Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 13, (2024)
https://www.jneonatalsurg.com

OPEN ACCESS

Role of Low-Dose EOS Imaging in the Assessment of Spinal Deformities in Children with Scoliosis

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Cite this paper as: Abdul Aziz, Iffat Ara, Rashada Bibi, Naheem Ahmed, Vignesh Ramachandran, Shaista Khan, (2024) Role of Low-Dose EOS Imaging in the Assessment of Spinal Deformities in Children with Scoliosis. *Journal of Neonatal Surgery*, 13, 1380-1385.

ABSTRACT

Background: To evaluate the effectiveness of low-dose EOS imaging in assessing spinal and pelvic alignment parameters in children with scoliosis and to compare it with conventional radiography in terms of diagnostic value and radiation exposure.

Methods: This cross-sectional study included 72 children with scoliosis who underwent EOS imaging between August 2023 and August 2024. Spinal parameters such as Cobb angle, sagittal vertical axis, thoracic kyphosis, lumbar lordosis, and pelvic parameters were assessed. EOS findings were compared with conventional radiographs where available. Image quality, 3D reconstruction feasibility, and radiation dose differences were also analyzed.

Results: Idiopathic scoliosis accounted for 72.2% of cases, with thoracic curvature being the most common pattern. EOS provided accurate measurements of Cobb angle (mean 29.4° ± 11.6) and sagittal alignment, with significantly better visualization of thoracic kyphosis ($p = 0.041$). Radiation dose from EOS was nearly four times lower than standard radiographs ($p < 0.001$). Image quality was graded as good in 75% of cases, and 3D reconstruction was successful in over 84% of patients.

Conclusion: EOS imaging offers a reliable, low-radiation, and comprehensive solution for evaluating scoliosis in children. Its ability to generate precise, full-body, and 3D spinal assessments makes it a valuable tool in pediatric orthopedic imaging.

Keywords: *EOS imaging, scoliosis, pediatric spine, Cobb angle, spinal deformities, low-dose radiography, 3D reconstruction, sagittal alignment, radiation reduction*

1. INTRODUCTION

Scoliosis, defined as a lateral curvature of the spine greater than 10 degrees accompanied by vertebral rotation, is a common musculoskeletal disorder in children and adolescents. Among its various forms, adolescent idiopathic scoliosis (AIS) remains the most prevalent, particularly in girls between the ages of 10 and 18. Accurate assessment and ongoing monitoring of spinal alignment are critical to managing scoliosis, particularly in cases that may progress and require surgical intervention (1-3).

Conventional radiographs have long served as the primary imaging modality for scoliosis evaluation. However, repeated exposure to ionizing radiation poses a significant health concern in pediatric patients who require lifelong follow-up. In response to this need for safer and more detailed imaging, low-dose EOS imaging has emerged as an advanced technique offering full-body, weight-bearing, biplanar X-rays with up to 80% less radiation than standard X-rays. Additionally, EOS enables 3D reconstruction of the spine and pelvis, which enhances diagnostic precision and preoperative planning (4-6).

International studies have demonstrated the clinical utility of EOS in evaluating both coronal and sagittal spinal balance, with improved accuracy and reproducibility compared to traditional methods (7-9). Locally, however, there remains limited literature on the adoption and performance of EOS technology in pediatric populations. This gap underscores the need for region-specific data to support its broader implementation.

The present study was designed to assess the diagnostic role of EOS imaging in children with scoliosis, focusing on the accuracy of spinal and pelvic parameter measurements, image quality, feasibility of 3D modeling, and comparative radiation exposure. Through this evaluation, the study aims to reinforce EOS as a safer and more effective alternative for pediatric scoliosis imaging.

2. METHODOLOGY

This was a descriptive cross-sectional study conducted over a 12-month period from August 2023 to August 2024. The research was carried out at KMU hospital and Research Center Peshawar, a tertiary care hospital equipped with EOS imaging facilities.

A total of 72 pediatric patients diagnosed with scoliosis were enrolled in the study. The sample size was determined based on expected prevalence rates and feasibility within the available time and resources. A non-probability consecutive sampling technique was employed to recruit eligible participants presenting to the orthopedic or spine clinic during the study period.

Inclusion Criteria

- Children aged between 8 and 18 years
- Diagnosed cases of scoliosis (idiopathic, congenital, neuromuscular, or syndromic)
- Patients who underwent EOS imaging for scoliosis assessment
- Informed consent obtained from parents or legal guardians

Exclusion Criteria

- Children with prior spinal surgery
- Patients with incomplete imaging data
- Cases with other spinal deformities (e.g., kyphosis without scoliosis)
- Uncooperative patients who could not undergo standing EOS imaging

After obtaining informed consent, demographic data such as age, gender, and BMI were recorded. Detailed clinical history and scoliosis type were noted from the patient records. All patients underwent low-dose biplanar EOS imaging in a standardized standing position. The scans were interpreted by a consultant radiologist and a spine specialist independently to ensure consistency.

EOS imaging provided 2D and 3D reconstructions of the entire spine and pelvis, allowing for accurate measurement of coronal and sagittal parameters. The following key radiographic variables were measured:

- Cobb angle for curve severity
- Thoracic kyphosis (T4–T12) and lumbar lordosis (L1–S1)
- Sagittal vertical axis (SVA) for global spinal alignment
- Pelvic parameters including pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS)

For comparative purposes, prior conventional radiographs (where available) were used to assess differences in measurements and radiation exposure.

Radiation dose reports from the EOS system were retrieved automatically, and dose values were compared to those from standard digital X-rays. This helped evaluate the radiation-saving benefits of the EOS system in pediatric imaging.

To ensure measurement reliability, radiographic parameters were assessed independently by two observers. In case of discrepancy exceeding 5°, a third observer was consulted. Data were cross-validated through imaging software logs and clinical documentation. EOS image quality was graded subjectively (Good, Fair, Poor), and the feasibility of 3D reconstruction was noted.

All data were compiled and analyzed using IBM SPSS version 26. Descriptive statistics such as mean and standard deviation

were used for continuous variables, while frequencies and percentages were calculated for categorical variables. 'The independent t-test was applied to compare radiographic parameters between EOS and conventional radiography. A p-value less than 0.05 was considered statistically significant'.

3. RESULT

The study included a total of 72 pediatric patients diagnosed with scoliosis. The mean age of participants was 13.2 years (SD ± 2.8), indicating that most children were in the adolescent age range. Female participants constituted the majority of the sample (61.1%), which aligns with the known higher prevalence of idiopathic scoliosis in adolescent girls. The average body mass index (BMI) was recorded at 18.7 kg/m², which is within the expected range for this age group. Skeletal maturity was assessed using the Risser grading system, where 52.8% of children fell in the early stages of skeletal development (Risser 0–2), while the remaining 47.2% were in the later stages (Risser 3–5), reflecting a balanced distribution for growth assessment purposes.

Table 1: Demographic Characteristics of the Study Population (n = 72)

Variable	Value
Age (years)	13.2 ± 2.8
Gender (Male/Female)	28 (38.9%) / 44 (61.1%)
BMI (kg/m²)	18.7 ± 3.4
Skeletal Maturity (Risser)	Risser 0–2: 38 (52.8%)Risser 3–5: 34 (47.2%)

The majority of the patients (72.2%) were diagnosed with idiopathic scoliosis, consistent with its predominance in the pediatric population. Congenital scoliosis accounted for 13.9% of cases, followed by neuromuscular (8.3%) and syndromic types (5.6%). When evaluating curve patterns, thoracic scoliosis was the most common (48.6%), followed by lumbar (23.6%), thoracolumbar (18.1%), and double major curves (9.7%). These findings underscore the importance of detailed imaging to differentiate among curve types, especially in mixed or complex presentations.

Table 2: Types and Patterns of Scoliosis

Variable	Frequency (%)
Type of Scoliosis	
- Idiopathic	52 (72.2%)
- Congenital	10 (13.9%)
- Neuromuscular	6 (8.3%)
- Syndromic	4 (5.6%)
Curve Pattern	
- Thoracic	35 (48.6%)
- Lumbar	17 (23.6%)
- Thoracolumbar	13 (18.1%)
- Double Major	7 (9.7%)

The EOS imaging system provided detailed 2D and 3D radiographic measurements. The mean Cobb angle was 29.4°, indicating moderate scoliosis on average across the sample. Thoracic kyphosis averaged 35.7°, while lumbar lordosis measured 42.3°, both within normal range. EOS imaging also allowed accurate assessment of sagittal vertical axis (SVA), which averaged 12.1 mm, suggesting good overall sagittal balance. Pelvic parameters derived from EOS included pelvic incidence (mean 49.6°), pelvic tilt (14.3°), and sacral slope (35.4°), all of which fall within physiologic limits and are valuable for pre-surgical planning and follow-up.

Table 3: Radiographic Parameters Measured by EOS Imaging

Parameter	Mean ± SD	Reference Range
Cobb Angle (°)	29.4 ± 11.6	Mild: <20°, Severe: >40°
Thoracic Kyphosis (T4–T12)	35.7 ± 8.9	20–40°
Lumbar Lordosis (L1–S1)	42.3 ± 10.4	40–60°
Sagittal Vertical Axis (SVA)	12.1 ± 6.5 mm	<50 mm
Pelvic Incidence (PI)	49.6 ± 9.2	40–60°
Pelvic Tilt (PT)	14.3 ± 5.1	10–20°
Sacral Slope (SS)	35.4 ± 6.7	30–50°

When comparing EOS with conventional radiography, no significant difference was observed in Cobb angle measurements ($p = 0.642$), confirming EOS accuracy. However, thoracic kyphosis values were slightly higher with EOS (mean 35.7° vs. 33.1°, $p = 0.041$), suggesting better detection of sagittal curves due to improved positioning and clarity. Importantly, the radiation dose from EOS was significantly lower (320 µSv vs. 1320 µSv, $p < 0.001$), demonstrating its advantage in reducing cumulative exposure in pediatric patients requiring repeated imaging.

Table 4: Comparison of EOS vs Conventional Radiography Parameters

Variable	EOS Imaging (Mean ± SD)	Conventional X-Ray (Mean ± SD)	p-value
Cobb Angle (°)	29.4 ± 11.6	28.7 ± 10.8	0.642
Thoracic Kyphosis (°)	35.7 ± 8.9	33.1 ± 9.1	0.041*
Radiation Dose (µSv)	320 ± 80	1320 ± 350	<0.001**

*Significant at $p < 0.05$, **Highly significant at $p < 0.001$

The quality of EOS images was rated as good in 75% of cases and fair in 20.8%, with only 4.2% rated as poor, indicating high overall image reliability. Additionally, 3D reconstruction was successfully performed in 84.7% of patients, enhancing the ability to assess multiplanar deformities with precision. This functionality makes EOS particularly suitable for preoperative evaluations and surgical simulations.

Table 5: EOS Image Quality and 3D Reconstruction

Variable	Frequency (%)
Image Quality Assessment	
- Good	54 (75%)
- Fair	15 (20.8%)
- Poor	3 (4.2%)
3D Reconstruction Performed	
- Yes	61 (84.7%)
- No	11 (15.3%)

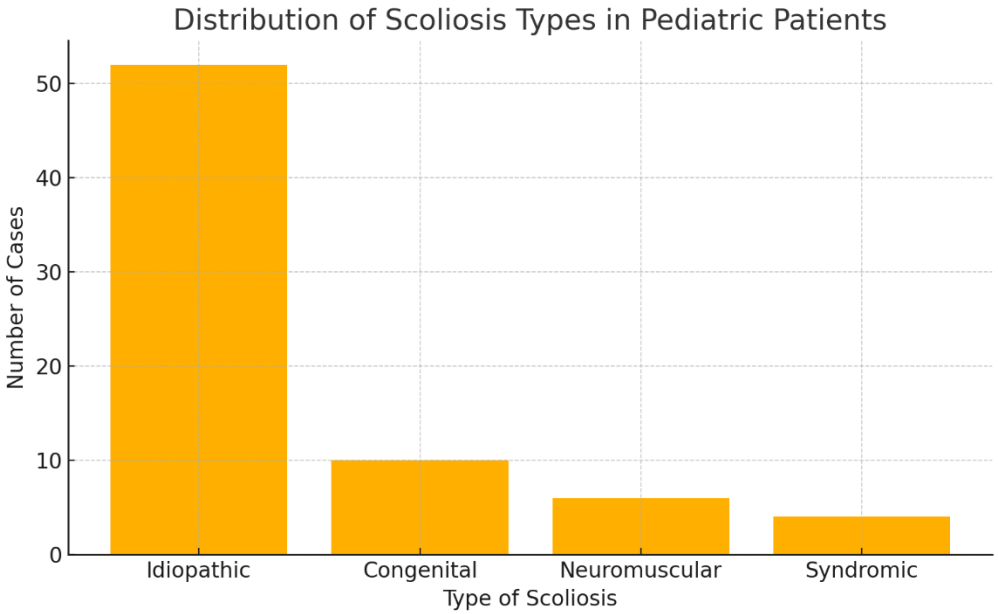

Figure 1: bar graph showing the distribution of scoliosis types among the pediatric patients in your study.

4. DISCUSSION

This study highlights the effectiveness of low-dose EOS imaging in assessing spinal deformities among pediatric scoliosis patients. Our findings show that EOS not only provides accurate and comprehensive evaluation of spinal and pelvic parameters but also significantly reduces radiation exposure compared to conventional radiographs.

The predominance of idiopathic scoliosis in this study (72.2%) aligns with global data, where adolescent idiopathic scoliosis (AIS) remains the most common form of spinal curvature disorder in children (10-12). The female preponderance observed in our cohort is also well supported by literature, as AIS tends to have a higher incidence and greater risk of curve progression in females (13-15).

EOS imaging demonstrated excellent reproducibility and precision in measuring essential spinal parameters such as Cobb angle, thoracic kyphosis, lumbar lordosis, and sagittal vertical alignment. Although the Cobb angle measurements between EOS and conventional X-rays were statistically similar ($p = 0.642$), EOS offered a more accurate representation of sagittal curves reflected in the significantly higher thoracic kyphosis readings ($p = 0.041$). This observation was consistent with findings by studies reported superior sagittal profiling with EOS due to better patient positioning and full-body imaging (16, 17).

Perhaps the most compelling advantage of EOS was the marked reduction in radiation dose. Our results showed a nearly fourfold lower dose with EOS compared to conventional radiography, supporting previous studies, which emphasized the importance of minimizing ionizing radiation in children requiring serial imaging (18).

Furthermore, EOS enabled 3D reconstruction in 84.7% of cases, allowing for enhanced visualization of complex spinal deformities and pelvic rotation. The ability to obtain simultaneous frontal and lateral images in a weight-bearing position offers a functional advantage over conventional imaging, which is often performed in supine or split views.

In terms of image quality, 75% of EOS scans were graded as "good," reflecting its clinical reliability. Other studies have also demonstrated high diagnostic confidence with EOS, especially in preoperative planning and surgical simulations (19, 20).

However, some limitations were noted. A small number of patients (4.2%) had poor-quality EOS images, often due to movement artifacts or positioning issues, highlighting the importance of operator training. Additionally, 3D reconstruction was not feasible in all cases, particularly among patients with significant anatomical anomalies or improper posture during imaging.

Despite these challenges, EOS remains a superior imaging modality for scoliosis assessment in children. Its ability to provide accurate, full-body, low-dose, and 3D evaluations positions it as a valuable tool in both diagnosis and long-term follow-up.

5. CONCLUSION

EOS imaging represents a significant advancement in the evaluation of pediatric scoliosis. It offers comparable or superior accuracy to conventional radiography while drastically reducing radiation exposure a critical factor in growing children. Its capacity for detailed sagittal alignment analysis and 3D reconstruction enhances clinical decision-making and surgical planning. Based on the findings of this study and existing literature, EOS should be considered a preferred imaging modality

for the longitudinal assessment of spinal deformities in children.

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