle screws for each case with anteroposterior and lateral imaging. For lateral image intensifier screening in 17 (57%) cases, S1 was on the same side of the patient as the X-ray tube and S2 was on the side of the receiver and for 13 (43%) cases, S2 was on the same side as the X-ray tube and S1 was on the receiver side.

To calculate total body radiation exposure, the operational quantity ''ambient dose equivalent'' H*(10) was used to estimate the upper limit of radiation exposure of the whole body and H*(0.07) to estimate the upper exposure limits of the skin. To estimate the eye dose, H*(3) would have to be used; however, dosimeters that allow us to perform these measurements are not widely available and were not used in this study. Therefore, the eye dose was estimated by taking two-thirds of the measured value of the collar dosimeter and using H*(0.07). The ambient dose equivalent H*(0.07) is likely to be an overestimate of the eye dose and a maximum measure of radiation exposure to the eyes.

The patients were monitored using the dose area product (DAP) measurements from the image intensifier; the screening time; and also by estimating the radiation dose using the Monte Carlo calculation (Software PCXMC-Version 2.0, TUK Radiation and Nuclear Safety Authority, Finland).

The DAP is a surrogate measurement for the entire amount of energy delivered to the patient by the beam. It is defined as the product absorbed dose and the area irradiated, measured in gray square centimeters (Gycm^2) [20].

The Monte Carlo calculation uses basic physics interaction probabilities to determine the fate of the representative particles. It follows the path of individual representative particles through the accelerator, beam modifiers, and phantom patient to determine the radiation exposure. The calculation also takes into account the DAP during procedure and the patient's BMI. Finally, the result from the Monte Carlo calculation can then be used to calculate the cancer risk each patient is exposed to.

Results

In total, 30 consecutive scoliosis cases were assessed during the study period. For the patients, we recorded an average screening time of 23 seconds. The average DAP per procedure was 91.3 cGycm^2. The Monte Carlo calculation revealed an average radiation dose of 252.9 μSv per patient (Table 1—patient data overview).

There was no recorded finger dose for either surgeon for any month in the monitoring period. This means a dose of less than 0.15 mSv in any month was never exceeded. The mean eye dose per procedure for the two surgeons S1 and S2 was 0.8 μSv and 1.3 μSv, respectively. The mean thyroid dose for S2 and S1 was 1.2 μSv and 1.4 μSv, respectively (Table 2).

The total dose of radiation exposure over 6 months recorded on the side of the X-ray tube was 62 μSv and the radiation exposure on the side of the X-ray receiver was 16 μSv. This difference was statistically significant ($p<.05$).

According to the International Commision on Radiological Protection Publication 103, cancer rate increases by 4.1% per Sievert (Sv). This would imply that the radiation exposure in patients per procedure would increase their cancer risk by 0.001%. If the surgeons were to operate on 60 scoliosis cases per year, then their cancer risk would increase by 0.0005% each year.

Table 1
Patients data overview

Number of patients	30
Sex	M: 6 F: 24
Diagnosis	
Neuromuscular	6
Idiopathic	20
Scheuermanns	2
Congenital	2
	Mean (range)
Age (y)	15 (3–32)
BMI (Kg/m^2)	20.9 (14.9–27.8)
Number of pedicle screws	11.6 (4–16)
Surgical time (min)	277 (195–405)
Screening time (min)	0.39 (0.1–0.8)
DAP (cGycm^2)	91.3 (9–225.9)
Radiation dose (μSv)	252.9 (2.5–891)

M, male; F, female; BMI, body mass index; DAP, dose area product.

Discussion

The results of our study show that the surgeon will receive a significantly higher dose of radiation if standing next to the X-ray tube during scoliosis surgery compared with the other side of the operating table. Rampersaud et al. [15] also demonstrated this on a cadaveric model by performing fluoroscopic-assisted pedicle screw placement for the levels T11 to S1. The study was performed in six cadavers using only lateral fluoroscopic imaging. He recommended ongoing monitoring for the spinal surgeons as the radiation exposure was 10 to 12 times higher than in nonspinal musculoskeletal procedures that involve the use of a fluoroscope.

A more recent prospective study in 2013 by Mulconrey [14] evaluated the radiation exposure in spinal surgeons and patients in 35 cases. The results of this in vivo study indicated that fluoroscopic dosage to the spine surgeon remained below the annual maximum limit of radiation exposure. It also recommended monitoring fluoroscopic time and maintaining a distance from the beam source.

The low doses recorded from our study can justify that further monitoring for our surgeons is not necessary, providing no significant changes in workload occur. Normally, if the doses received by the employees approaches 10% of any relevant dose limit (whole body or extremity), on-going monitoring is usually recommended. The doses seen in this study are far below this level. If surgeons are performing large numbers of other procedures in addition to scoliosis surgery, then whole body monitoring on those operators might be advisable. Surgeons should always consult their country's respective authority on radiation protection for advice on the necessity of intraoperative monitoring of radiation exposure.

Table 2
Surgeons' radiation exposure

	Estimated eye dose (μSv)		Estimated thyroid dose (μSv)	
	S1	S2	S1	S2
Maximum dose per mo	13.3	5.3	16	10
6 mo total	38	23.3	42	36
Mean per procedure	1.3	0.8	1.4	1.2

During the study period, the overall use of image intensifier screening during each scoliosis case reduced for both surgeons as the surgeons themselves became more aware of the radiation exposure. They were able to view the current DAP on the image intensifier monitor at all times and as the study progressed, they were able to better judge their own and the patient's radiation exposure. This in turn led the surgeons to make small adjustments to their image intensifier use. This included meticulously aligning the image intensifier correctly over the desired field, rather than screening after a rough estimation. Unless there were any immediate concerns, screening was generally performed at the end of the procedure once all implants were in position. The surgeons also attempted to keep more distance from the image intensifier during screening.

Scoliosis patients are also exposed to the radiation from regular outpatient checkup spine radiographs in addition to the intraoperative radiation and, therefore, their overall cancer risk would be higher than the value we have calculated from just the intraoperative exposure. Routine posteroanterior instead of anteroposterior radiographs of the spine in children can reduce their radiation exposure in the outpatient setting as shown by Levy et al. [21,22]. Scoliosis surgeons should also use appropriate clinical judgment to assess the necessity of any imaging requiring X-rays to keep radiation exposure to a minimum.

Conclusion

It was extremely useful to undertake the study to raise awareness of radiation exposure and reduce the amount of radiation incurred by surgeons and patients.

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