Case story
H-3000-1295-02

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World leading epilepsy surgery centre in Milan uses the *neuromate*® Frameless Gen II stereotactic robot system for implantation of intracerebral electrodes

The neurosurgeons at the Claudio Munari Epilepsy and Parkinson Surgery Centre of the Niguarda Hospital in Milan, Italy, use the Renishaw neuromate* stereotactic system in SEEG procedures to define the epileptogenic zone, increasing accuracy and reducing surgery time, with a very low complication rate.

Dr. Francesco Cardinale is passionate about disseminating his robotic stereotactic technique, based on the classical Talairach methodology. "Surgery has long been considered a treatment of last resort after patients have unsuccessfully tested combinations of antiepileptic medications for many years. However, after two drugs have been determined to be ineffective or intolerable, the chance of a third drug being effective is lower than 5% [1]. Surgery has long been shown in randomized controlled clinical trials to be superior over medical therapy in clinical and psychosocial outcomes [2], not to mention the economic and social impact of a lifetime coping with severe impairment. Isn't it time that surgery became an early alternative, especially for young children who do not respond satisfactorily to one or two antiepileptic drugs?"

Epilepsy

Epilepsy is a disorder characterised by uncontrolled electric discharges within the brain that affects up to 1% of the population and is the second most common cause of mental health disability [2]. The disease often starts in childhood and is poorly controlled by medications in one third of patients [1]. In children for whom medical management fails to adequately control the disease, the disabling symptoms of the disease, the severe side effects of the medication and the social stigma create considerable challenges to leading independent and satisfying lives. Adults who have experienced a lifetime of severe impairment, even if they can be rendered free of seizures, are often unable to catch up on the lost psychosocial development. In addition, brains of young children are highly plastic so that functional areas violated by surgery often develop anew in another region of the brain [8]. For all these reasons epilepsy surgery should be considered as early as possible [3].

Dr. Cardinale using the *neuromate** during an SEEG procedure

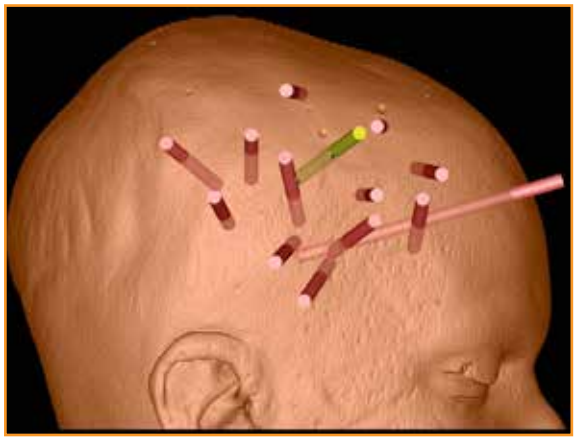
Non-invasive investigations

The five recording electrodes are first implanted on the contralateral side to where the disease was first diagnosed. They are placed in a '+' pattern, with the centre electrode following the planned trajectory, and the other four 2 mm away from the centre point. The outer sheath of each implant has a macro-electrode contact at its tip and within this is a sliding inner lead with a micro-electrode contact at the end.

Depth electrode implantations

In the remaining one third of the subjects, intracerebral recordings are necessary for the definition of the Epileptogenic Zone (EZ). Stereo-electroencephalography (SEEG) is a stereotactic procedure aimed at placing recording electrodes directly within brain structures, with a patient-tailored exploration strategy on the basis of non-invasive studies. Up to 20 electrodes are inserted deep within the brain, each bearing up to 18 electrical contacts all along its length, to provide electrophysiological recordings of unmatched spatial density and accuracy. A retrospective evaluation of 81 electrode implantation procedures made with the *neuromate** robotic stereotactic system demonstrated a median application accuracy of 0.78 mm [4].

Since the brain and especially the cortical surface are dense in blood vessels, image planning and precise implantation based on accurate visualization of the vessels is essential. The combination of the stable *neuromate** robotic platform, driven by the surgeon through advanced surgical planning software, makes for a much more efficient technique for the delivery of multiple depth electrodes [5].



Surgical planning software showing depth electrode target vectors

Low complication rates

Dr. Massimo Cossu, neurosurgeon, comments, “Out of a series of over 400 cases, with more than 5500 electrodes, we have two suspected cases of infection on MRI and the patients recovered. We have less than 1% rate of intracerebral haemorrhage and no occurrence of cerebral oedema. The total rate of complications is 5.4%, compared to a 20% complication rate in subdural electrodes [5, 6]”. Dr. Cardinale ascribes this very low bleeding rate to the careful planning tailored to each patient, based on high resolution neuroimaging, and the great geometrical accuracy of the *neuromate** robot. Dr. Cossu attributes the very low infection rate to the minimally invasive percutaneous approach.

The surgical procedure

The *neuromate** robot enables the precise and accurate positioning of the tool holder along a pre-planned trajectory, at a specified distance to the patient’s skull and cerebral target. The surgeon percutaneously drills down to a depth corresponding to the inner surface of the skull. A monopolar coagulator is used to coagulate the dura mater, thus opening the protective membrane surrounding the brain. The surgeon mounts a hollow screw into the drill hole through the robot guide, thus ensuring perfect alignment with the planned trajectory in a matter of seconds. The robot then moves into position for the next screw placement.

In the second phase of the surgery, the surgeon positions SEEG electrodes through the guiding screws. A rigid stylet is first inserted and retracted to create a track within the brain parenchyma. Then, the semi-rigid electrode is inserted (Microdeep Intracerebral Electrodes – D08®, Depth Electrodes Range 2069®). Various models of electrodes are available with a range of lengths and numbers of contacts. This entire process occurs under 2D X-ray control performed with the O-arm®. The video-SEEG monitoring takes about five to fifteen days. Ninety percent of the patients who undergo SEEG are subsequently referred to surgical treatment.

*neuromate** being used to accurately and rapidly position the drill guide

A recent procedure

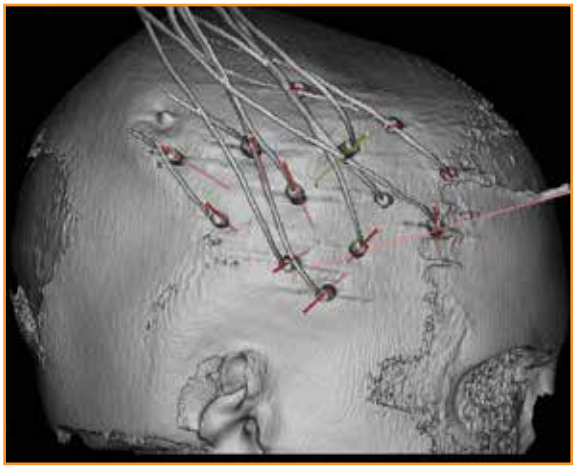
In a recent procedure on an eight-year-old child [9], by Dr. Cardinale and Dr. Cossu, non-invasive investigations revealed a small potentially epileptogenic lesion (a nodule of heterotopic gray matter) located above the right insular lobe. The interdisciplinary evaluation team scheduled an SEEG investigation in order to confirm the epileptogenic role of the lesion and the surrounding cortex, and to determine its relationship with high-risk structures such as the insular and primary motor cortex and the corticospinal tract.

The planning

Dr. Cardinale co-registered a combination of multiple imaging datasets. 3D rotational angiography provided bone and vessel structures at a high resolution, while different MRI modalities allowed the visualisation of parenchymal structures. The surgeon determined the surgical plan for inserting the electrodes, avoiding vessels. These imaging and planning steps were performed well in advance of the surgery, and the patient was undisturbed by any mounted stereotactic frame or fiducial markers.

On the day of the surgery, the patient, under general anaesthesia, had his head placed in the Talairach stereotactic frame, mounted on the base of the *neuromate** robot, and the O-arm® intraoperative imaging device was moved into position around the patient's head. The limited 3D field of view of the O-arm® does not allow the use of large 3D frame localisers, so that 2D localisers are used and the O-arm® acquires two orthogonal 2D projective images. For this purpose, four fiducial markers (Cranial Marker System®) were mounted to the skull and visualised on 2D and 3D scans, allowing co-registration of these 2D scans with the 3D planning datasets.

*neuromate** interfaced with the Medtronic O-arm® Imaging System



Electrodes in situ, as visualised by surgical planning software

Post-operative care

Following the stereotactic electrode implantation, the surgical team immediately performed post-operative controls within the operating room with an O-arm® 3D scan, co-registered to the preoperative MRI anatomical data to provide precise localisation information on each contact of the SEEG electrodes. The electrodes were then tested for proper functioning, allowing their immediate replacement in case of failure. SEEG traces confirmed the placement of each individual contact into gray matter, white matter or cerebrospinal fluid.

The next day, the patient was transferred into a video-EEG monitoring room, where he remained under constant observation for a period of nine days. Video and electrophysiological monitoring systems recorded several seizures, until a satisfactory assessment of the origin and spreading pattern of the seizures could be determined. The electrophysiologist also used electrical stimulations through the implanted electrodes to complete the definition of the EZ and to perform brain mapping.

SEEG as a treatment tool in well-selected cases

In some very selective cases, Dr. Cardinale has taken the opportunity to attempt a technique pioneered in Lyon [7]. In this case a suitable patient was identified and, before removing the electrodes, the surgical team performed a radiofrequency thermal lesion of the heterotopic nodule through the intralesional leads. The child, 28 months since the treatment, is still seizure-free.

Two subjects treated with this radiofrequency thermal lesioning technique are still seizure-free, after a long-term follow-up period. In both cases, the coagulated lesion is very small, with radiological diagnosis of nodular gray matter heterotopy. SEEG monitoring demonstrated an important role of the nodule as ictal onset zone.

Note that the data for these cases have not been published.

Treatment following SEEG monitoring

Patients not eligible for thermal lesioning, or in which seizures recur after the use of this method, undergo tailored microsurgical resections aimed at removal of the epileptogenic zone, under MRI-based neuronavigation [5].

NOTE: The *neuromate** stereotactic robot system is CE marked and cleared for sale in the USA.

Renishaw plc
New Mills, Wotton-under-Edge,
Gloucestershire, GL12 8JR
United Kingdom

T +44 (0)1453 524777
F +44 (0)1453 524901
E neuro@renishaw.com
www.renishaw.com/neuro

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