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New EOS Imaging Protocol Allows a Substantial Reduction in Radiation Exposure for Scoliosis Patients

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Abstract

Study Design: Prospective.
Objective: To evaluate the reliability of three-dimensional (3D) spinal models from Micro Dose EOS x-rays compared to standard, Low Dose EOS x-rays utilized for evaluating patients with adolescent idiopathic scoliosis (AIS).
Summary of Background Data: There is a strong suggestion that radiation exposure to scoliosis patients can be further reduced.
Methods: Sixty AIS patients who received biplanar, posteroanterior, and lateral standard Low Dose spine x-rays in our EOS imaging unit (~0.33 mGy) as part of routine care also underwent an additional set of new reduced "Micro Dose" EOS x-rays (~0.05 mGy) using a recently developed protocol. Two measurers created 3D models of the images using sterEOS software (Low Dose x2, Micro Dose x2). From this 3D modeling software, coronal Cobb angles, sagittal (T1–T12, T4–T12, L1–L5, L1–S1), and apical axial rotation measurements were obtained. Intraclass correlations (ICCs) and standard error of measurement (upper bound of 95% confidence interval) for the differences between Low Dose and Micro Dose measurements were compared. Interrater reliability was assessed on standard two-dimensional (2D) radiographic measurements.
Results: The ICCs were rated as "substantial" to "almost perfect" for Low Dose 3D, Micro Dose 3D, and 2D measures (range 0.78–0.99). The calculated measurement error was not significantly different between groups except for intrarater error on 3D L1–L5 lordosis (2.9° Micro Dose vs. 2.2°, p = .04), interrater 3D rotation of the lumbar apex (2.6° Micro Dose vs. 1.7°, p = .03), and 2D T12–sacrum lordosis (4.6° Micro Dose vs. 3.4°, p = .04).
Conclusions: Although statistically significant differences in average measurement error were observed in lordosis and lumbar apex rotation, these differences are not believed to be clinically significant. The Micro Dose images have slightly less clarity qualitatively, yet the critical 2D and 3D measures of the curvature were reliably measured with error of measurement comparable to standard radiologic techniques.

This study was conducted at Rady Children's Hospital, San Diego, CA.

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IRB approval was obtained for this study.

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Introduction

Adolescent idiopathic scoliosis (AIS) patients are subjected to a large number of diagnostic imaging tests with high cumulative radiation throughout the course of their treatment. This is particularly alarming because both acute and protracted exposure to ionizing radiation have been shown to increase the risk of developing cancer [1]. Although hazardous in adults, high cumulative doses can be even more perilous in the pediatric patient. Children are inherently more sensitive to radiation than adults and because of the young age of exposure are more likely to develop malignancies during their lifetimes [2,3]. Unfortunately, iatrogenic radiation exposure in the United States has been on a steady rise and has reached levels that suggest a need for a reduction in the number of imaging tests performed and the amount of radiation per procedure. Although the benefits of interventional and fluoroscopic imaging are clear, risk reduction should be an aim for every health care worker, especially those treating children [2].

The Society of Pediatric Radiology (SPR) recommends that radiation exposure of both patients and physicians be kept As Low As Reasonably Achievable (ALARA) in an effort to address this growing crisis [3]. The SPR has suggested a number of strategies including the modification of equipment to optimize efficacy while minimizing harm [3]. With this intention, a novel tool in diagnostics has emerged that is both safer and simultaneously more accurate for the diagnosis and prognosis of patients with AIS.

Recent technology from EOS Imaging (Paris, France) utilizing a slot scanner and an innovative x-ray particle detector has allowed the reduction of radiation exposure by approximately 6–9 times that of computed radiography [4]. By obtaining simultaneous, upright, biplanar x-ray images of the spine, this technology also allows for accurate three-dimensional (3D) modeling of the spine [5], which promotes a greater understanding of the true 3D deformity of AIS. Further efforts to reduce x-ray radiation exposure to patients have resulted in a new filter (copper vs. aluminum) for the EOS Imaging system that is purported to reduce the radiation exposure to the patient by approximately five to seven times (Micro Dose) compared to the current, Low Dose images.

The current study sought to evaluate the reliability of both 2D and 3D measurements obtained from these new, Micro Dose images compared to those obtained from the currently available standard, Low Dose EOS images that are utilized for routine care at our institution.

Methods

IRB approval was obtained for this study. Sixty-one subjects were enrolled, but one patient was excluded because of a technical problem with the image acquisition. Sixty subjects were included in the analysis. All subjects had to meet the following criteria for inclusion in the study: diagnosis of idiopathic scoliosis, age 10–21 years old, were receiving standard Low Dose posteroanterior and lateral spine x-rays in our EOS imaging unit as part of their routine care. In addition, patients had to have a coronal Cobb $>20^{\circ}$ and no fusion/instrumentation ($n = 30$), or they had to have undergone a posterior spinal fusion and instrumentation ($n = 30$). Each subject received one set of Micro Dose posteroanterior and lateral spine x-rays in our EOS imaging unit on the same day that the standard Low Dose posteroanterior and lateral x-rays were obtained. The reported entrance doses for each, per the manufacturer, are presented in Table 1. Identical positioning protocols were used to obtain the Low Dose and Micro Dose x-rays. Each subject was provided with the same positioning instructions and had the same radiology technician who used the same device to obtain both the Micro Dose and Low Dose x-rays.

Utilizing sterEOS software (EOS Imaging, Paris, France), two individuals trained in sterEOS modeling conducted full 3D models of each subject's Low Dose and each subject's Micro Dose images. This was done again for each patient on another day, resulting in 2 sets of Micro Dose and 2 sets of Low Dose 3D models by each of the two individuals performing the sterEOS 3D modeling. The 3D measurements included coronal Cobb angles, kyphosis (T1–T12, T4–T12), lordosis (L1–L5, L1–S1), pelvic parameters (sacral slope, pelvic incidence, sagittal sacral slope), and apical rotation. The two measurers also conducted standard 2D radiographic measurements of both the Low Dose and Micro Dose images for each subject. The following 2D measurements were performed once by each measurer: coronal Cobb angles, kyphosis (T2–T5, T4–T12), and lordosis (T12–top of sacrum).

Intraclass correlation (ICC) coefficients were calculated to evaluate inter- and intrarater reliability of radiographic measures. The standard error of measurement (upper bound of 95% confidence interval) for the differences between Low Dose and Micro Dose EOS image measurements were calculated and compared utilizing analysis of variance techniques. Alpha was set at $p < .05$ to declare significance and all analyses were performed utilizing SPSS v. 12 (SPSS Inc, Chicago, IL). The dose area product ($mGy \cdot cm^2$) was recorded from the dicoms, and the difference between such

Table 1
Reported entrance doses for Micro Dose and Low Dose full spine x-rays per the manufacturer.

	Micro Dose			Low Dose		
Morphotype setting	0	1	2	0	1	2
Entrance dose AP projection (mGy)	0.010	0.017	0.034	0.074	0.124	0.185
Entrance dose Lat projection (mGy)	0.021	0.036	0.064	0.116	0.206	0.284
Total entrance dose (mGy)	0.032	0.053	0.098	0.190	0.330	0.469

AP, anteroposterior; Lat, lateral.

Morphotype value corresponds to patient size (ie, smaller morphotypes setting used for smaller patients).

for the Low Dose and Micro Dose images was calculated and compared.

Results

The average age of the subjects was 15 ± 2 years (range 10–20 years). The majority of subjects were female (56 F, 4 M). The average BMI was 20.8 ± 4.8 (range 13–44). The average Cobb angle for the nonfusion/instrumentation group was 37 ± 12° (range 23–61°). The average Cobb angle for the postoperative instrumentation/fusion group was 15 ± 10° (range 4–47°) in the thoracic spine and 15 ± 8° (3–36°) in the lumbar spine.

The two measurers conducted a total of 720 sets of measurements (120 Micro Dose 3D models, 120 Low Dose 3D models, 60 Micro Dose 2D measurements, 60 Low Dose 2D measurements per measurer). The ICCs were rated as "substantial" to "almost perfect" for Low Dose 3D, Micro Dose 3D, and 2D measures (range 0.78–0.99). The ICCs can be found in Table 2 for the 3D measurements and in Table 3 for the 2D measurements. The measurements with the lowest reliability were the thoracic apical rotation from the 3D Micro Dose measurements and the 2D T2–T5 kyphosis measurements, although these still resulted in ICC values representing "substantial" agreement according to Landis and Koch's criteria [6].

Table 3
Intraclass correlations (reliability) of 2D measurements.

	2D interrater reliability	
2D Measurements	Low Dose EOS	Micro Dose EOS
Upper thoracic Cobb (°)	0.963	0.983
Thoracic Cobb (°)	0.971	0.982
Lumbar Cobb (°)	0.975	0.978
T2–T5 kyphosis (°)	0.779	0.788
T4–T12 kyphosis (°)	0.957	0.919
T12–top of Sacrum (°)	0.96	0.946

The interrater and intrarater measurement error for the 3D Low Dose and Micro Dose measurements can be found in Table 4. The maximum 3D measurement error ranged from 1.4° to 5.1° for the Low Dose measurements and 0.8° to 5.9° for the Micro Dose images. The maximum intrarater measurement error for the Low Dose vs. Micro Dose 3D measurements ranged from 3.2° to 5.3°, with the greatest measurement error in the sagittal measurements. Similarly, the 2D interrater measurement error was greatest in the sagittal plane measurements (Table 5).

The calculated error in measurement was not significantly different between the Low Dose and Micro Dose measurements, except for the following variables: intrarater 3D error on 3D L1–L5 lordosis (2.9° Micro Dose vs. 2.2°, $p = .04$) (Table 6), interrater 3D rotation of the apex of the lumbar curve (2.6° Micro Dose vs. 1.7°, $p = .03$) (Table 7), and 2D T12–sacrum lordosis (4.6° Micro Dose vs. 3.4°, $p = .04$) (Table 8). The differences in these error values between Low Dose and Micro Dose were not considered clinically relevant.

Table 2
Intraclass correlations (reliability) of 3D measurements.

3D Measurements	Low Dose				Micro Dose			
	Measurer 1 Intrarater	Measurer 2 Intrarater	Interrater Time 1	Interrater Time 2	Measurer 1 Intrarater	Measurer 2 Intrarater	Interrater Time 1	Interrater Time 2
Upper thoracic Cobb (°)	0.935	0.974	0.899	0.93	0.929	0.972	0.865	0.921
Thoracic Cobb (°)	0.987	0.996	0.983	0.987	0.989	0.994	0.982	0.985
Lumbar Cobb (°)	0.98	0.994	0.983	0.981	0.98	0.993	0.98	0.985
T1–T12 kyphosis (°)	0.967	0.983	0.961	0.964	0.951	0.981	0.964	0.967
T4–T12 kyphosis (°)	0.968	0.982	0.939	0.946	0.972	0.974	0.948	0.971
L1–L5 lordosis (°)	0.961	0.993	0.95	0.924	0.963	0.988	0.953	0.974
L1–S1 lordosis (°)	0.96	0.983	0.968	0.973	0.973	0.983	0.962	0.977
Thoracic apical rotation (°)	0.906	0.975	0.854	0.844	0.888	0.974	0.792	0.776
Lumbar apical rotation (°)	0.965	0.987	0.968	0.984	0.959	0.99	0.937	0.95
Sacral slope (°)	0.958	0.97	0.956	0.956	0.98	0.979	0.953	0.969
Pelvic incidence (°)	0.958	0.987	0.966	0.951	0.987	0.987	0.97	0.975
Pelvic tilt (°)	0.978	0.999	0.988	0.966	0.997	0.998	0.988	0.988

Table 4
Measurement error of 3D models.

3D Measurements	Low Dose		Micro Dose		Low Dose		Micro Dose		Low Dose versus Micro Dose	
	Intrarater		Intrarater		Interrater		Interrater		Intrarater	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Upper thoracic Cobb (°)	2.1	2.3	2.3	2.9	3.3	3.9	3.4	5.1	2.5	3.4
Thoracic Cobb (°)	1.7	3.5	2.2	3.3	3.3	3.8	3.6	4.1	2.3	4.0
Lumbar Cobb (°)	2.1	3.6	2.3	3.4	3.3	3.5	3.2	3.6	2.7	3.8
T1–T12 kyphosis (°)	2.5	3.5	2.8	4.0	3.7	3.8	3.4	3.8	4.2	5.3
T4–T12 kyphosis (°)	2.3	3.7	2.6	3.2	4.4	4.7	3.0	4.3	4.1	5.3
L1–L5 lordosis (°)	2.0	3.7	2.6	4.4	4.5	5.1	3.6	4.8	3.5	5.4
L1–S1 lordosis (°)	2.6	3.6	2.6	3.3	3.2	3.4	3.4	4.0	4.4	5.3
Thoracic apical rotation (°)	2.1	3.8	2.2	4.2	4.8	5.0	5.7	5.9	2.5	4.5
Lumbar apical rotation (°)	1.7	3.1	1.7	3.0	2.1	3.2	3.3	3.6	2.3	4.4
Sacral slope (°)	2.6	3.0	2.2	2.6	3.1	3.3	3.2	3.6	3.5	4.2
Pelvic incidence (°)	2.6	3.8	2.4	2.6	3.7	4.4	3.6	3.9	3.0	4.1
Pelvic tilt (°)	0.5	1.4	0.7	0.8	1.3	1.9	1.3	1.4	2.5	3.2

Minimum and maximum values refer to a 95% confidence interval.

Table 5
Measurement error of 2D measurements.

2D Measurements	Low Dose	Micro Dose	Low Dose versus Micro Dose	
	Interrater	Interrater	Intrarater	
	Max	Max	Min	Max
Upper thoracic Cobb (°)	2.6	1.8	2.7	2.7
Thoracic Cobb (°)	4.5	3.9	3.6	3.9
Lumbar Cobb (°)	3.3	3.4	2.9	3.8
T2–T5 kyphosis (°)	4.3	4.1	3.5	5.4
T4–T12 kyphosis (°)	3.5	4.6	4.4	6.1
T12–top of sacrum (°)	4.2	5.5	5.5	5.6

Values refer to a 95% confidence interval.

Table 6
Comparison of intrarater 3D measurements between Low Dose and Micro Dose measurements.

3D Measurements	Low Dose (mean ± SD)	Micro Dose (mean ± SD)	n	p value
Upper thoracic Cobb (°)	1.8 ± 1.8	2.1 ± 1.9	108	.17
Thoracic Cobb (°)	2.2 ± 2.1	2.3 ± 2.0	120	.65
Lumbar Cobb (°)	2.3 ± 2.3	2.2 ± 2.5	120	.78
T1–T12 kyphosis (°)	2.6 ± 2.0	2.8 ± 2.4	120	.39
T4–T12 kyphosis (°)	2.6 ± 1.9	2.4 ± 2.0	120	.42
L1–L5 lordosis (°)	2.2 ± 2.6	2.9 ± 2.6	120	**.04**
L1–S1 lordosis (°)	2.5 ± 2.7	2.3 ± 2.6	120	.62
Thoracic apical rotation (°)	2.4 ± 2.4	2.6 ± 2.4	120	.40
Lumbar apical rotation (°)	1.9 ± 2.3	1.9 ± 1.8	120	.86
Sacral slope (°)	2.2 ± 2.5	1.9 ± 2.1	120	.28
Pelvic incidence (°)	2.4 ± 3.4	1.9 ± 2.2	120	.26
Pelvic tilt (°)	0.6 ± 1.7	0.5 ± 0.7	120	.73

Bold values represent statistically significant differences. Subjects without an upper thoracic curve were excluded from the upper thoracic Cobb measurement.

Table 7
Comparison of interrater 3D measurements between Low Dose and Micro Dose measurements.

3D Measurements	Low Dose (mean ± SD)	Micro Dose (mean ± SD)	n	p value
Upper thoracic Cobb (°)	2.8 ± 2.1	2.8 ± 2.4	48	.999
Thoracic Cobb (°)	2.7 ± 2.4	3.0 ± 2.6	60	.528
Lumbar Cobb (°)	2.8 ± 2.6	2.7 ± 2.0	60	.806
T1–T12 kyphosis (°)	3.2 ± 2.3	2.8 ± 2.2	60	.44
T4–T12 kyphosis (°)	3.8 ± 2.6	2.5 ± 1.9	60	**.003**
L1–L5 lordosis (°)	3.8 ± 5.0	2.9 ± 2.9	60	.142
L1–S1 lordosis (°)	2.6 ± 2.5	2.8 ± 2.4	60	.612
Thoracic apical rotation (°)	3.9 ± 3.8	4.8 ± 4.4	60	*.064*
Lumbar apical rotation (°)	1.7 ± 1.6	2.6 ± 2.9	60	**.031**
Sacral slope (°)	2.6 ± 2.8	2.6 ± 2.3	60	.937
Pelvic incidence (°)	3.2 ± 4.5	2.9 ± 3.0	60	.508
Pelvic tilt (°)	1.2 ± 2.9	0.9 ± 1.6	60	.453

Bold values represent statistically significant differences. Subjects without an upper thoracic curve were excluded from the upper thoracic Cobb measurement.

Italics represent a trend toward statistical significance.

Table 8
Differences in interrater 2D measurements.

2D Measurements	Low Dose (mean ± SD)	Micro Dose (mean ± SD)	n	p value
Upper thoracic Cobb (°)	2.2 ± 1.9	1.5 ± 1.4	60	**.038**
Thoracic Cobb (°)	3.5 ± 4.0	3.3 ± 2.5	60	.596
Lumbar Cobb (°)	2.4 ± 3.3	2.8 ± 2.4	60	.352
T2–T5 kyphosis (°)	3.6 ± 3.0	3.4 ± 2.8	60	.728
T4–T12 kyphosis (°)	2.9 ± 2.5	3.7 ± 3.6	60	.164
T12–top of sacrum (°)	3.4 ± 3.4	4.6 ± 3.7	60	**.037**

Bold values represent statistically significant differences.

The average dose area product for the Micro Dose images was 172.7 mGy•cm^2 (54.5 mGy•cm^2 for posteroanterior (PA) images plus 118.1 mGy•cm^2 for the lateral [Lat] images) and 1283.5 mGy•cm^2 for the Low Dose images (391.9 mGy•cm^2 for the PA images plus 891.6 mGy•cm^2 for the Lat images) ($p < .001$). The average rate of radiation reduction was 7.6 ± 1 times less in the Micro Dose group (range 4.5–9.3× less).

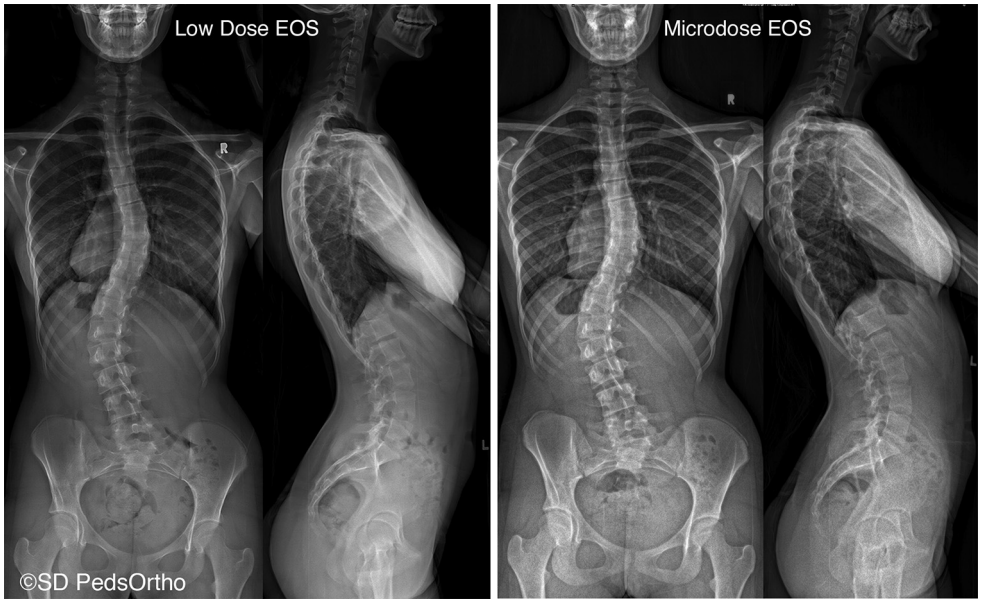

Fig. 1. Side-by-side comparison of Low Dose images to Micro Dose images in a patient without spinal fusion/instrumentation.

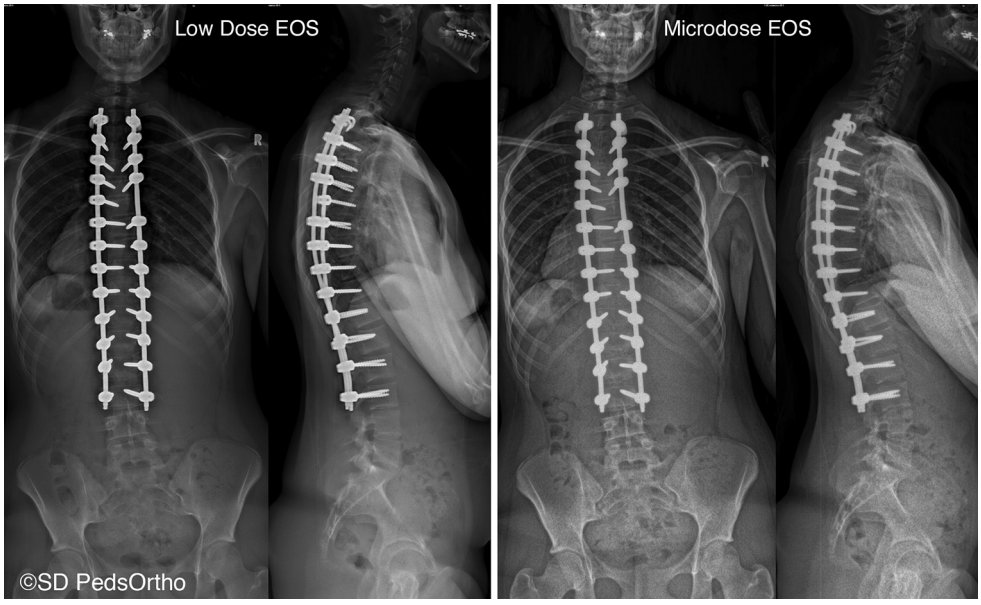

Fig. 2. Side-by-side comparison of Low Dose images to Micro Dose images in a patient who underwent spinal fusion and instrumentation.

Qualitatively, the Micro Dose images demonstrated slightly less clarity (Figs. 1 and 2), but all of the critical 2D and 3D measures of the curvature were reliably measured.

Discussion

Reducing the risks associated with radiation exposure while maximizing the clinical benefit of radiographs is especially important in AIS. Presciutti et al. reported that idiopathic scoliosis patients undergoing surgical treatment for their deformity received an average of up to 12.2 radiographs annually and 1,400 mrad/year [7] (100 mrad = 1 mGy, thus 14 mGy/year). Patients treated with a brace but no operation still received an average of 5.7 radiographs annually and 700 mrad/year (7 mGy/year) of radiation. In comparison, the observation group only received an average of 3.5 radiographs per year and 400 mrad/year (4 mGy/year), which is only a fraction of that received by the operative cohort, but a value that could still be reduced [7]. Of note, the cumulative annual radiation values from their study included all forms of imaging (computed tomography, fluoroscopy, radiographs), with 78% of the operative group's exposure occurring intraoperatively.

In a systematic review by Pace et al., the reported effective doses from spine radiographs of adolescents ranged from 0.170 to 1.090 mSv for anteroposterior (AP) x-rays, 0.290 to 0.490 mSv for PA x-rays, and 0.260 to 0.540 mSv for Lat x-rays [8] (1 msv = 1 mGy). A separate study calculated the effects of exposure to patients undergoing treatment for AIS and determined that these children are at a 4% higher risk of developing radiation-induced breast cancer than their peers [9]. Considering this increased risk to scoliosis patients from serial x-ray exams, the need for reducing radiation exposure is of great importance.

In an effort to further reduce the risk to the patient, a new Micro Dose filter and postprocessing software algorithm have been developed for the EOS Imaging system [10]. This Micro Dose technique (~0.05 mGy/PA+Lat) has the potential to offer an approximate 50-fold reduction in radiation exposure over standard computed radiography (with some reports of ~3 mGy and greater for PA+Lat views [4,11-13]) and an additional 5–7-fold reduction from the current standard, Low Dose EOS (~0.33 mGy/PA+Lat) images. The current study compared the reliability of 2D and 3D measurements obtained from Micro Dose images to those obtained from the current standard of care, Low Dose EOS images. Good reliability and similar measurement error were found between the two sets of images. There was "substantial" to "almost perfect" agreement for Low Dose 3D, Micro Dose 3D, and 2D measurements. The measurement error for both the Micro Dose and Low Dose images ranged from 1 to 6 degrees, with the greatest error in the sagittal plane measurements. This is similar to what has been reported previously in the literature using standard radiographic methods [14]. The calculated error in measurement was not significantly greater in the Micro Dose images compared to the Low Dose images for all variables except for intrarater error on 3D L1–L5 lordosis, interrater 3D apical rotation of the lumbar curve, and 2D T12–sacrum lordosis. Although these statistically significant differences were found between the Micro Dose and Low Dose measurements, the average differences were approximately one degree for each and were not believed to be clinically significant. These differences would most likely not affect the diagnostic or prognostic evaluation of the patient. Thus, the negligible magnitude of difference of average error between the Micro Dose and Low Dose groups fails to suggest that one modality is superior to the other in either 2D or 3D measurements.

The lumbar spine seemed to be the area with the most variability. One possible explanation for this intra- and interrater variability in the lumbar region may stem from the confounding anatomy of gastrointestinal and abdominal organs, including the associated intraluminal gas. This finding was not surprising, as previous studies have reported high measurement error in the sagittal plane on 2D radiographs, although previous studies reported greater variability in measurements of thoracic kyphosis [14,15].

The authors suggest that the standard EOS Low Dose images provide better image detail/quality and should be used for initial diagnostic evaluation and preoperative assessment. The Micro Dose images may best be utilized for following curve progression after initial diagnosis has been made, and for evaluating postoperative outcomes. The Micro Dose images currently do not have the detail to be considered "diagnostic quality" for many of the subtle potential radiographic finding (eg, lucencies, pulmonary findings, etc) that may appear on a spinal radiograph. For this reason, we along with our radiologist colleagues have adopted a policy to use standard low-dose images on all first appointment imaging for new patients referred for spinal deformity assessment. Follow-up images are obtained utilizing the Micro Dose protocol because measures of progression can be accurately made. This protocol, we believe, allows the physician/surgeon/radiologist to make an accurate and appropriate initial diagnosis employing diagnostic quality standard low dose images with higher resolution radiography while keeping the cumulative exposure as low as reasonably possible through the use of the reliable Micro Dose imaging for all further monitoring of curve progression.

Previous research has suggested that the EOS imaging unit might not be as cost effective as CR because of the higher cost of acquiring and maintaining the system [16]. Dietrich and Pfirrmann conducted a study evaluating the workflow and the financial break-even points of standard digital radiography compared to a biplanar low-dose x-ray system and found that the biplanar system required more examinations per year to break even, but also allowed for more examinations and lower labor costs per examination because of the shorter exam time. They suggested that the biplanar system may be cost effective for institutions with a high number of examinations [17]. The potential to reduce the cumulative radiation exposure to children with spinal deformities using EOS Imaging Low Dose and Micro Dose protocols is substantial, and as stewards of our patients we should advocate for reducing the radiation exposure when possible.

Conclusion

The use of Micro Dose filtering and postprocessing algorithms with EOS x-ray scanners has the potential to substantially reduce radiation exposure to AIS patients compared to computed or digital radiography without sacrificing intra- and interobserver measurement reliability of 3D modeling. Although statistically significant differences in average measurement error were observed for three specific 3D and 2D measures of lordosis and rotation, the average differences were small and not thought to be clinically important. With the appropriate integration into standard of care protocols for AIS treatment, the Micro Dose technology can mitigate the real radiation-associated risks AIS patients face, including malignancies and other iatrogenic diseases associated with cumulative radiation exposure over the course of disease management.

Key points:

1. "Substantial" to "Almost Perfect" reliability was found between 3D and 2D measurements of the standard Low Dose and Micro Dose EOS images in patients with adolescent idiopathic scoliosis (AIS).
2. Micro Dose images reduced radiation by an additional ~7× that of the current Low Dose EOS images.
3. The Micro Dose images demonstrated slightly less clarity, but all of the critical measures of the curvature were reliably measured.
4. EOS Micro Dose imaging technique and sterEOS software 3D models are adequate and appropriate for assessing curve magnitude on follow-up examinations.

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