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

Luigi La Barbera (1,2), A. Noelle Larson (3), Carl-Eric Aubin (1,2)

1. Dept. of Mechanical Engineering, Polytechnique Montréal, Canada; 2. Research Center, CHU Sainte-Justine, Canada; 3. Dept. of Orthopedic Surgery, Mayo Clinic, Rochester, MN, USA

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-automated 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];
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 vertebra 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.

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

4. La Barbera et al, Spine, under revision since 2020/01/24.

Acknowledgements

Natural Sciences and Engineering Research Council of Canada-Medtronic Industrial Research Chair in Spine Biomechanics, Canada Research Chair in Orthopedic Engineering, Canada First Research Excellence Fund through Trans-MedTech Institute Postdoctoral Fellowship.