Spine Deformity
www.spine-deformity.org

Spine Deformity 2 (2014) 270–275

Case Series

The Utility of 3-Dimensional-Navigation in the Surgical Treatment of Children With Idiopathic Scoliosis

Sergei Vissarionov, MD[a,b,†], Joshua E. Schroeder, MD[c,†], Sergey N. Novikov, MD, PhD[d], Dmitriy Kokyshin, MD[e], Sergei Belanchikov, MD[e], Leon Kaplan, MD[f,*]

[a]*Department of Science, Federal State Budgetary Institution Turner Research Institute of Infantile Orthopedics, Russian Ministry of Health and Social Development, St. Petersburg, Russia 196603*

[b]*Department of Pediatric Traumatology and Orthopedics, SEI FVE Saint-Petersburg Medical Academy of Postgraduate Education, 64-68 Parkovaya Street, Pushkin, St. Petersburg, Russia 196603*

[c]*Department of Spine Surgery, Hospital for Special Surgery, 535 East 70th st, New York, NY 10021 USA*

[d]*Department Radiation Oncology and Nuclear Medicine, N.N. Petrov Institute of Oncology, 68 Leningradskaya St, St Petersburg, Russia*

[e]*Department of Spinal Disorders and Neurosurgery, Federal State Budgetary Institution Turner Research Institute of Infantile Orthopedics, Russian Ministry of Health and Social Development, 64-68 Parkovaya Street, Pushkin, St. Petersburg, Russia 196603*

[f]*Spine Surgery Unit, Department of Orthopedic Surgery, Hadassah-Hebrew University Medical Center, POB 12000, Jerusalem 91120, Israel*

Received 4 September 2013; revised 7 March 2014; accepted 11 March 2014

Abstract

Study Design: Ambispective study of patients undergoing surgical correction of adolescent idiopathic scoliosis.
Objective: To evaluate the accuracy of screw placement using preoperative 3-dimensional (3D) computed tomography (CT)-based navigation with intraoperative fluoroscopic guidance compared with freehand placement.
Summary of Background Data: Pedicle screws placed in deformed vertebrae have a high malposition rate. The use of navigation-based systems has increased placement accuracy.
Methods: Intraoperative registration of patient anatomy to preoperative 3D-CT was performed using anatomic landmarks. When registration accuracy was high (mean square error, <1.0 mm), screw tracts were drilled under navigation guidance; when the error was >1.0 mm, re-registration was performed. The researchers documented times for registration, navigation, and screw placement, and the number of passes. Results were compared with outcomes in cases operated on with freehand screw placement.
Results: A total of 62 patients were included (54 females and 8 males; mean age was 15.1 years [range, 12–18 years]). Mean deformity was 67° (range, 52° to 80°). Mean follow-up was 35 months (range, 42–19 months). In the navigation group, 710 pedicle screws were placed. Mean times were 55 seconds for tracker placement, 94.5 seconds per vertebra for patient registration, 131.1 seconds for screw tract formation on the concave side of the deformity, and 129.5 seconds on the convex side. Average total procedure time was 3.5 hours (range, 2–7 hours). Mean overall registration accuracy was 0.7 mm. Pedicle integrity was breached in 1.6% trajectories. In the freehand group, 470 pedicle screws were placed. Average time for screw placement was 135.2 seconds ($p < .001$ vs. navigation). Pedicle integrity was breached in 5.1% of trajectories ($p < .0001$ vs. navigation). No patient developed neurological or other complications. There was no destabilization of the instrumented spine during short- or long-term follow-up.
Conclusions: Intraoperative optic fluoroscopic navigation based on anatomic landmark registration to preoperative 3D-CT spine images enables precise pedicle screw placement with only a minor increase in pedicle preparation time in patients with adolescent idiopathic scoliosis.

Keywords: Adolescent idiopathic scoliosis; Computer-assisted surgery; Navigation; Pedicle screw; Spine deformity

Introduction

Surgical correction of patients with adolescent idiopathic scoliosis (AIS) who have a deformity over 45° or a curvature that does not respond to bracing has become the standard of care in Western society [1]. Screw and hook instrumentation has replaced rod and wire fixation,

Author disclosures: SV (none); JES (none); SNN (none); DK (none); SB (none); LK (none).

*Corresponding author. Spine Surgery Unit, Department of Orthopedic Surgery, Hadassah-Hebrew University Medical Center, POB 12000, Jerusalem 91120, Israel. Tel.: +972-2-677-6342; fax: +972-2-64203074.
E-mail address: kapileon@netvision.net.il (L. Kaplan).

† Both authors contributed equally to the study.

2212-134X/$ - see front matter © 2014 Scoliosis Research Society.
http://dx.doi.org/10.1016/j.jspd.2014.03.004

allowing better correction, stabilization, and fixation of all 3 columns with lower failure rates. In addition, the use of screws has been shown to reduce the need for anterior approaches, even in extreme deformities [2]. However, this technique is challenging, especially screw placement in deformed vertebrae within the scoliotic curve, with over 10% of screws malpositioned in some reports [3]. Poor screw placement may lead to serious complications, including pedicle perforation, canal migration, and nerve root injury, which may prompt surgeons to use laminar and pedicle hooks as support elements for thoracic spine fixation [4,5].

Computer navigation and robotic systems are emerging techniques that can help to improve the accuracy of pedicle screw placement in children with AIS. Recent publications have shown that computer navigation assistance can increase the accuracy of pedicle screw placement by 1.7- to 3.0-fold [6,7]. Computer navigation may be based on 2-dimensional (2D) or 3-dimensional (3D) fluoroscopy, 3D computer tomography (CT) navigation with anatomical landmark registration, or intraoperative 3D-CT navigation [8]. Intraoperative 3D-CT navigation has been shown to be the most accurate, and may be considered a reference standard navigation technique for optimal accuracy of screw placement during a surgery [8,9]; however, high equipment cost, limited availability of intraoperative CT, the high risk of contamination within the surgical field, and increased patient exposure to ionizing radiation under multilevel registration have restricted its use.

In this study, the authors aimed to test the feasibility of preoperative 3D-CT–based navigation combined with intraoperative fluoroscopic guidance and confirmation in patients with AIS.

Materials and Methods

Pediatric patients aged 10–18 years with AIS who had failed conservative management (bracing), and who underwent corrective surgery from January, 2009 to February, 2012 for thoracolumbar scoliosis with all posterior pedicle screw constructs were included in the study. Patients were divided into 2 cohorts: those operated on using preoperative 3D-CT navigation with intraoperative fluoroscopic guidance for screw placement, and those who had surgery with screw placement using a freehand technique. Imaging and clinical files were reviewed. Patient presentation and demographic information, as well as details regarding the registration procedure and outcomes were recorded (time required for registration, number and location of vertebrae to be instrumented, number of registrations performed, time required for pedicle tract formation, and registration error as documented in the operating room by a dedicated researcher). Data were recorded using Microsoft Excel 2010 (Microsoft, Seattle, WA, USA). The researchers' institutional review board approved the study and waived the requirement for informed consent owing to the ambispective study design.

Surgeries performed with 3D navigation for screw placement

Patients undergoing surgery with 3D navigation had preoperative multislice computed tomography of the spine from T1 to S1. To achieve the closest possible approximation of the spine's position during surgery, patients were scanned in the prone position. Study parameters were 1.0-mm slice thickness and 512 × 512 pixel matrix for the field of view. For data processing, preoperative planning, and registration during surgery, CT data were exported to the computer navigation system with SpineMap 3D software (Stryker Corp., Portage MI, USA) (Fig. 1). During surgery, registration was performed in the thoracic spine performed using the spinous and transverse processes of referent vertebrae (Fig. 2). In the lumbar spine, reference points were the spinous process, the middle of the facet joint, and the spinous process. Preoperative planning was performed for all vertebrae that would be instrumented during surgery.

The patient was positioned for surgery, anesthesia was induced, and surgical exposure was obtained. The navigation system was then introduced. An infrared reader was placed over the patient's lower limbs. A tracker was attached to a spinous process 1 or 2 vertebrae caudal to the lowest level for pedicle screw placement (Fig. 3). Intraoperative fluoroscopic registration of the patient's anatomy to the preoperative CT

Fig. 1. The navigation station.