IN SILICO PATIENT-SPECIFIC OPTIMIZATION OF CORRECTION STRATEGIES FOR THORACIC ADOLESCENT IDIOPATHIC SCOLIOSIS

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Introduction

The surgical instrumentation of complex spinal deformities is challenging. Although the primary aim of surgery is to achieve optimal 3D correction, this can be achieved using strategies combining a variety of possible instrumentation constructs and surgical maneuvers [1]. Thus, there is wide variability in surgical techniques with number of screws (or implant densities, i.e. screws per vertebra), levels to fuse, rods curvatures/stiffnesses, and correction maneuvers, which also depends on which planes of deformity are prioritized [1,2]. *In silico* patient-specific models represent an ideal approach to optimize the surgical planning of complex spinal deformities.
The aim was to test a surgery planning approach intended to assist surgeons in the identification of the optimal instrumentation options.

Methods

A patient-specific biomechanical model of a typical thoracic scoliotic curve was built following a validated workflow [3]. MD Adams 2018 Multibody Dynamics Simulation Solution (MSC Software, Santa Ana, CA) was used. A semi-automatic algorithm allowed the investigation of clinically relevant instrumentation parameters according to a full-factorial design approach:

i) upper instrumented vertebrae (UIV): T3, T4, T5, T6;
ii) lower instrumented vertebra (LIV): L1, L2, L3;
iii) screw pattern: alternate, periapical dropout, convex alternate, convex periapical dropout, bilateral [1];
iv) differential *concave-convex rods curvature*: 30°-15°, 45°-15°, 60°-15°, 45°-30°, 60°-30°, 60°-45°;
v) rod stiffness (material/diameter): low (Ti/5.5mm), medium (CoCr/5.5), high (CoCr/6).

Concave rod rotation and *en bloc* derotation were simulated as primary correction maneuvers. Cobb, thoracic kyphosis and apical vertebral rotation quantified the 3D correction of the instrumented spine. Each of 1080 simulated instrumentation scenarios was rated using an established objective function [4]. 12 surgeon-dependent weight factors expressing the importance of 3D descriptors and mobility were considered, based on a published survey on correction objectives [5]. Cost function minimization (or maximization) allowed identifying the optimal (or worst) constructs.

Results

Multiple optimal (and worst) surgery plannings were found, depending on the selected correction objectives. All simulated optimal constructs presented a better average coronal and transverse plane correction compared to the worst cases, with kyphosis in the normal range (Table 1). Worst cases demonstrated higher variability, both in 3D correction predictors, number of screws, fused vertebrae and density (Table 1). All optimal constructs were low-density alternate screw patterns with a caudal LIV (L3), a more distal UIV (T6: 83% occurrence; T5: 17%), and high-stiffness differential-contoured rods (60°-15°: 83%; 45°-15°: 17%). Worst cases typically had shorter fusion levels (T6-L1: 75%) high-density constructs and also some longer (T3-L1: 17%; T3-L3: 8%) low-density ones.

	Pre-op.	Post-op.	
		Optimal	Worst cases
Cobb (°)	69.1	17.2±1.3	35.3±3.3
Thoracic kyphosis (°)	34.1	20.6±0.3	14.2±10.2
Apical vertebral rotation (°)	16.1	8.1±0.2	11.0±0.7
Number of screws	-	13.2±0.4	14.7±2.3
Fused vertebrae	-	10.2±0.4	8.9±1.7
Implant density	-	1.3±0.0	1.7±0.2

Table 1: Pre-op. and post-op. characteristics of optimal and worst simulated constructs among 12 tested surgeon-dependent correction objectives.

Discussion

Lower-density alternate constructs were found to be optimal in achieving 3D correction, while limiting mobility, for a single thoracic scoliosis. This extends previous findings [3] and supports the recent results of ongoing multicentered randomized clinical studies related to implant density [6]. Our results suggest that a couple of screws could be spared without affecting the overall 3D correction. The proposed *in silico* patient-specific approach represents a promising tool to optimize the surgery planning of complex spinal deformities while taking into account surgeon-dependent correction objectives. An optimal strategy may have a direct impact in reducing the high intraoperative costs in scoliosis surgery.

References

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