Comparison of Operative Time with Conventional Fluoroscopy Versus Spinal Neuronavigation in Instrumented Spinal Tumor Surgery

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■ OBJECTIVE: **Spinal neuronavigation improves accuracy of pedicle screw placement but may increase operative time, and its use in oncologic operations remains relatively unstudied. We compared the use of two-dimensional (2D) fluoroscopy and three-dimensional (3D) spinal neuronavigation relative to operative time in instrumented oncology procedures.**

■ METHODS: **Consecutive instrumented oncologic spinal operations for multiple myeloma or metastatic disease performed between 2012 and 2014 were retrospectively reviewed. Patients were placed in 2 groups based on the method used for pedicle screw placement: 2D fluoroscopy versus spinal neuronavigation with 3D imaging. These groups were compared by age, number of screws placed, number of laminectomy levels, operative time, estimated blood loss, length of hospital stay after surgery, and rate of reoperation as a result of screw misplacement.**

■ RESULTS: **Fourteen operations used 2D fluoroscopy and 25 used spinal neuronavigation. In the fluoroscopy and neuronavigation groups, respectively, patient ages were 64.71 ± 7.21 years and 63.24 ± 6.95 years ($P = 0.534$), number of screws was 8.07 ± 1.98 and 7.84 ± 1.34 ($P = 0.667$), laminectomy levels were 2.18 ± 1.25 and 1.60 ± 1.02 ($P = 0.126$), operative time was 200.79 ± 34.99 minutes and 193.48 ± 43.77 minutes ($P = 0.596$), estimated blood loss was 790.00 ± 769.61 mL and 389.80 ± 551.43 mL ($P = 0.068$), and length of stay after the operation was 7.64 ± 4.63 days and 6.40 ± 3.23 days ($P = 0.331$). One patient in the 2D fluoroscopy group and no patients in the spinal neuronavigation group required a reoperation for screw misplacement.**

■ CONCLUSIONS: **There was no significant difference in length of operative time when neuronavigation was compared with fluoroscopy for instrumented oncologic spinal surgery. There was a trend toward a decrease in estimated blood loss in the neuronavigation cases.**

INTRODUCTION

Spinal metastases occur in approximately 30% of patients with cancer.[1-3] Primary sites such as the breast and the prostate have even higher rates of spinal metastases.[4] Surgical management is an integral part of the care for patients with spinal metastatic disease.[5] Operative decompression before radiotherapy in patients with myelopathy results in improved ambulation, decreased need for opioids, and prolonged survival.[6] Further, instrumented spinal stabilization in patients with spinal metastatic disease results in improved neurologic outcomes, including a higher chance of recovery of ambulation after presentation with paraplegia.[7,8] Recent studies also support separation surgery followed by stereotactic radiosurgery for epidural decompression, stabilization, and disease control without requiring extensive vertebral body resection.[9,10]

Multiple myeloma accounts for 10% of all hematologic malignancies and frequently results in osteolytic bone disease, with the spine being the most commonly affected site.[11,12] Vertebral body destruction as part of the multiple myeloma disease process can lead to pain, spinal deformity, and neural element compression.[13]

Key words
- 2D fluoroscopy
- 3D neuronavigation
- Instrumentation
- Laminectomy
- Metastasis
- Oncology
- Spine surgery

Abbreviations and Acronyms
2D: Two-dimensional
3D: Three-dimensional
AP: Anteroposterior
CT: Computed tomography

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Surgical management of multiple myeloma-related vertebral column disease includes kyphoplasty for pathologic vertebral compression fractures, with resection and instrumentation recommended for cases of instability.[14-16]

Misplacement of pedicle screws during spinal stabilization surgery can result in an injury to an adjacent nerve root or the spinal cord itself, cerebrospinal fluid leak, and hemorrhage.[17-20] Freehand pedicle screw placement is based on anatomic landmarks and is subject to a learning curve; misplacement rates, as defined by perforation of the pedicle, vary with technique and have been reported as high as 55%.[17,18,21-23] Fluoroscopic guidance is a common surgical tool for the placement of spinal instrumentation. Intraoperative two-dimensional (2D) fluoroscopy, three-dimensional (3D) fluoroscopy, and computed tomography (CT)-based neuronavigation allow for greater accuracy than does conventional fluoroscopy.[21,24] The reported screw misplacement rates using spinal neuronavigation are lower than with freehand placement or use of traditional fluoroscopy.[17,18,21,22,25-30]

Both advantages and disadvantages have been reported for the use of spinal neuronavigation. Radiation exposure to the surgical team has been found to be decreased with 3D neuronavigation compared with traditional fluoroscopy.[17] Radiation exposure to the patient also is likely decreased, especially when guidance and confirmatory imaging are obtained intraoperatively, thereby eliminating preoperative and postoperative imaging. Still, some studies have found increased radiation exposure in patients with 3D navigation.[17,29,31-38] A major reason that surgeons have given for not implementing neuronavigation in spine surgery is concern regarding an increase in operative time.[39] Studies addressing this concern are mixed, because some centers report a longer operative time with 3D spinal navigation and others report an insignificant operative time difference.[37,40-42]

There is limited literature regarding the use of 3D neuronavigation in spinal tumor surgery, and there is no report on conventional fluoroscopy versus spinal neuronavigation operative time comparisons for this cohort of patients. Spinal oncology surgery is more likely to be performed in the thoracic spine with smaller pedicles and feature longer constructs incorporating more pedicle screws than do degenerative spinal operations. Thus, any spinal neuronavigation effect on operative time has the potential to be more pronounced in this surgical group. Because of the medical complexities and increased comorbidities of patients with metastatic disease to the spine,[43] any increase in operative time and thus anesthesia time could be detrimental. Further, increased operative time could result in increased blood loss during an oncologic procedure. The purpose of our study was to examine and compare operative time in a cohort of consecutive patients requiring laminectomy and posterior instrumentation for spinal column tumors (metastatic disease or multiple myeloma) before and after the integration of 3D-based spinal neuronavigation at our institution.

METHODS

This study was approved by our institutional review board. Consecutive spinal operations performed by a single neurosurgeon (A.J.F.) between 2012 and 2014 were retrospectively identified with data collected and managed using the REDCap system (Research Electronic Data Capture, licensed by Vanderbilt University Medical Center). Patients undergoing oncologic instrumented spinal surgery were included in the study. Patients were excluded if they had a primary diagnosis other than metastasis from a solid tumor or multiple myeloma. Patients undergoing reoperation and patients undergoing laminectomy without instrumentation placement were also excluded.

Data including age and sex, primary disease diagnosis, operative time, the number of pedicle screws placed, the number of laminectomy levels, estimated blood loss, and postoperative date of discharge were extracted from the database. Reoperation for instrumentation revision or replacement was evaluated. Operative time and estimated blood loss were documented by the anesthesiologist. Laminectomy number was defined as the sum of the total number of levels in which laminectomy was performed, with 1 representing a total laminectomy at a particular level and 0.5 representing a partial laminectomy at a particular level.

Two groups of operative techniques were evaluated: spinal instrumentation operations using 2D fluoroscopy and spinal instrumentation operations using spinal neuronavigation and 3D imaging. The 2D fluoroscopy technique used a standard C-arm for preoperative level localization to mark the incision, a draped C-arm for intraoperative level localization, and a draped C-arm to provide anteroposterior (AP) and lateral intraoperative radiographs for pedicle screw placement. In the AP projection, a pedicle entry point was identified, a pilot hole was drilled through the cortex, and live AP fluoroscopy was used to cannulate the pedicle with a gearshift. Once the medial portion of the pedicle was reached, the lateral fluoroscopic projection was used. Once this tract was created through the pedicle, a screw was then placed using live lateral fluoroscopic guidance. A draped C-arm was used to confirm satisfactory final instrumentation placement in both the AP and lateral projections. Any misplaced screws were removed and replaced, repeating the initial technique.

All spinal neuronavigation cases were performed with the O-Arm Surgical Imaging System (Medtronic, Minneapolis, Minnesota, USA). Spinal neuronavigation cases were consecutive cases performed after the incorporation of this technology into the surgeon's clinical practice. Once instituted, spinal neuronavigation was used for intraoperative imaging on all cases; thus, the spinal neuronavigation cases in this series occur later than the 2D fluoroscopy cases. Preoperative fluoroscopic images were obtained for level localization and to mark the incision in addition to intraoperative fluoroscopic images and a 3D image was acquired while the patient was draped for level localization. The 3D image was then downloaded onto the Stealth workstation (Medtronic) and used for intraoperative neuronavigation for pedicle screw placement. A navigated pointer was used to identify the pedicle entry point and a pilot hole was drilled through the cortex. A navigated probe was then used to cannulate the pedicle. Once this tract was created through the pedicle, a screw was placed. A repeat 3D image was obtained with the patient draped to confirm satisfactory final placement of the instrumentation. Any misplaced screws were removed and replaced using neuronavigation from the most recent 3D image. The 3D imaging was repeated to prove satisfactory placement of all instrumentation.