

TECHNICAL NOTE

Use of robot-guided stereotactic placement of intracerebral electrodes for investigation of focal epilepsy: initial experience in the UK

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Abstract

We describe the operative technique and our preliminary experience with use of the Renishaw neuromate[®] stereotactic robot to implant depth electrodes for investigation of focal epilepsy in the UK. Conventional electrocorticography involving a craniotomy and implantation of grids of electrodes directly onto the brain surface is invasive and carries a high risk of major complications such as acute subdural haematoma and infection. Robot-guided depth electrodes implantation for stereotactic electroencephalography is a less invasive technique that allows accurate implantation of multiple deep brain electrodes along predefined trajectories, and has not been associated with any major surgical complications in our initial experience.

Keywords: epilepsy; robot; stereotactic electroencephalography

We describe our preliminary experience and technique and its first reported use in the UK, utilising Renishaw neuromate[®] stereotactic robot to implant depth electrodes for investigation of focal epilepsy. Unlike the technique described in this paper, the use of this robot in the UK has been reported previously for functional neurosurgery, including for insertion of depth electrodes utilising a frameless ultrasound registration system.¹ Conventional electrocorticography (ECoG) involves a craniotomy and implantation of two dimensional grids of electrodes directly onto the brain surface. The procedure is invasive and carries a high risk of major complications such as acute subdural haematoma and infection.² Robot-guided stereotactic implantation of multiple deep brain electrodes for stereotactic electroencephalography (SEEG) is a less invasive technique and allows the creation of a three-dimensional grid of electrodes. As the procedure is considerably less risky, it has the potential to revolutionise the investigation of the focal epilepsy using depth electrodes.

Surgical technique

This technique involves the positioning of multiple electrodes in the brain through twist drill holes in the skin and

skull, executed accurately using the Renishaw neuromate[®] surgical robot.

The key to the success of this technique is the formulation of a detailed hypothesis regarding the potential origin and spread of seizures by the multidisciplinary epilepsy team. Gadolinium-enhanced MRI is used to determine the position of the surface vessels on the brain. Multiple trajectories are then planned on the robot software, and the exact length of the electrodes, the number of contacts and the thickness of bone to be drilled are determined. We use a safety margin of 4 mm between the planned cortical entry site and any nearby surface vessels. The Leksell stereotactic frame is used for the preoperative localisation. A reference CT data set is acquired in the frame, which is then fused to the preoperative MRI. Trajectories plans are then transferred to the reference data set.

The Leksell frame is then fixed to a standard frame holder attached to the robot. Care is taken to immobilise the operating table completely at this stage to avoid inadvertent movement between operating table and robot during the procedure. The robot software allows the calculation of a safety sphere around the patient's head that prevents the robot arm coming into direct contact with the patient. A dummy run is performed to determine the skin entry point for each electrode followed by shaving of the skin around each relevant point.

The robotic arm is now driven to each electrode position followed by puncturing of the skin with a sharp probe and use of a twist drill. The exact trajectory of the drill is controlled by a drill guide attached to the robot. The exact distance to the inner table of the bone is calculated and a 'stop' applied to the drill to prevent drilling of the dura and cortex itself, which is diathermied and punctured to a depth of 5 mm from the pial surface (Fig. 1).

The distance from the inner table to a point 5 mm from the skin surface is calculated in order to determine the length of the skull screw that is then used to fix the electrode in place. The screw with the appropriate length is then fixed in place.



Fig. 1. Twist drill of electrode trajectory guided according to a preoperative plan avoiding surface vessels on the brain, as defined on Gadolinium-enhanced MRI. A 'stop' on the drill prevents penetration beyond the inner table of the skull.

The exact length of each electrode from the fixation screw to the target is calculated and the stop on the electrode is moved to that length. A blunt-ended probe of the same length is then introduced to create the electrode track in the brain followed by insertion of the electrode, which is finally fixed to the screw. Electrodes, screws and associated instrumentation are all supplied by DIXI medical.

An immediate postoperative CT scan in the frame is then acquired to compare each actual electrode position in relation to the planned trajectories (Fig. 2). EEG trace from each electrode is acquired by the neurophysiology team followed by minor adjustments to each electrode position, if required. The Leksell frame is then disconnected from the robot and removed from the patient. The head dressing is applied and the patient is returned to the ward. Routine postoperative neurological observation is carried out overnight. Antiepileptic drug dosage reduction is started immediately and the EEG recording is instigated the next day.

Discussion

Of the 29 patients investigated with ECoG prior to the introduction of robot-assisted stereotactic placement of intracerebral electrodes for SEEG, seven had major complications including haematoma and infection (24%). Of the five patients undergoing the robotic procedure in our department since October 2011, there have been no surgical complications.

The mean operative time for robot-assisted placement of electrodes has been longer than for ECoG at 5.6 (5–6.3) versus 3.1 (1.7–4.5) h, respectively. This reflects the increased care needed to implement a new technique and the process of moving patients to the radiology department for preoperative scanning. Future plans to streamline the process include the use of the O arm and intraoperative CT.

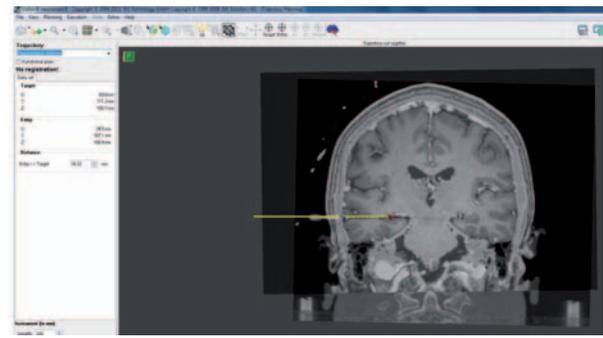


Fig. 2. Postoperative CT fused with the preoperative MRI demonstrating the accuracy of the implanted electrode in relation to the planned trajectory.

It was immediately apparent that the patients tolerated the robot-assisted implantation of electrodes better than ECoG in that they were more alert and complained of less headache in the early postoperative period. There was reduced alteration in the patients' regular seizure pattern with depth electrodes, as reflected in a lower required recording time at a mean total duration of 8.8 (6–12) days for SEEG in comparison with 10.6 (1–42) days for ECoG.

Our preliminary findings were consistent with the reported low morbidity associated with the robotic technique.³ In a retrospective analysis of 211 patients undergoing 215 stereotactic implantations of intracerebral electrodes, a total of 2666 electrodes were inserted with associated morbidity in 12 procedures (5.6%), with severe permanent deficits from intracerebral haemorrhage in 2 (1%) patients.³

As with other image guidance technologies, the main source for error lies in the application of the device rather than with the mechanical accuracy of the device itself. In an early case we encountered problems with frame application that produced minor inaccuracies in the entry points. Variations in bone thickness and the trajectory of bone drilling were other potential sources of error that we will continue to monitor.

Declaration of interest: The authors report no declarations of interest. The authors alone are responsible for the content and writing of the paper.

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