Original Article

Evaluation of angle trunk rotation measurements to improve quality and safety in the management of adolescent idiopathic scoliosis

Jill E. Larson^a, Maximilian A. Meyer^b, Barrett Boody^c, John F. Sarwark^{a,*}^a Department of Surgery, Ann & Robert H. Lurie Children's Hospital, Chicago, IL, United States^b Department of Orthopaedic Surgery, Massachusetts General Hospital, Boston, MA, United States^c Department of Orthopaedic Surgery, The Rothman Institute, Philadelphia, PA, United States

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ABSTRACT

Purpose: The evaluation, management and follow-up of adolescent idiopathic scoliosis (AIS) occur frequently within a pediatric orthopedic surgery practice. Curve status can be assessed with Scolimeter measurements of angle trunk rotation (ATR), which are reliable and reproducible to within 3°. This study assessed the longitudinal efficacy, safety and cost savings of integrating ATR measurements to monitor curve status and progression in AIS, and suggests a quality-based management strategy.

Methods: A retrospective review of medical records between 2004 and 2014 included patients with AIS between 10–17 years, excluding those with Cobb angle > 52° at presentation. Two cohorts were analyzed based on presentation prior to menarche (PRE) or after menarche (POST). The PRE groups was further classified based on whether the curve was Stable or Unstable. The cost of a single PA thoracolumbar radiograph was defined based on the 2015 CMS fee schedule (\$36.27). Safety was defined based on the effective radiation dose avoided (0.14 millisieverts/radiograph).

Results: A total of 59 children were included with 45 in PRE and 14 in the POST cohort. The use of ATR measurements provided a cost benefit in both the PRE Stable and Unstable cohorts, by avoiding radiographs with an average savings of \$161.76 and \$147.50 respectively. Similarly in POST, there was an average cost savings of \$105.18 per patient. The safety benefit of using ATR measurements included avoiding an average of 0.62, 0.56 and 0.4 millisieverts of radiation in the PRE Stable, PRE Unstable and POST groups respectively.

Conclusions: An evaluation strategy with ATR measurements provides for a reliable, cost-effective and safety advantage in the monitoring of curve progression in both skeletally mature and immature patients with AIS. These findings suggest that stable ATR measurements are a safe and cost effective alternative to serial radiographs in the clinical monitoring of AIS. Recent evidence from 25 years of scoliosis treatment in Denmark noted a cancer rate 17 times that of an age-matched population. Thus, reducing radiation exposure during scoliosis monitoring using ATR measurements has important clinical significance for cancer risk reduction.

1. Introduction

Adolescent Idiopathic Scoliosis (AIS) is one of the most common deformities in pediatrics with a prevalence of up to 3% of the prepubescent and adolescent population, age greater than 10 years.¹ In addition to its significant prevalence, the natural history of untreated scoliosis can have high morbidity and mortality rates when severe spinal deformities ultimately jeopardize cardiac and respiratory function. Moderately-sized curve patterns also demonstrate poor outcomes if left untreated; the natural history of idiopathic scoliosis demonstrates that continued curve progression leads to early degenerative arthritis, back pain and poorer self-image.^{1–3}

Although significant progress has been made in the treatment of AIS through bracing and surgery, the timing of treatment initiation has critical implications on outcomes and requires regular clinical monitoring as well as radiographic evaluation to track curve progression. Standard guidelines for treatment include bracing when curves reach a radiographic Cobb angle of 25°, and surgery when Cobb angle is greater than 45°. In addition to radiographic measurements, the physical exam can also help monitor curve progression with the use of a Scolimeter. The Scolimeter is an inclinometer that measures the asymmetries between the sides of the trunk by measuring axial rotation in degrees. Numerous studies have looked at the reliability of Scolimeter measurements, finding a high correlation between

* Corresponding author at: 255 E. Chicago Ave., Department of Surgery, Division of Orthopaedics & Sports Medicine, Ann & Robert H. Lurie Children's Hospital, Chicago, IL, 60611, United States.

E-mail address: jsarwark@luriechildrens.org (J.F. Sarwark).

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the axial trunk rotation (ATR) values and the Cobb angles with sufficient intra and inter-rater reliabilities.^{4–11} These studies have demonstrated that using a Scoliometer measurement is a reliable, non-invasive method of repetitively assessing spinal axial rotation when used by a trained professional. Additionally, other studies have demonstrated that in patients with scoliotic curves as high as 52°, the vertebral rotation could be estimated from the surface rotation with an average error of 3.1°.¹² Thus, the current definition of a stable spinal curve at Ann & Robert H. Lurie Children's Hospital of Chicago (Lurie Children's) is based on follow-up Scoliometer measurements that remain within three degrees of previous measurements. If there is a significant increase in ATR measurement (> 3°) then the patient receives a coronal plane radiograph to compare Cobb angles to prior imaging to confirm curve progression and determine if a change in current treatment plan is necessary. If Scoliometer measurements are unchanged from prior examinations, then a radiograph is not obtained, and the patient is instructed to follow up at the routine set interval for follow-up clinical evaluation. In this scenario, the patient is not subjected to the additional cost of the radiograph and is also protected from the incremental radiation exposure of a spinal radiograph.

Studies have demonstrated that patients with idiopathic scoliosis are exposed to approximately 25 radiographic examinations of their spine throughout the clinical monitoring period to assess for curvature progression.⁶ Excessive exposure to radiation in patients with spinal deformity has been associated with an increased risk of developing breast cancer up to 5.4%.^{13,14} Thus, one aim of this study was to determine if using ATR measurements, as an alternative to follow-up radiographs, decreases the average number of radiographic exams and thus decreases the amount of radiation exposure encountered during the course of monitored scoliosis treatment.

To our knowledge there is no published data analyzing the cost effectiveness of utilizing ATR measurements as an alternative to radiographic Cobb measurements in the assessment of curve progression AIS. In addition to performing a cost analysis, this study also evaluated the incremental decrease in radiation exposure by using ATR measurements as an alternative to radiographic Cobb measurements, which could have significant implications on how curve progression is monitored long-term in patients with AIS.

2. Materials and methods

A retrospective cohort study was performed to analyze the cost effectiveness and radiation protection of utilizing Scoliometer measurements for the evaluation of curve progression in adolescent idiopathic scoliosis. IRB (institutional review board) approval was obtained before beginning data collection. No external or internal funding sources were obtained. Data was collected using a secure RedCap database after chart review of electronic medical record. The study population included children with a diagnosis of AIS, at or after the age of 10 years, who presented to orthopedic surgery clinic between January 1, 2004 and November 18, 2014. Patients were excluded if the diagnosis was not idiopathic scoliosis (i.e. neuromuscular scoliosis, syndromic, early onset, etc.), if age at presentation was > 17 years or if patients had

scoliosis with an initial Cobb angle > 52 degrees at presentation. Recorded variables included time of initial presentation as well as pertinent clinical facts including sex, menarchal status, family history of scoliosis, other medical problems or conditions, curve pattern, Scoliometer measurement of ATR, height, weight, shoulder asymmetry, rib prominence, whether or not a radiograph was performed and measured Cobb angle based on the radiograph. At subsequent follow-up visits, it was noted whether an x-ray was obtained and whether Scoliometer measurements of ATR were used.

Two cohorts were analyzed: Group PRE (pre-menarchal females and males with Risser < 5) and POST (post-menarchal females and males with Risser 5). "Unstable" was defined as patients with ≥ 4 degrees of change from initial to final ATR measurement.

The cost of a single PA thoracolumbar radiograph (\$36.27) was defined by the 2015 CMS fee schedule. Cost savings was therefore defined as number of non-XR ATR encounters multiplied by the cost of a single PA thoracolumbar radiograph. Safety was defined based on the effective radiation dose avoided (0.14 millisieverts per spinal PA thoracolumbar spinal radiograph) by performing an ATR measurement in lieu of obtaining a spinal radiograph. Descriptive statistics were used to analyze the cohorts and a paired *t*-test analysis was performed to compare the PRE Unstable and Stable cohorts. Statistical significance was defined as < 0.05.

3. Results

A total of 59 children were included in the study with 45 in the PRE cohort and 14 in the POST cohort. Within the PRE cohort, there were 41 pre-menarchal female and 4 males with Risser < 5. Within the PRE cohort, 30 (67%) patients were determined to have "Stable" curve patterns and 15 (33%) had "Unstable" curve patterns with interval change in ATR measurements > 4 degrees. There were no unstable curve patterns in the POST group. See Table 1 for demographics and average clinical characteristics for the respective cohorts. There was no significant difference in the PRE Stable and PRE Unstable cohorts in terms of degree of spinal curvature at presentation (initial Cobb angle), duration of observation, number of clinical encounters, or average time between encounters. As expected based on the defined Stable and Unstable cohorts, a significant difference was found between the two groups in terms of the number of XRs obtained, the change in Cobb Angle and the change in ATR. Five of the 15 patients in the Unstable PRE cohort went on to have surgery during the study period where none of the Stable PRE or POST cohort patients required surgical intervention.

The use of ATR measurements provided a cost benefit in both the PRE Stable and Unstable cohorts, by avoiding radiographs with an average savings of \$161.76 per patient and \$147.50 per patient, respectively over the course of their treatment period. Similarly within POST, there was an average cost savings of \$105.18 per patient over the duration of observation. The safety benefit of using ATR measurements included avoiding an average of 0.62, 0.56 and 0.4 millisieverts of radiation in the PRE Stable, PRE Unstable and POST groups respectively.

Table 1
Average ATR measurements for cohorts.

AVERAGES	n =	Age at presentation (years)	Cobb angle at presentation (degrees)	Duration of observation	# of encounters	Time between encounters (months)	# of XR encounters	# of non-XR encounters	Change in Cobb angle	Change in ATR (degrees)
PRE Stable	30	12.2	17.3	3.47	7.4	5.6	2.93	4.46	7.0	1.4
PRE Unstable	15	11.4	21.9	4.0	8.8	5.8	4.7	4.1	18.2	6.2
p value		0.04	0.07	0.32	0.11	0.83	0.00	0.56	0.00	0.00
POST Stable	14	13.7	22.6	2.54	5.7	5.3	2.8	2.9	4.4	0.7
POST Unstable	0	–	–	–	–	–	–	–	–	–

PRE, Group PRE (pre-menarchal females and males with Risser < 5); POST, Group POST (post-menarchal females and males with Risser 5); Unstable, patients with ≥ 4 degrees of change from initial to final ATR measurement; XR, X-ray.

4. Discussion

The results of this study demonstrate that an evaluation strategy that includes ATR measurements provides a reliable, cost-effective and safety advantage in the monitoring of curve progression in both skeletally mature and immature patients with AIS. In an era of increased focus on value and cost savings in the medical community, the use of ATR measurement in the monitoring of AIS curve progression is a practical way to minimize expenditures. While the raw dollar amount of cost savings per patient may be minimal in relationship to other cost-saving initiatives, AIS monitoring can represent a notable proportion of a pediatric orthopedic surgeon's practice. Thus, although a small incremental cost saving per patient, the cumulative savings when monitoring hundreds of patients within a practice or hospital system becomes more significant. Additionally, the added value of radiation dose and cancer risk reduction by performing an ATR measurement in lieu of a radiographic evaluation is compounded by avoiding the costs associated with potential cancer treatment related to radiation induced breast or radiation induced carcinomas. This study has notable limitations including the retrospective nature of prospectively collected data and associated bias. The Unstable and Stable cohorts within the PRE group had statistically significant differences in age of presentation, potentially suggesting a selection bias; however, the curve magnitude was not statistically different. The cost savings data was calculated using the 2015 cost of a radiograph despite radiographs taken prior 2015; thus, the assumption was made that the annual incremental cost of a radiograph was proportional to inflation. While this assumption may not be correct and therefore the exact cost savings may be slightly higher/lower, the same cost per patient equation was applied universally to all cohorts, so comparisons can safely be made between the cohorts.

Despite these limitations, the findings of this study do suggest that stable ATR measurements, without radiographs, are a safe and cost effective alternative to serial radiographs in the clinical monitoring of AIS. Recent evidence from 25 years of scoliosis treatment in Denmark noted a cancer rate 17 times that of an age-matched population.¹⁵ Thus, reducing radiation exposure during scoliosis monitoring by using ATR measurements has important clinical significance for cancer risk reduction, and is a value driven treatment strategy in the monitoring of AIS curve progression.

Conflict of interest

None.

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