The accuracy of pedicle screw placement in scoliosis surgery: comparison between intraoperative O-arm-based and computed tomography-based navigation

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Background: The use of pedicle screw instrumentation in scoliosis surgery has become more widespread over the last decade because several authors have reported advantages in using pedicle screws that enhance correction rates. In contrast to the comparative efficacy of pedicle screws in scoliosis, pedicle screw placement poses the potential risk of serious complications including injuries to nerve roots or the spinal cord, and to major vessels. Recently, some clinical studies have demonstrated that computed tomography (CT) -based navigation can improve the accuracy of pedicle screw placement in scoliotic surgery. However, the intervertebral anatomical relationships while the patient is prone during surgery may not match the preoperative CT data obtained while the patient is most often supine. Intervertebral motion may result in errors during surgery and prolonged surgical time because of the need for point or surface registration for each vertebra. The most recently developed O-arm-assisted spinal navigation system is the only technology that involves acquisition of high-resolution images and 3D data sets on the operating table and allows fully automatic registration. Presently, no reports of pedicle screw insertion in scoliotic surgery comparing the results of O-arm-based navigation versus conventional computed tomography (CT) -based navigation have been published to our knowledge. The purpose of the present study is to compare the accuracy of O-arm-based navigation versus CT-based navigation in scoliotic surgery.

Methods: Sixty-one consecutive scoliotic patients who underwent posterior corrective surgery from Jan 2010 to Aug 2011 were retrospectively reviewed. Overall, 222 pedicle screws were implanted in 29 patients using CT-based navigation from Jan 2010 to Oct 2010 (group C) and 416 screws were implanted in 32 patients using O-arm-based navigation from Nov 2010 to Aug 2011 (group O). Postoperative CT was performed to assess screw accuracy using the established Neo classification (Grade 0: no perforation, Grade 1: perforation <2 mm, Grade 2: perforation ³2 mm and <4 mm, Grade 3: perforation ³4 mm). The time to position one screw, including registration, was calculated.

Results: In group C, 188 (84.7%) of the 222 pedicle screw placements were categorized as Grade 0, 23 (10.4%) were Grade 1, 11 (5.0%) were Grade 2, and 0 were Grade 3. In group O, 351 (84.4%) of the 416 pedicle screw placements were categorized as Grade 0, 52 (12.5%) were Grade 1, 13 (3.1%) were Grade 2, and 0 were Grade 3. Statistical analysis showed no significant difference in the prevalence of Grade 2–3 perforations between groups C and O. The time required for the registration

procedure and insertion of one pedicle screw was 10.9±3.2 minutes in group C, but significantly decreased to 5.4±1.1 minutes in group O.

Discussion: O-arm based navigation has some benefits compared with CT-based navigation. The O-arm based navigation uses CT data from patients acquired in the operative position and obtains updated data when needed. Selecting data from a 3D model of the spine created by a computer system using preoperative CT is not necessary. Surgeons are not dependent on a preoperative CT where the patient position may vary from surgical position in the operating room. The image quality of the O-arm system is almost comparable to that of recent multidetector helical CT scans. These benefits can decrease potential navigation errors compared with CT-based navigation.

The perforation rates in reports of surgery that employed a navigation system were between 1.8% and 11.4%. In the present study, the rate was as low as 5.0% in the C group and 3.1% in the O group. The perforation rate in both of our groups was comparable to that in previous studies. The perforation rate in the O group was lower than that in the C group; however, the difference was not significant. Both CT-based and O-arm based navigations may reach the limit to increase placement accuracy for scoliotic pedicle screws. Furthermore, surgeons tend to insert small and thick concave pedicle screws in the apex in O groups, while they often use ultra-high molecular weight polyethylene tapes instead of concave pedicle screws in C groups. These concave pedicle screws were difficult to insert accurately in the O group, and therefore there was decreased accuracy in their placement in the O group patients.

O-arm based navigation does not require point-to-point surface matching, which increases the operative time in CT-based navigation. The O-arm navigation computer recognizes the optical tracker of both the O-arm and the reference frame that is attached to the patient's spine. Therefore the registration time using O-arm is decreased. In our study, the time required for the registration procedure and insertion of one pedicle screw was 10.9±3.2 minutes in group C, but significantly decreased to 5.4±1.1 minutes in group O. Because it is not necessary to preoperatively select reference points from 3-D models when using the O-arm, the burden for surgeons is decreased. The O-arm technique is less invasive for patients.

Conclusion: The use of O-arm-based navigation successfully reduced the time needed for computer-assisted surgery, demonstrating advantages in safety and accurate pedicle screw placement for scoliotic surgery.