SOSORT AWARD NOMINEES GROUP ONE

PREDICTION OF FUTURE CURVE ANGLE USING PRIOR VISIT INFORMATION IN PREVIOUSLY UNTREATED IDIOPATHIC SCOLIOSIS: NATURAL HISTORY IN PATIENTS UNDER 26 YEARS OLD WITH PRIOR RADIOGRAPHS

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Introduction
Treatment selection for idiopathic scoliosis is informed by the risk of curve progression if untreated. Previous models predicting curve progression were limited by lack of validation, not including the full growth spectrum or including treated patients.

Research Question
The objective was to develop and validate a model to predict future curve angles using clinical and radiographic data collected prior to an initial specialist consultation in idiopathic scoliosis.

Methods
This is an analysis from all 2317 patients with juvenile, adolescent or adult idiopathic scoliosis between 6 and 25 years old who were previously untreated and presented with at least one prior radiograph in addition to the one captured when entered prospectively in the database (since 2003) at first consult. We excluded those previously treated using scoliosis-specific exercises, bracing or surgery. All radiographs were re-measured by evaluators blinded to the predicted outcome: the maximum Cobb angle on the last radiograph while untreated. Linear mixed-effect models with random effects (SAS procedure Mixed) and maximum likelihood estimate were used to examine the effect of age at the baseline visit, sex, maximum baseline Cobb angle, retrospective Max Cobb angle, time (from baseline to prediction), Risser, and curve type on Cobb angle outcome. Interactions of baseline angle with time, quadratic time, and cubic time; of time with sex and time with Risser were also tested. A variance components structure was used in the covariance matrix. The models accounting for repeated measures from the same patient were evaluated by the smallest Akaike and Bayesian Information Criterion.

Results
We included 2317 patients (83% were females) with 3255 total prior x-rays where 71% had 1, 21.1% had 2, 5.6% had 3, and 1.9% had 4 or more (with maximum 8). Mean age was 13.9±2.2yrs and 81% had AIS. Curve type was: 50% Double, 26% Thoracolumbar-Lumbar, 16% Thoracic, and 8% other. Cobb angle at first x-ray was 20±10o (0-80) vs 29±13o (6-122) at the specialist visit. Time between the first x-ray and the outcome clinic visit was 28±22mths. In the best model (Table 1), larger values of the following variables predicted larger future curves: Max Cobb Angle at baseline, Retrospective Max Cobb angle (on a previous x-ray), time to the target prediction (in half-years), and time cubed. Larger values on the following variables predicted a smaller future Max Cobb angle: Time squared, Baseline Risser, Baseline Age, Time*Risser interaction, and time*female sex interaction. Ten-fold cross-validation found a median error of 4.5o (worst interquartile range limits 1.8-8.9o, 54.9% within prediction interval, 84% within 10o of observed value). (Figure 2 and 3)

Conclusions
A novel internally validated model predicted future Cobb angle with good accuracy in non-treated idiopathic scoliosis over the full growth spectrum.

Discussion
The model can help clinicians predict how much curves would progress without treatment at future timepoints of their choice using six simple variables. Predictions can inform treatment prescription or show families why no treatment is recommended. The non-linear effects of time account for the rapid increase in curve angle at the beginning of growth and the slowed progression after maturity.

Disclosures (any Conflicts of Interest)
No relevant COI disclosures.

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Figure 1. Linear Mixed-Effects Model to Predict Maximum Curve Angle at a Future Time of Interest from the Baseline x-ray.

Variable	Coefficient estimate	95% CI for the estimate*		*p-value*
		Lower limit	Upper limit	
Intercept	3.50	1.26	5.75	0.002
Max Cobb angle at baseline (°)	0.10	0.03	0.16	0.003
Max Cobb angle at retrospective visit[a]	1.04	0.98	1.09	<0.0001
Time (in half-years)[b]	2.49	2.05	2.93	<0.0001
Time (in half-years)^2	-0.12	-0.17	-0.07	<0.0001
Time (in half-years)^3	0.002	0.0006	0.004	0.007
Risser grade at baseline	-1.13	-1.52	-0.74	<0.0001
Age at baseline (in years)	-0.25	-0.42	-0.08	0.004
*Time (in half-years) *Risser grade*	-0.29	-0.36	-0.22	<0.0001
*Time (in half-years) *sex (Female=1, Male= 0)*	-0.18	-0.32	-0.05	0.008

* 95% CI = 95% Confidence interval,
[a] The retrospective visit is a visit following baseline in a patient with multiple x-ray predating the specialist's consult.
[b] Time correspond to the time from the baseline x-ray in half-years to the predicted timepoint of interest as selected by the user of the model making the prediction.

Figure 2: Ten-fold Cross-validation Results in Subsets of 321 to 336 Participants where the Error is a Difference between the Predicted Value and the Observed Value.

Cross-validation round #	N	Mean Error (°)	Standard Deviation	Median	25th percentile	75th percentile	Minimum	Maximum
Round 1	321	5.83	6.24	4.23	2.15	7.52	0.02	56.19
Round 2	326	6.43	6.02	4.89	1.91	8.92	0.01	32.87
Round 3	336	5.80	4.95	4.45	2.14	8.13	0.07	29.76
Round 4	332	6.37	6.38	4.82	2.42	8.04	0.00	53.13
Round 5	323	6.10	6.08	4.36	2.31	7.74	0.02	49.06
Round 6	323	5.74	5.36	4.36	2.30	7.68	0.01	42.48
Round 7	323	6.20	5.61	4.85	2.23	8.49	0.04	40.27
Round 8	317	5.14	4.49	4.25	1.82	7.24	0.00	38.15
Round 9	327	5.69	5.14	4.35	1.96	8.47	0.00	44.26
Round 10	327	6.00	6.16	4.44	2.15	7.58	0.06	49.29
Average	-	**5.93**	-	**4.50**	-	-	-	-

Figure 3: Percentage of Predicted Observations within 10º of the True Observed Value.

Cross validation	Observed value falls within predicted value ± 10º	N	Percent
Round 1	No	46	14.3
	Yes	275	85.7
Round 2	No	63	19.3
	Yes	263	80.7
Round 3	No	53	15.8
	Yes	283	84.2
Round 4	No	58	17.5
	Yes	274	82.5
Round 5	No	53	16.4
	Yes	270	83.6
Round 6	No	43	13.3
	Yes	280	86.7
Round 7	No	62	19.2
	Yes	261	80.8
Round 8	No	37	11.7
	Yes	280	88.3
Round 9	No	51	15.6
	Yes	276	84.4
Round 10	No	53	16.2
	Yes	274	83.8
Average	No	-	**15.93**
	Yes	-	**84.07**