Robotic Cervical Fixation and sEEG Depth Electrode Placement – Pushing the Boundaries

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INTRODUCTION

The ExcelsiusGPS (Globus Medical, Inc., Audubon, PA) robot received clearance from the United States Food and Drug Administration for clinical use in 2017 with the first in human use for lumbar spine instrumentation at Johns Hopkins Hospital the same year. The applications of the robot soon expanded with the first interbody cage placement in 2020 and first deep brain stimulation performed in 2021. A metanalysis by Kosmopoulos et al[1] found that of 37,337 pedicle screws implanted by freehand, 34,107 (91.3%) were found to be placed accurately. Furthermore, there was a higher rate of accuracy in the navigation group (95.2%) compared to without navigation (90.3%). Initial studies with the ExcelsiusGPS robot reported successful lumbar pedicle screw placement rate of 97.4% (339/348)[2] and 99% (555/562).[3] The ExcelsiusGPS robot has been shown to increase screw placement accuracy enabling utilization of longer screw length and diameters, reduce radiation exposure and surgical time.[4] While conventional uses of the robot in spine surgery are pedicle screw placement and sacroiliac fusion, newer navigated interbody placement software hopes to minimize spinal cord injury during interbody placement. Current use in cranial surgery include biopsy, deep brain stimulation, and stereoelectroencephalography (sEEG).

High cervical fixation involving C1 and C2 is a complex surgery with potentially severe complications including screw malposition causing damage to neural and/or vascular structures. In a study evaluating the accuracy of free-hand technique of C2 pars screw placement, 11% of screws were mispositioned using the cortical-breach grading system[5]. Among high cervical transarticular screws, the most common complication included screw misposition at 7% while vertebral artery injury occurred in about 3% of patients[6]. It was noted that anatomic constraints for this procedure involve alignment of C1 and C2 while inadequate reduction of C1 and C2 contributed to screw misposition. Due to these complications, higher accuracy is needed. Common complications of depth electrode placement for sEEG are hemorrhage related (eg: subdural hematoma, epidural hematoma or intracerebral hemorrhage) and hardware related complications such as malpositioning, electrode fracture, or electrode-recording malfunction[7]. Robotic navigation aims to reduce these events and increase accuracy. Here we report the first case series of high cervical fixation and sEEG depth electrode placement using the ExcelsiusGPS robot.

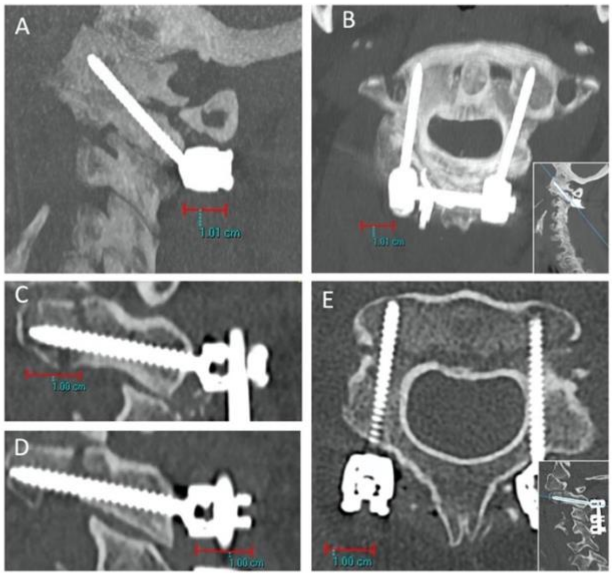

Fig 1. Sagittal (A) and axial (B) CT post-operative images showing excellent placement of C1-2 trans-articular screws attached by a horizontal rod. Sagittal (C and D) and axial (E) CT post-operative images of accurate screw placement in the C2 pars through the fracture line. One cm scale bar for reference.

MATERIALS AND METHODS

Patients who underwent robotic high cervical fixation and robotic sEEG depth electrode placement at a single tertiary care academic hospital were retrospectively reviewed for this study. The ExcelsiusGPS robotic system consists of a surgeon-controlled foot pedal attached to the robotic arm, a dynamic reference base (DRB; this is fixed onto the patient or attached to the Mayfield skull clamp), a surveillance marker attached close to the DRB and a camera that tracks movement. For cranial procedures, it includes an interchangeable end effector and a patient stabilization stand placed underneath the surgeon table. The DRB is fixed to the skull clamp for cranial procedures and may be fixed to either the spinous process or skull clamp for cervical cases. The preoperative computed tomography scan is then merged with intraoperative fluoroscopic scans to enable the robot to navigate the field.

RESULTS

Two patients underwent high cervical robotic fixation**.** Indications for surgery included right side occipital neuralgia secondary to C1-2 joint arthritis and traumatic hangman's fracture. Surgery consisted of robotic C1-2 transarticular screw (Figure 1A-B) for occipital neuralgia and robotic C2 pars screws (Figure 1C-E) with C2-4 fusion for hangman's fracture. Both cervical spine patients had uncomplicated postoperative courses and at last follow up were asymptomatic. Five patients underwent robotic sEEG depth electrode placement for intractable seizure (Figure 2A and B). Leads were placed in the temporal lobes with a median of 11 leads per patient. There were no complications with placement or removal of leads.

Fig 2. Surgeon guides the robotic arm (A and B) for sEEG depth electrode placement. ExcelsiusGPS robot (C. From left to right: Robot system with real-time display and robotic arm with end effector attached, patient stabilization device used in cranial procedures, camera system).

DISCUSSION

Here we report the first robotic high cervical fixation and sEEG depth electrode placement using the ExcelsiusGPS robot. All surgeries were performed successfully and there were no complications. Demonstrated benefits of robotic spine and cranial surgery are increased accuracy, decreased length of surgery and less invasiveness[8]. Limitations specific to this study include a small sample size and a single academic center. This study demonstrates the capability of the ExcelsiusGPS robot in both spine and cranial surgeries. Current ongoing research seeks to utilize preoperative magnetic resonance imaging instead of CT in order to further decrease radiation exposure. Future research is warranted to quantify the healthcare cost-savings and the learning curve for these complex robotic surgeries.

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