

Efficacy of computer-based simulation for the correction of kyphotic deformities

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Objectives: When designing the preoperative plan for an osteotomy, especially for the treatment of kyphotic deformity in patients with ankylosing spondylitis, computer simulations can be very effective and are much simpler than existing methods. We evaluated the feasibility of preoperative computer measurements for kyphosis correction in patients with ankylosing spondylitis.

Methods: The subjects of the study were 18 patients with ankylosing spondylitis accompanied by fixed kyphotic deformity and underwent pedicle subtraction osteotomy from October 2007 to August 2010. The average age of the patients was 36.5 years (30-53). The enrolled subjects were followed-up for an average of 27.0 months (14.9-48.7). The correction angle was measured through a computer simulation before pedicle subtraction osteotomy for every patient. Inability to maintain standing posture or face forward while standing were the main indications for operation.

Surgimap Spine® software (Nemaris Inc., New York, NY, USA) was used for computer simulations. The distances of thoracic kyphosis, lumbar lordosis, and the sagittal plane from the posterosuperior end plate of S1 were measured through long-cassette standing lateral spinal radiographs, and computer simulations were promoted by setting an appropriate angle at the lumbar spine. To select the segment for corrective osteotomy, simulations of osteotomies in three different vertebral bodies, including the upper and lower vertebral bodies of the apex of kyphosis, were conducted to compare the sagittal vertical axis (SVA) in each segment. The segment that realized the best correction of the SVA was selected for surgery. To determine the correction angle, osteotomies in the shapes of isosceles and right triangles at the selected segment were simulated. When conducting the isosceles triangle osteotomy simulation, the correction angle was the largest and the SVA were most improved; thus, isosceles triangle osteotomies were conducted. The segment and angle determined via computer simulations was used in the actual surgeries.

Long-cassette standing lateral spinal radiographs that were taken in the standing posture before and after surgery was used for the preoperative simulation, and the values of thoracic kyphosis, lumbar lordosis, and SVA before surgery as well as the computer-measured value before and after surgery were assessed. Each value was measured three times by three observers.

For clinical evaluation, the Short Form-36 (SF-36) and EuroQol-5 Dimension (EQ5D) were used to determine quality of life. The Bath Ankylosing Spondylitis Function Index (BASFI), which is composed of 10 questions for the evaluation of physical functions and degree of ordinary life limitation, and the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI), which is composed of 6 questions related to major symptoms, were used to evaluate disease states. Values before and after surgery were compared and analyzed.

Results: Of the 18 patients, osteotomies were conducted at L2 in 2 patients and at L3 in 16 patients. The thoracic kyphosis was corrected from an average of 32.4° (15-63) before the operation to an average of 31.9° (10-57) after surgery. The lumbar lordosis was significantly improved from an average of 11.5° (1-25) to an average of 26.9° (14-36) while the SVA was improved from an average of 125.7mm (69-206) to an average of 65.1mm (25-101) ($p=0.000$, $p=0.000$ respectively).

Regarding the respective intra-observer reproducibility of the thoracic kyphosis, lumbar lordosis, and SVA, the values of the intragroup correlation coefficients ranged from 0.98 to 1.00; indicating significant coincidence. Similar coincidence values (between 0.98 and 1.00) were found for inter-observer reliability.

When comparing the preoperative computer simulation to the post-surgery results, thoracic kyphosis showed similar coincidence with 32.4° (15-63) and 31.9° (10-57) on average and an intragroup correlation coefficient of 0.9. The lumbar lordosis was 25.1° (2-52) and 26.9° (14-36) on average with an intragroup correlation coefficient of 0.6. The SVA showed significant coincidence (59.9mm (3-145) and 65.2mm (25-101) respectively) with an intragroup correlation coefficient of 0.7.

The average Physical Component Summary (PCS) from SF-36 before the operation was 50 points (12-72) and the average Mental Component Summary (MCS) was 64 points (33-81). Meanwhile, the average PCS after the operation was 67 points (48-84) and the average MCS was 68 points (53-82), showing statistically significant increases ($p=0.000$, $p=0.005$ respectively). The EQ5D value showed a statistically significant improvement from an average of 5.27 points (4-7) before the operation to 7.23 points (5-12) after the operation ($p=0.000$). The average BASDAI and BASFI before the operation were 5.9 points (4-7) and 6.0 points (2-6), respectively, and 4.8 points (3-6) and 5.0 points (4-6) after the operation; nonetheless, these results were not statistically significant ($p=0.53$, $p=0.45$ respectively).

There were no signs of surgically related complications, such as paralysis, vessel injury, or CSF leakage in any of the patients.

Conclusions: Computer simulations improve preoperative planning for the treatment of complicated kyphoses and produce relatively accurate measurements. Thus, the use of simulations is considered to be effective for preoperative measurements and can reduce the incidence of complications such as over- and under-correction.

In conclusion, preoperative simulations are simpler and easier than previously suggested methods for selecting correction segments and angles in patients with kyphotic deformities due to ankylosing spondylitis. The values of sagittal plane indexes between radiographs taken before and after surgery were similar. Computer simulations facilitate preoperative planning when correcting complicated cases of kyphosis and accurately predict outcomes. Patients may achieve increased levels of postoperative satisfaction, as they can view postoperative posture changes before the actual operation.