Robotic-Assisted Stereoelectroencephalography

Robotic-assisted stereoelectroencephalography (SEEG) is an advanced neurosurgical technique used to map and localize the regions of the brain responsible for epileptic seizures, often as a preparatory step for epilepsy surgery. SEEG involves the implantation of multiple electrodes into the brain to record electrical activity and pinpoint seizure origins with high precision. When robotic systems assist in this procedure, they improve accuracy, safety, and efficiency.

Key Features of Robotic-Assisted SEEG

High Precision in Electrode Placement:

Robotic systems allow for the extremely precise insertion of SEEG electrodes, which is crucial in targeting deep brain structures. These systems utilize preoperative imaging (CT, MRI) to create a stereotactic plan, ensuring that electrodes are placed with sub-millimeter accuracy.

Minimally Invasive:

The robotic approach enables minimally invasive electrode placement through small burr holes in the skull. This reduces the risk of infection, minimizes tissue damage, and promotes faster recovery. Reduction in Procedure Time:

Robots like ROSA (Robotized Stereotactic Assistant) and iSys1 significantly speed up the process by automating many of the manual steps involved in electrode placement. This decreases overall surgical time, leading to reduced anesthesia duration and less fatigue for the surgical team. Improved Safety and Consistency:

Robotic assistance reduces the potential for human error by automating the complex geometries of electrode trajectories. The system precisely follows pre-programmed paths, ensuring consistent and reproducible results across patients. Steps in Robotic-Assisted SEEG: Preoperative Imaging and Planning:

Before surgery, MRI or CT scans are used to map out the brain's anatomy. Surgeons use these images to plan where the electrodes need to be placed, based on suspected epileptogenic zones. Robotic System Setup:

The robotic arm is programmed based on the preoperative plan. It aligns with the patient's head in a fixed stereotactic frame or a frameless setup using fiducials or other navigation markers. Electrode Insertion:

The robot assists in drilling tiny holes in the skull (burr holes) and guides the precise insertion of depth electrodes into targeted brain regions. Postoperative Monitoring:

After electrode placement, brain activity is monitored to detect seizure origins. This monitoring can last for several days to weeks, during which time the electrodes remain in place. Benefits of Robotic-Assisted SEEG: Enhanced Precision: Robotic guidance ensures precise placement of electrodes in three-dimensional space, even in deep or difficult-to-reach regions of the brain. Less Invasive: The technique requires only minimal incisions, which decreases the patient's postoperative discomfort and recovery time. Faster Workflow: Robotics streamline the procedure, enabling the surgeon to insert multiple electrodes efficiently with a high degree of accuracy. Safety: By reducing human error and increasing accuracy, the risk of complications, such as bleeding or infection, is minimized. Common Robotic Systems Used: ROSA: This is one of the most commonly used robots for SEEG procedures. ROSA assists in positioning electrodes based on the surgeon's preoperative plan and can navigate complex trajectories to reach specific brain areas. Neuromate: Another robotic system that is often used for stereotactic procedures, including SEEG. Future Prospects: Integration with AI and Imaging: Future advancements may involve real-time imaging and AI-based analysis during SEEG to enhance the speed and precision of electrode placement, allowing for even better localization of epileptic foci. Autonomous Functions: While current systems are semi-autonomous, future systems might involve more autonomous decision-making, potentially simplifying the procedure for surgeons. Conclusion: Robotic-Assisted SEEG represents a major advancement in epilepsy treatment, offering superior precision, efficiency, and safety in electrode placement compared to traditional manual techniques. This technology is pivotal for patients with drug-resistant epilepsy, aiding in the accurate localization of seizure origins and improving the outcomes of epilepsy surgery.

Systematic reviews and meta-analysis

Robotic assistance in stereoelectroencephalography (SEEG) holds promising potential for enhancing accuracy, efficiency, and safety during electrode placement and surgical procedures. This systematic review and meta-analysis, following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and International Prospective Register of Systematic Reviews (PROSPERO) registration, delves into the latest advancements and implications of robotic systems in SEEG, while meticulously evaluating outcomes and safety measures. Among 855 patients suffering from medication-refractory epilepsy who underwent SEEG in 29 studies, averaging 24.6 years in age, the most prevalent robots employed were robotic surgical assistant (ROSA) (450 patients), Neuromate (207), Sinovation (140), and ISys1 (58). A total of 8,184 electrodes were successfully implanted, with an average operative time of 157.2 minutes per procedure and 15.1 minutes per electrode, resulting in an overall mean operative time of 157.7 minutes across all studies. Notably, the mean target point error (TPE) stood at 2.13 mm, the mean entry point error (EPE) at 1.48 mm, and postoperative complications occurred in 7.69% of robotically assisted (RA) SEEG cases (60), with 85% of these complications being asymptomatic. This comprehensive analysis underscores the safety and efficacy of RA-SEEG in patients with medication-refractory epilepsy, characterized by low complication rates, reduced operative time, and precise electrode placement, supporting its widespread adoption in clinical practice, with no discernible differences noted among the various robotic systems [1)]

1)

Vasconcellos FN, Almeida T, Müller Fiedler A, Fountain H, Santos Piedade G, Monaco BA, Jagid J, Cordeiro JG. Robotic-Assisted Stereoelectroencephalography: A Systematic Review and Meta-Analysis of Safety, Outcomes, and Precision in Refractory Epilepsy Patients. Cureus. 2023 Oct 25;15(10):e47675. doi: 10.7759/cureus.47675. PMID: 38021558; PMCID: PMC10672406.