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Intraoperative Navigation Is Associated with Reduced Blood Loss During C1–C2 Posterior Cervical Fixation

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■ OBJECTIVE: **Traumatic injuries, degenerative/rheumatologic conditions, tumors, or infections of the upper cervical spine may in certain circumstances require surgical stabilization. C1 lateral mass screws (Harms technique) in combination with C2 instrumentation (pars, pedicle, translaminar screws) have become a mainstay of surgical treatment. The surgical anatomy of the C1 lateral mass can be challenging especially with the robust venous plexus that often causes significant bleeding with exposure of the C1–C2 articular complex. The purpose of this study was to examine whether the use of navigation reduced intraoperative blood loss during atlantoaxial fixation.**

■ METHODS: **We reviewed our institutional experience with atlantoaxial instrumentation with and without navigation from 2007 to 2016. We limited our cases to those requiring C1–C2 stabilization in traumatic and degenerative cases and not as part of more extensive surgical stabilizations. We identified 45 consecutive patients and compared intraoperative blood loss, need for transfusion, and time of procedure with and without the use of navigation.**

■ RESULTS: **There was a significant reduction in the amount of intraoperative blood loss in the navigated ($n = 20$) versus non-navigated cases ($n = 25$). In addition, although the navigated cases initially were longer, currently there is no significant difference in the length of the cases.**

■ CONCLUSIONS: **In our series, surgical navigation significantly reduced blood loss compared with non-navigated cases without increasing surgical time or risk of complication. Furthermore, navigation has the potential to reduce operative times due to a reduction in blood loss.**

INTRODUCTION

The Harms technique of placement of C1 lateral mass screws has become the mainstay method for upper cervical instrumentation. It has proven to be more versatile than the previously used transarticular screws, especially in combination with various methods to instrument C2, including pars, pedicle, and translaminar screws. The standard technique for C1 lateral mass instrumentation is to expose the lateral mass to allow direct anatomic visualization. This, often in combination with intraoperative fluoroscopy, is used to place the screws. Exposure of the lateral mass requires manipulation of the significant venous structures in this region and the C2 nerve root, which is either retracted or transected. Even with various techniques of electrocautery, procoagulant products, and mechanical compression, bleeding can be substantial and may cause significant prolongation of the cases. Significant blood loss and need for transfusion carries many risks, including infection and coagulopathy, especially in trauma patients and in elderly patients with other comorbidities.[1-4]

Recently, intraoperative imaging and navigation systems have been developed that assist surgeons in the correct placement of fixation hardware.[5-7] O-arm or C-arm intraoperative imaging combined with intraoperative navigation allows for visualization of the screw path so that it may be placed without injury to vital structures such as the spinal cord and vertebral arteries and at times with less need for exposure of the native anatomy. During posterior cervical fixation surgery, the cervical venous plexus may be disrupted with a resultant large amount of bleeding.[8] Typically,

Key words
- Blood loss
- Cervical fusion
- Intraoperative navigation

Abbreviations and Acronyms
EBL: Estimated blood loss

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surgeries that are performed with navigation require less exposure due to image guidance of hardware placement and therefore a diminished need for direct visualization. Furthermore, although additional time is needed for the intraoperative imaging, navigation may in fact reduce operative time as the result of quicker screw placement. The effect of intraoperative navigation on time or blood loss in the operating room has not been studied. In this study, we compared blood loss and operative time during cervical fixation with and without intraoperative navigation in a retrospective chart review to determine whether surgery with navigation is superior in either regard.

METHODS

Study Population

The Penn Medicine health system serves the greater Philadelphia area and includes Penn Presbyterian Medical Center, the Hospital of the University of Pennsylvania, and Pennsylvania Hospital. The electronic medical record was used to identify all patients who underwent C1–C2 posterior cervical fixation by Current Procedural Terminology code. The study population included both elective and emergent cases. No patients were excluded from the study.

Data Collection

With the patient population identified, patient charts were reviewed retrospectively with Epic, Medview, or Onbase. The study period included patients who underwent surgery between January 1, 2007, and April 12, 2016. Patient age, sex, diagnosis, procedure, use of intraoperative navigation, estimated blood loss (EBL), blood transfusion, and time from incision to skin closure were recorded for each case. Length of follow-up and complications also were recorded. This study (entitled "The Effect of Image Navigation on Intraoperative Blood Loss During Cervical Fusion Surgery") was approved by the University of Pennsylvania institutional review board.

Surgical Technique Navigated

The navigated surgical technique has the patient placed prone on a radiolucent Jackson table with the head fixed in a Mayfield skull clamp. The alignment is checked with cross table radiology and any reduction or realignment is performed at that time. The fiducial array is attached with an articulated arm to the Mayfield adapter oriented with the navigation detector at the head of the bed. The patient is prepped and draped in a standard fashion, and the sterile fiducial array is attached to the articulating arm through the drape. A standard exposure of the C1–C2 region is performed and the navigation scan is obtained (O-arm, StealthStation; Medtronic, Minneapolis, Minnesota, USA). The surgical instruments are registered (probe, drill guide, screwdriver). The high-speed drill also is registered with the Medtronic SureTrack system so it can be navigated. Hence, the navigation scan and subsequent navigation setup are done during the procedure time as defined previously (time of incision to time of closure).

The navigated probe is used to plan the trajectory for the C1 screws. Minimal retraction and electrocautery is used to expose the posterior/inferior portion of the C1 ring dorsal to the C1 lateral mass. The navigated high-speed drill is used to make a notch in the lamina to facilitate placement of subsequent instruments and is then positioned on the lateral mass itself. The navigation is used to verify the position and trajectory of the drill. The drill is advanced approximately 1–2 mm into the lateral mass to provide a starting point for the screw and to minimize the need for subsequent tapping. This trajectory is locked in place on the navigation system. The navigated drill guide is then used to plan screw trajectory and length using the previously saved trajectory as a starting point. The tract is drilled using the 2.4-mm bit, and a new trajectory is saved. A screw of appropriate length to allow clearance of the C1 lamina (fully threaded or with a smooth shaft portion) is then placed using the navigated screwdriver. All other instrumentation is placed, and an intraoperative scan is used to verify the placement. Bony arthrodesis of choice is then performed (lamina/lateral mass decortication with allograft/autograft or Sonntag/Gallie).[9]

Surgical Technique Non-Navigated

The patient is positioned prone and the head is fixed in a Mayfield skull clamp. The alignment is checked with cross table radiology, and any reduction or realignment is performed at that time. The standard technique for C1 lateral mass instrumentation is to expose the lateral mass to allow direct anatomic visualization. This, and sometimes in combination with intraoperative fluoroscopy, is used to place the screws. The C2 nerve root is either retracted or transected. Electrocautery, procoagulant products, and mechanical compression are used to control bleeding and the inferior arch of C1, the lateral mass of C1, and the C1–C2 facet joint are exposed. Using direct visualization and fluoroscopy, a starting hole is made in the lateral mass. Subsequently, the pilot hole is drilled under fluoroscopic guidance and verification of depth with a blunt probe. Subsequently, the screw can be placed under radiographic guidance. Additional hardware is then placed. The C1–C2 joint can be decorticated and bone graft or agents can be placed to promote arthrodesis. Other grafting techniques were surgeon specific and included Sonntag/Gallie and lamina/lateral mass fusion.

Statistical Analysis

Statistical significance was assessed by 2-tailed unpaired Student *t* tests with Welch correction or the Fisher exact test when appropriate. Linear regression was used to determine the effect of time on length of procedure and blood loss. Results were considered significant if $P < 0.05$. Averages are presented as mean $\pm$ standard error of the mean. Analysis was performed with GraphPad Prism software (GraphPad Software, La Jolla, California, USA).

RESULTS

Patient Characteristics

We identified 45 consecutive patients who underwent C1 lateral mass screws as part of high posterior cervical fixation between January 1, 2007, and April 12, 2016. Intraoperative navigation with Medtronic S7 StealthStation and O-arm surgical imaging was used for 20 of these cases (44%). A total of 25 of these patients (56%) underwent the procedure without the use of Medtronic StealthStation navigation. The patients in the 2 groups were similar with regard to age, sex, and indication for surgery (Tables 1 and 2).