

How Low Can You Go?

Development & Implementation of a Low Dose Scoliosis Protocol in Pediatric Patients

Erin Taylor, MD^{1,2}

Kevin Grizzard, PhD^{1,3}

Cicero T Silva, MD^{1,4}

Matthew Hoerner, PhD^{1,3}

Department of Radiology and Biomedical imaging¹

Body Imaging², Medical Physics³, Pediatrics⁴

Yale School of Medicine

Yale
NewHaven
Health



Purpose

- The “As Low as Reasonably Achievable” (ALARA) principle states that the lowest possible radiation dose should be utilized to achieve clinical diagnosis.
- *Follow up* scoliosis radiographs are intended to follow the degree of spinal curvature and assess skeletal maturity, both of which can be assessed at lower exposures than those used on standard dose radiographs.
- The EOS system utilizes slot-scanning technology and has the lowest effective dose in the literature for scoliosis imaging; however, many institutions do not have access to the system.
- At our institution, we developed a protocol to reduce patient dose of follow up scoliosis radiographs in the pediatric population utilizing existing software and equipment.

Background

- **Scoliosis** is defined as a curvature in the spine in the coronal plane by greater than 10 degrees (as measured by the Cobb angle)
- Divided into infantile, juvenile, and adolescent subtypes
 - Adolescent Idiopathic Scoliosis (AIS) is the most common
- **Radiographic Evaluation**
 - **Purpose of initial scoliosis radiographs:**
 - Confirm the suspected clinical diagnosis of scoliosis, assess severity, assess skeletal maturity
 - Evaluate the etiology (congenital, neuromuscular, idiopathic)
 - Wedged vertebrae, hemivertebrae (congenital scoliosis)
 - Paraspinal masses, vertebral body or pedicle lucency to suggest bone tumor
 - Widening of interpedicular space

For initial scoliosis radiographs, it's important to produce an image with fine osseous detail.

However, follow up radiographs are primarily obtained to follow the degree of spinal curvature and to inform treatment decisions. Therefore, fine osseous detail is not necessary on each follow up, and excess radiation violates the ALARA principle.

Methods: Protocol Development

- Dose reduction methods are based on the principle that the *detector exposure to produce adequate image quality is constant across patients of different sizes*
- Required tube output can be calculated using:
 - Acquisition geometry
 - Beam attenuation due to the patient (patient thickness)
 - Target dose to the detector

Principle: The size of the patients affects how much radiation is required

Solution: Utilize height and weight to estimate patient thickness to **tailor radiation to each patient**

Principle: Contrast is improved through the use of a grid by reduction of scatter (particularly at higher kVp). However, grids increase dose.

Solution: Use a **virtual grid** to remove scatter but avoid dose penalty

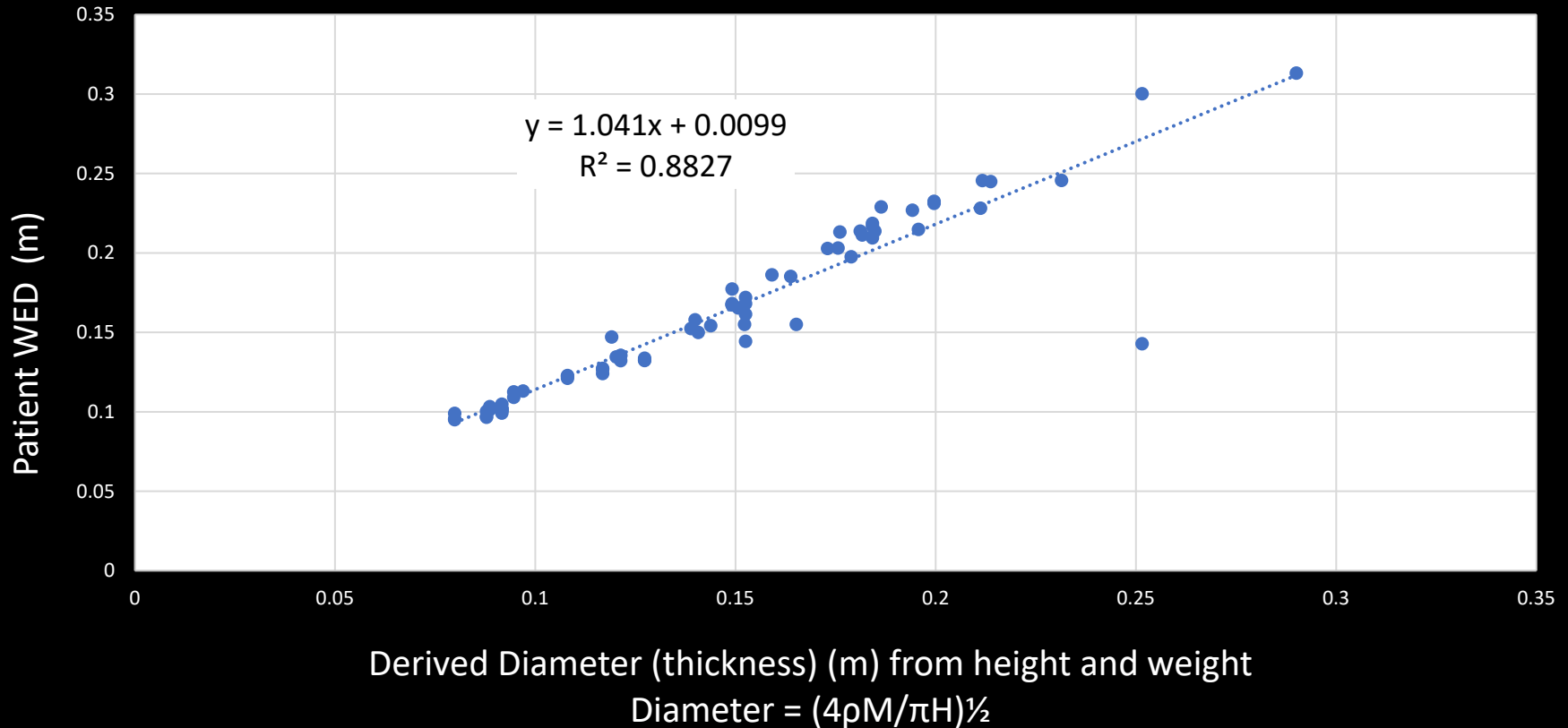
*Note our standard dose protocol also uses a virtual grid

Principle: Image quality should be defined as adequate if it can answer the clinical question.

Solution: **Dose for follow up scoliosis radiographs can be lowered as fine osseous detail is not required (primary intent is to assess Cobb angle and skeletal maturity).**

Methods: Estimation of Patient Thickness Utilizing Patient Height and Weight

Graph showing the close relationship between Patient Water-Equivalent Diameter (WED) and Derived Diameter from Height and Weight



- This is derived from the fact that the patient can be modeled as a water-filled cylinder with density ρ , height H , mass M , and diameter (D) $M = \rho V = H \frac{\pi}{4} D^2$
- Validated using water-equivalent diameter from a cohort of pediatric patients undergoing CT exams of the chest and abdomen using the AAPM Task Group 220 methodology

Methods: Technique Chart Development and Acquisition Parameters

		Patient Height (m)														
		0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
Patient Weight (kg)	10	80/1.25	80/1	80/0.63	80/0.63	80/0.5	80/0.5	80/0.5	80/0.5	80/0.5	80/0.5	80/0.5	80/0.5	80/0.5	80/0.5	80/0.5
	15	85/1.6	85/1.25	85/1.25	80/1	80/1	80/0.8	80/0.63	80/0.63	80/0.5	80/0.5	80/0.5	80/0.63	80/0.5	80/0.5	80/0.5
	20	90/2	85/2	85/1.6	85/1.25	85/1.25	80/1.25	80/1	80/1	80/0.8	80/0.63	80/0.63	80/0.63	80/0.5	80/0.5	80/0.5
	25	90/3.2	90/2	85/2.5	85/2	85/1.6	85/1.25	85/1.25	85/1	80/1.25	80/1	80/1	80/0.8	80/0.8	80/0.63	80/0.63
	30	95/4	90/3.2	90/2.5	90/1.6	85/2	85/1.6	85/1.25	85/1.25	85/1.25	85/1.25	80/1	80/1	80/1	80/1	80/0.8
	35	95/6.3	95/4	90/3.2	90/2.5	90/2	85/2.5	85/2	85/1.6	85/1.25	85/1.25	85/1.25	85/1.25	85/1	80/1.25	80/1
	40	95/10	95/5	90/5	90/3.2	90/2.5	90/2	85/2.5	85/2	85/2	85/1.6	85/1.25	85/1.25	85/1.25	85/1.25	85/1
	45	100/10	95/8	95/5	90/5	90/3.2	90/2.5	90/2	90/1.6	85/2.5	85/2	85/1.6	85/1.25	85/1.25	85/1.25	85/1.25
	50	100/12.5	100/8	95/6.3	95/5	90/4	90/3.2	90/2.5	90/2	90/2	85/2.5	85/2	85/1.6	85/1.6	85/1.6	85/1.25
	55	100/20	100/10	95/10	95/6.3	95/4	90/4	90/3.2	90/2.5	90/2	90/2	90/1.6	85/2.5	85/2	85/1.6	85/1.6
	60	105/25	100/12.5	100/8	95/8	95/5	95/4	90/4	90/3.2	90/2.5	90/2.5	90/2	90/1.6	85/2.5	85/2	85/2
	65	105/32	100/16	100/10	95/10	95/6.3	95/5	95/5	90/4	90/3.2	90/2.5	90/2.5	90/2	90/1.6	85/2.5	85/2.5
	70	105/40	105/20	100/12.5	100/8	95/8	95/6.3	95/5	95/4	90/3.2	90/2.5	90/2.5	90/2	90/2	90/2	90/1.6
	75	110/40	105/25	100/16	100/10	100/8	95/8	95/6.3	95/5	95/4	90/4	90/3.2	90/2.5	90/2.5	90/2	90/2
	80	110/50	105/32	105/20	100/12.5	100/10	95/10	95/6.3	95/5	95/4	90/5	90/4	90/3.2	90/3.2	90/2.5	90/2

Technique chart developed for scoliosis follow-up exams at Yale New Haven Health. Technologists use the patient's height (in meters) and weight (in kilograms) to input the appropriate technique, which is given as a "kVp/mAs" combination.

Note: PA acquisition is preferred to lower breast and thyroid dose. With PA acquisition, breast shields are not utilized. We also no longer use gonadal shields at our institution, unless requested by the patient and/or their family.

Summary of changes to the protocol

↑ kVp

↓ mAs

↓ total output, dose to patient, and dose to detector

* More tailored to patient, less guesswork for technologists.

Yale
NewHaven
Health

Please update you or your child's height and weight during today's visit.

Patient Height _____

Patient Weight _____

For tech use only:

For PA scoliosis radiographs, record:

kVp _____

mAs _____

Please attach this form to the requisition for the study and place within the designated folder near the Tech Workstations at Longwharf.

Equipment specifications:
GE Proteus 80 kW generator & X-ray system (0.6 & 1.25 mm focal spots)
17" x 49" Fuji GL indirect digital detector
With Fuji Virtual Grid technology
DR-ID 300CL APL Software V9.0.0025

Results

The low dose protocol markedly decreased dose without compromised assessment of the parameters which are important on follow up scoliosis radiographs including:

- Cobb angle(s)
- Risser grade
- Proximal humeral epiphysis
- Coronal balance
- Pelvic tilt



Case example of dose reduction with the low dose protocol (a) Acquisition with the **new low dose protocol** (8 years old) has **effective dose of 0.9 μ Sv**. No shielding utilized in this PA standing acquisition. (b) Prior to implementation of low dose protocol (at 7 years old)/**standard dose protocol** has **effective dose of 95 μ Sv**. AP standing acquisition was utilized (patient unable to face away from parent) with breast shielding. Gonadal shielding was still utilized at our institution at that time.

Methods: Protocol Validation

- Consensus conference held between pediatric radiology and pediatric orthopedic surgeons to agree upon the definition of adequate quality for the new low dose protocol
- Categories of Assessment for PA/AP Scoliosis Radiographs
 - Ability to assess:
 - Cobb angle, pelvic tilt, coronal balance, Risser grade, and proximal humeral epiphysis
- Blinded review of 30 PA/AP radiographs performed by 2 pediatric radiologists and 3 pediatric orthopedic surgeons (15 low dose mixed with 15 standard dose radiographs).

Score Definitions:

- 1 = Uninterpretable (would need to repeat the radiograph to assess)
- 2 = Acceptable/able to assess
- 3 = Able to assess, plus there is room to further decrease dose

Mean scores were above "2" or Acceptable

Pediatric Radiologist Mean Scores*		
n = number of radiographs	Standard Dose	Low Dose
Cobb Angle (n = 60)	2.8	2.5
Risser Grade (n = 60)	2.7	2.4
Proximal humerus** (n = 52)	2.8	2.7
Coronal balance (n = 60)	2.9	2.7
Pelvic tilt (n = 60)	3	2.9
*Evaluation by 2 pediatric radiologists		
**Lower "n" as some proximal humeri excluded from view		

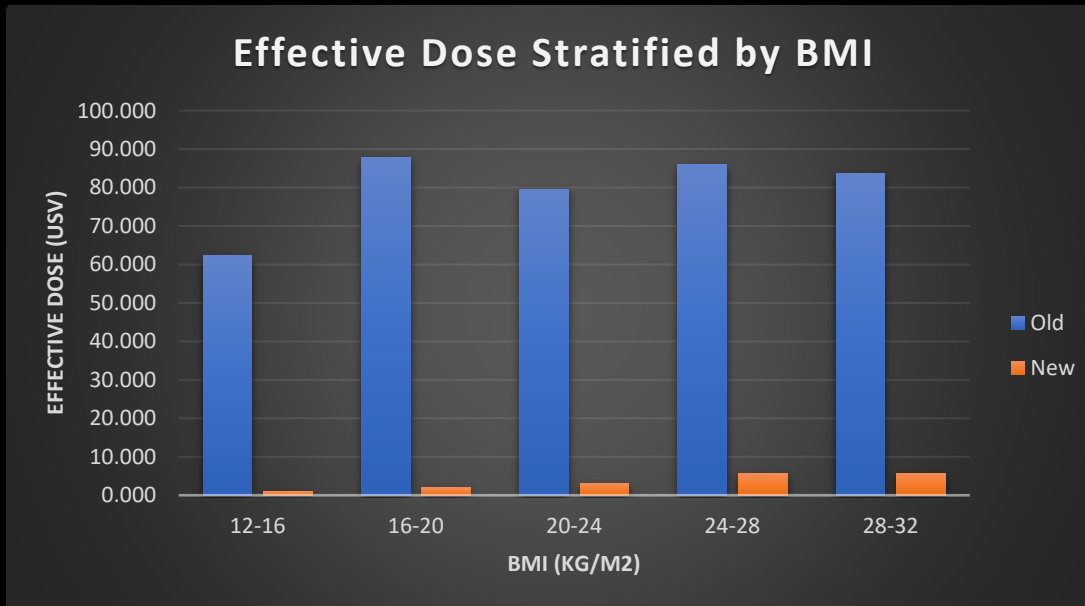
Pediatric Orthopedic Surgeon Mean Scores*		
n = number of radiographs	Standard Dose	Low Dose
Cobb Angle (n = 90)	2.4	2.2
Risser Grade (n = 90)	2.2	2.1
Proximal humerus** (n = 85)	2.1	2
Coronal balance (n = 90)	2.4	2.2
Pelvic tilt (n = 90)	2.7	2.6
*Evaluation by 3 pediatric orthopedists		
**Lower "n" as some proximal humeri excluded from view		

*For this step, the images were copied into a PowerPoint for easier review and scoring, and therefore, resolution was degraded and there was an inability to window. Orthopedic surgeons viewed with lower resolution monitors to emulate clinical practice, which may account for the overall lower scores from orthopedists compared to radiologists.

Results: Dose Reduction and Comparison with EOS

Standard Dose versus Low Dose Comparison		
	Standard Dose (n = 33)	Low Dose (n = 78)
Height (cm)	159.0	147.7
Weight (kg)	53.0	43.9
BMI (kg/m ²)	21.0	19.3
Estimated Diameter (cm)	34.4	32.7
kVp	78.0	83.5
ICRP-103 (μSv)	83.75	2.49
Reduction in ICRP-103 (%)		97.0%

Comparison of ICRP103 Doses (μSv) at YNHH vs. Published Data on EOS			
	Standard	Low-Dose	Reduction %
Hui et al. (EOS)	67.5	2.6	96.1%
YNHH	84	2.5	97.0%



Radiation risks of the standard dose versus the low dose protocols were compared by calculating the effective dose using a Monte-Carlo based software program (PCXMC, Radiation and Nuclear Safety Authority (STUK), Helsinki, Finland).

Dose reduction was greatest for patients with smaller BMIs.

Our institution implemented an EPIC optimization to create a separate EPIC order which allows orthopedists to choose the low dose protocol for follow up PA or AP scoliosis radiographs.

Results and Conclusions

- Mean effective dose for the low dose protocol was 2.5 μSv compared to 84 μSv for the standard dose protocol (97% dose reduction).
- Observed difference in image quality between the low dose and former standard dose radiographs did not subjectively impede clinical assessments of the Cobb angle, coronal balance, pelvic tilt or skeletal maturity measures.

Conclusion: Dose reduction with existing radiography units is achievable with comparative results to EOS through redefinition of adequate image quality, use of a virtual grid, and tailoring radiation to each patient's thickness (using their height and weight).

References:

- Hui SC, Pialasse JP, Wong JY, Lam TP, Ng BK, Cheng JC, Chu WC. Radiation dose of digital radiography (DR) versus micro-dose x-ray (EOS) on patients with adolescent idiopathic scoliosis: 2016 SOSORT- IRSSD "John Sevastic Award" Winner in Imaging Research. *Scoliosis Spinal Disord.* 2016 Dec 29;11:46. doi: 10.1186/s13013-016-0106-7.
- Kim H, Kim HS, Moon ES, Yoon CS, Chung TS, Song HT, Suh JS, Lee YH, Kim S. Scoliosis imaging: what radiologists should know. *Radiographics.* 2010 Nov;30(7):1823-42. doi: 10.1148/rg.307105061. Erratum in: *Radiographics.* 2015 Jul-Aug;35(4):1316. PMID: 21057122.