neuro | mate® - key features

About *neuromate®*

- The first certified image-guided neurosurgical robot to be used in the world
- Designed specifically for neurosurgery and can be used for neuro-endoscopy, stereoencephalography (SEEG), deep brain stimulation (DBS), biopsy and several other applications
- Estimated at over $30 million R&D investment to date[1]
- Renishaw is a world leader in precision engineering
- Installed systems in several countries worldwide

Surgical applications

- Stereotactic neurosurgery procedures
  - DBS
  - Biopsy
  - Implantation of depth electrodes for epilepsy monitoring (SEEG)
  - Motor cortex stimulation (MCS)
- Neuroendoscopy

And many other research applications

System benefits

- Complete procedure solution
  - Procedure specific modules / tools
  - Comprehensive surgical planning / navigation system
  - C-arm, O-arm & X-ray interfaces
  - 2D - 3D registration
  - Frameless & frame-based support (all standard frames)
- Time saving in multiple trajectories
- Compact, easy to transport and easy to clean
- Designed for quick parts replacement
- Quick to set up and operate
- On-board system diagnostics
- Customisable
  - Dimensions
  - Frame adaptors
  - Imaging modalities
  - Powered tool holders for standard or custom tools
- Strong international clinical support team

Safety features

- The *neuromate®* robot has been used for over 20 years in the clinical field for an estimated 10,000 procedures[2]
- Anti-collision system
- Constant accuracy checking with redundant encoders
- Safety line constantly monitoring the status of mechanical and electrical components
- Remote control with safety trigger
- Non-backdrivable joints with no backlash ensure immediate, stiff mechanical locking in case of error condition or power outage
- Full image guidance during planning and operation

As a replacement for the targeting arc of a stereotactic frame or for a tracking system, *neuromate®* offers the following safety benefits:

- Regular calibration ensures system remains within accuracy specifications
- Reduced risk of invisible mechanical damage or wear (compared to a stereotactic frame arc)
- No need for error-prone writing down or setting of target co-ordinates
- Stable mechanical attachment (compared to a stereotactic frame or clamping systems used with a navigation system)
- Stiff tool holding

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Planning and navigation software

(IVS Technology VoXim®/neuromate®)

General features

- Medical image analysis software
- Neurosurgical planning software
  - For stereotactic frame
  - For *neuromate*® system
- Neurosurgical execution and navigation software
  - For *neuromate*® system

DICOM import

- DICOM import
- Data import from DICOM files
- CT and MRI data supported
- CT gantry tilt supported

X-ray import

- Import of image files
- Direct scanner acquisition
- Co-registration
  - With localizer plates
  - With anatomical landmarks
- 2D / 3D / 3D fusion display supported

Patient database

- All data stored in the local file system
- Multiple independent databases can be defined
- Data can be archived, exported, imported, backed up to a CD, restored
- All actions are instantly and automatically saved

Analysis tools

- Zoom
- Move and turn
- Change gray scale
- Localize coordinates of points
- Measure 2D / 3D distances, angles, areas, volumes and bone density

3D reconstruction

- Support of segmentation thresholds
- 3D cut viewing modes

Segmentation

- Manually definable volume segmentations
- Customizable display of multiple segmentations across fused data sets
- Computation of segmentation volume

Co-registration and fusion

- Co-registration modalities:
  - Frame registration (using frame localizer)
  - Device coordinates (identical imaging device and patient position)
  - Automatic matching (mutual information algorithm)
  - Point matching (user-defined anatomical or fiducial point matching)
  - Scaling

Atlas co-registration

- Supported atlases:
  - Schaltenband-Wahren
  - Talairach-Tournoux atlas and connection map
- Co-registration modalities:
  - Talairach transform
  - User-defined point matching

Trajectory definition

- Can be defined anatomically or with statistical (AC/PC) coordinates
- Definition of AC/PC
- Definition of mid-plane: essential for targeting accuracy
  - Patient may be tilted or rotated
- Realignment of all views according to AC/PC line/mid-plane

Endoscopic trajectories

- Definition of safety volumes for endoscopic trajectories including tool insertion position
- Endoscope motion using remote control
- Full navigation capability with tool position display
- Modification of safety volume possible

Surgeon eye view

- Reconstructed planes parallel and perpendicular to the trajectory at various depths
- Dynamically updated view during execution (navigation capability)

Frame-based registration

- All standard frames
- 6 markers in at least 2 slices should be identifiable
- Automatic or manual marker identification supported
- Frame may be tilted

Printing a surgical plan

- Comprehensive multi-page surgical plan comprising surgical coordinates and frame coordinates
- Multiple frame configurations (e.g. reversed bow)

Frameless registration

- Marker search
- Robot control and frameless registration
- Definition of a safety region for robot arm motion

Verification trajectory

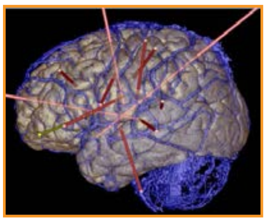
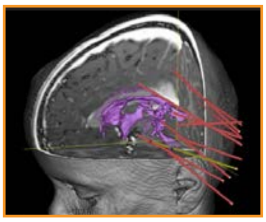
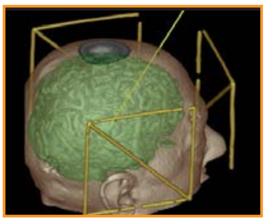
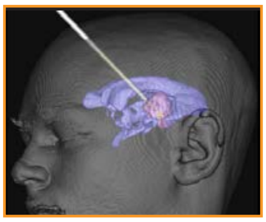
- Definition and execution of a trajectory pointing to a visible anatomic landmark, to verify the patient registration

Execution

- Full navigation capability with tool position display

References

[1] Renishaw internal data
[2] Renishaw field service data

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Excerpts from clinical literature – neuro | mate®

"The integration of a tailored computerized environment, CT and MRI imaging and the stereotactic robot developed by the neurosurgical and scientific teams in Grenoble has simplified many procedures for the benefit of the operated patients."
Devaux in Talairach (2007). Souvenirs des études stéréotaxiques du cerveau humain

"neuromate is a well-established robot in stereotactic functional neurosurgery. It provides a fast and easy way for trajectory modifications."
Benabid & Nowinski (2003). The Operating Room for the 21st Century

Frameless stereotaxy

"We have been able to demonstrate an application accuracy [of the neuromate in frameless mode] in phantom and clinical settings that is comparable to frame-based systems. A major advantage has been the ability to separate the imaging from the surgical procedure. Ample time is available for detailed image analysis and trajectory planning."
Varma & Eldridge (2006). Use of the neuromate stereotactic robot in a frameless mode for functional neurosurgery. MRCAS 2:2 107-13

"Robotic stereotactic neurosurgery is particularly appealing, as it enables neurosurgical procedures in excellent conditions, optionally freeing oneself from the stereotactic frame."
Blond et al. (2002). Clinical applications of stereotactic methodology. Ann Fr Anesth. 21:162-9

Stereotactic EEG

"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 [than conventional electrocorticography], it has the potential to revolutionise the investigation of the focal epilepsy using depth electrodes."
Abhinav K et al.(2013) Use of robot-guided stereotactic placement of intracerebral electrodes for investigation of focal epilepsy: initial experience in the UK. British Journal of Neurosurgery 27(5): 704–705

"SEEG is a safe and accurate methodology that is gaining popularity for invasive electroencephalography recordings aimed to identify the epileptogenic zone. The traditional Talairach methodology, recently updated by the use of the most advanced multimodal planning tools and robot-assisted surgery, allows one to directly record electric activity from every brain structure, providing valuable information in the most complex cases of refractory epilepsy."
Cardinale F et al.(2013) Stereoelectroencephalography: Surgical Methodology, Safety, and Stereotactic Application Accuracy in 500 Procedures. Neurosurgery 72(3) 353-366

Frame-based stereotaxy

"Each robot that is produced goes through a rigorous calibration process to ensure the highest accuracy possible. The robot arm can achieve a given prescribed target position with multiple arm orientations and tool orientations. The frame-based robotic system has the same level of application accuracy as the best standard localization system. [Standard] frame-based approaches are cumbersome to use and limited in terms of instruments."
Li et al. (2002). The application accuracy of the neuromate robot – A quantitative comparison with frameless and frame-based surgical localization systems. CAS 7:2 90-8

Deep brain stimulation

"The improvement was dramatic, postoperatively in the off medication condition, at five years. Most patients were independent in the activities of daily living […] whereas before surgery most had been fully dependent on a caregiver […] The cost of the hardware and all of the expenses related to the surgery, including hospitalization, is lower than the cost of medication, caregivers, accessories such as wheelchair, etc., during a period equivalent to the duration of life of the IPG."
Benabid et al. (2009) in Textbook of Stereotactic and Functional Neurosurgery

"37 out of 50 STN targets were satisfactorily identified using a single microelectrode trajectory and a mean of 1.6 trajectories were used. The final electrode position varied from the planned trajectory by a mean of 1.7 mm."
Varma et al. (2003). Use of the neuromate stereotactic robot in a frameless mode for movement disorder surgery. Stereotactic and functional neurosurgery 80:1-4 132-5

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Neuro-endoscopy

"Data from our series [of 33 patients with hypothalamic hamartoma] demonstrate that frameless stereotactic endoscopic disconnection should be considered as the treatment of choice in the presence of favorable anatomic conditions. A robot-guided endoscopic approach results, in almost all cases, in a seizure-free outcome or in a considerable seizure reduction—with an extremely low morbidity rate compared with conventional neurosurgical approaches."

Procaccini et al. (2006). Surgical management of hypothalamic hamartomas with epilepsy: the stereoendoscopic approach. Neurosurgery 59:4 Suppl 2 ONS336-44

Drug delivery

"Stereotactic endocavitary irradiation is a precise, focal, and noninvasive technique for the primary or adjuvant treatment of cystic craniopharyngiomas. It is a safe procedure, with a low rate of morbidity and a high (80%) rate of tumor control, and most often improves or preserves visual, cognitive, and endocrinological functions. Stereotactic methodology notably reduced the risk of leakage in the subarachnoid space or in the intraventricular system."

Derrey et al. (2008). Management of cystic cranio-pharyngiomas with stereotactic endocavitary irradiation using colloidal ^{186}Re: a retrospective study of 48 consecutive patients. Neurosurgery 63:6 1045-52

"Catheter placement in cystic craniopharyngioma allows intermittent drainage of the cyst and the placement of [chemotherapy drug] bleomycin. The neuromate stereotactic robot provides an accurate means of placing catheters into cysts. Advantages of neuromate include its stability, its excellent accuracy, and the ability to plan suitable tracks through the brain."

Golash et al. (2000). Robotic stereotactic placement of catheters into cystic craniopharyngiomas. Child's Nervous System 16 384

Radiosurgery

"Adjustable dose rates and steep dose gradients can be obtained. Radiosurgical tumour treatment can be executed immediately after the stereotactic biopsy without requiring radiation protection measures or dedicated facilities. The use of robotic systems to position, orientate and guide the system can guarantee a much higher level of accuracy than stereotactic headframe-based techniques."

Rossi et al. (2005). A telerobotic haptic system for minimally invasive stereotactic neurosurgery. MRCAS 1:2 64-75

Cell graft

"The development of a primordial structure of the nervous system after transplantation in human brain had never been observed. This study represents the first in vivo demonstration that a human striatal anlage, transplanted into the adult human brain, is able to progress in its development and to generate a new anatomical structure in the host."

Gallina et al. (2008). Development of human striatal anlagen after transplantation in a patient with Huntington's disease. Experimental neurology 213:1 241-4

"Our operative [technique], at best allowing to tailor the stereotactic procedure to the patient's anatomy, provided an optimization of the neurotransplantation technique in the devastating Huntington's disease."

Gallina et al. (2008). Human fetal striatal transplantation in Huntington's disease: a refinement of the stereotactic procedure. Stereotactic and functional neurosurgery 86:5 308-13

Biopsy

"The neuromate was used in the frameless mode. In 18 of 19 biopsies, diagnostic tissue was obtained. In one case the tissue obtained was not diagnostic but a postoperative scan confirmed that the biopsy had been obtained from the area of abnormality."

Varma & Eldridge (2006). Use of the neuromate stereotactic robot in a frameless mode for functional neurosurgery. MRCAS 2:2 107-13

"Robot-guided biopsy is an accurate procedure allowing easier transcerebellar approach than frame-based stereotactic biopsies."

Haegelen et al. (2006). Robotic stereotactic biopsies in the management of brain stem lesions: about a first series of 15 patients. Acta Neurochirurgica 148 XLIX

Transcranial magnetic stimulation

"Image-guided TMS, precisely orienting the electric field to be normal to the cortical surface at the targeted site, will be useful and may possibly be critical for applications anywhere in the cortex."

Fox et al. (2004). Column-based model of electric field excitation of cerebral cortex. Human brain mapping 22:1 1-14

"The overall accuracy in positioning the planned site of the TMS coil was approximately 2 mm. Robotic systems can provide exceptional aiming and holding capabilities for TMS coils."

Lancaster et al. (2004). Evaluation of an image-guided, robotically positioned transcranial magnetic stimulation system. Human brain mapping 22:4 329-40

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stereotactic robot

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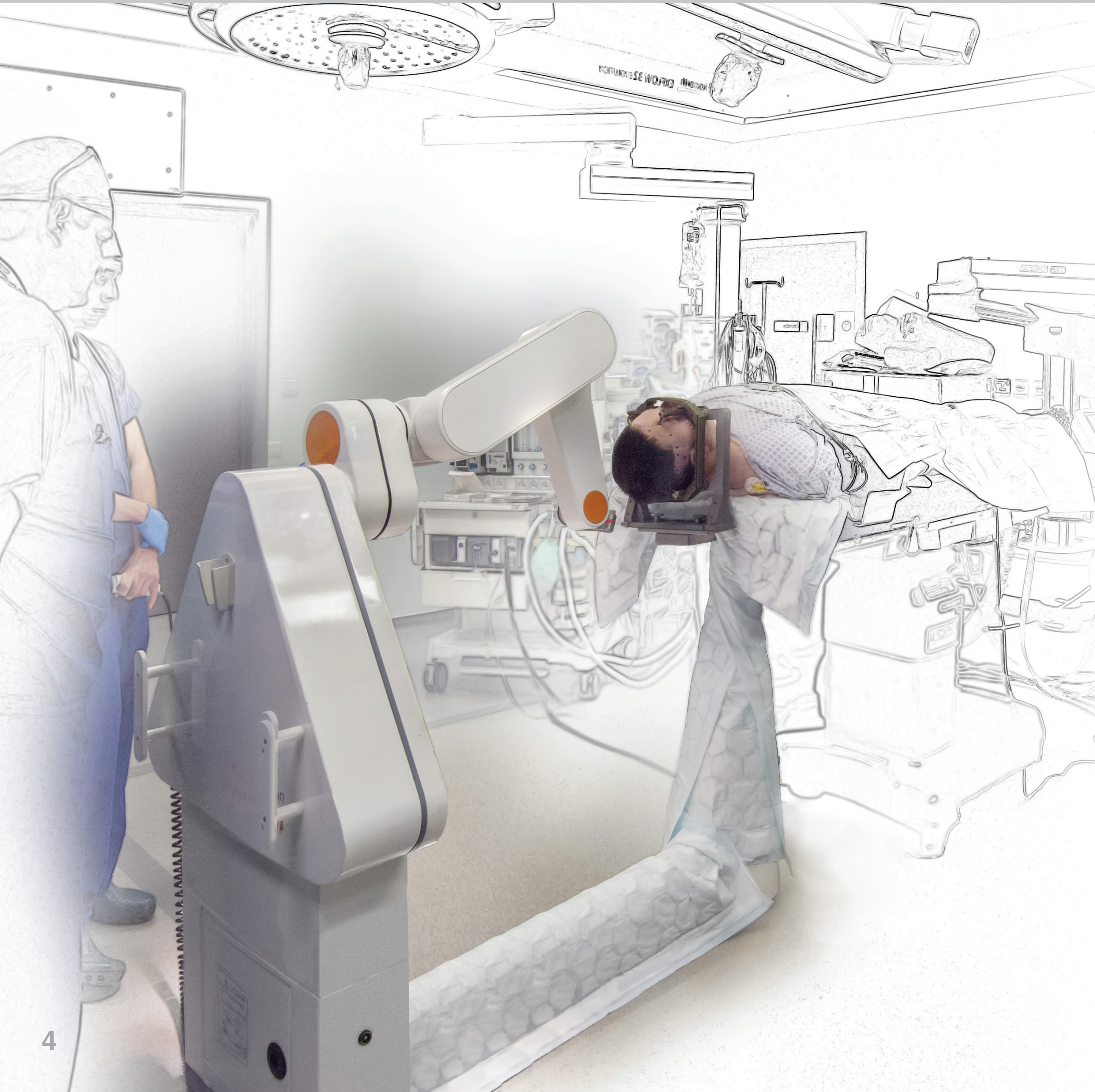

Precision in everything

The *neuromate®* stereotactic robot provides a consistent, accurate and repeatable platform for therapy delivery as well as diagnostic procedures. It is used in centres for applications such as deep brain stimulation (DBS), neuroendoscopy, stereoelectroencephalography (SEEG), biopsies and also many research applications.

Through the use of the *neuromate* robot we aim to enhance the safety and cost-effectiveness of procedures whilst improving patient outcome through accurate delivery of implantable devices.

The *neuromate* robot has both FDA clearance for sale in the USA and CE mark approval.

Adapting to your workflow

Before the installation of a *neuromate* system, our engineering team will evaluate your surgical workflows and, wherever possible, provide solutions to ensure optimal integration into your method of surgery.

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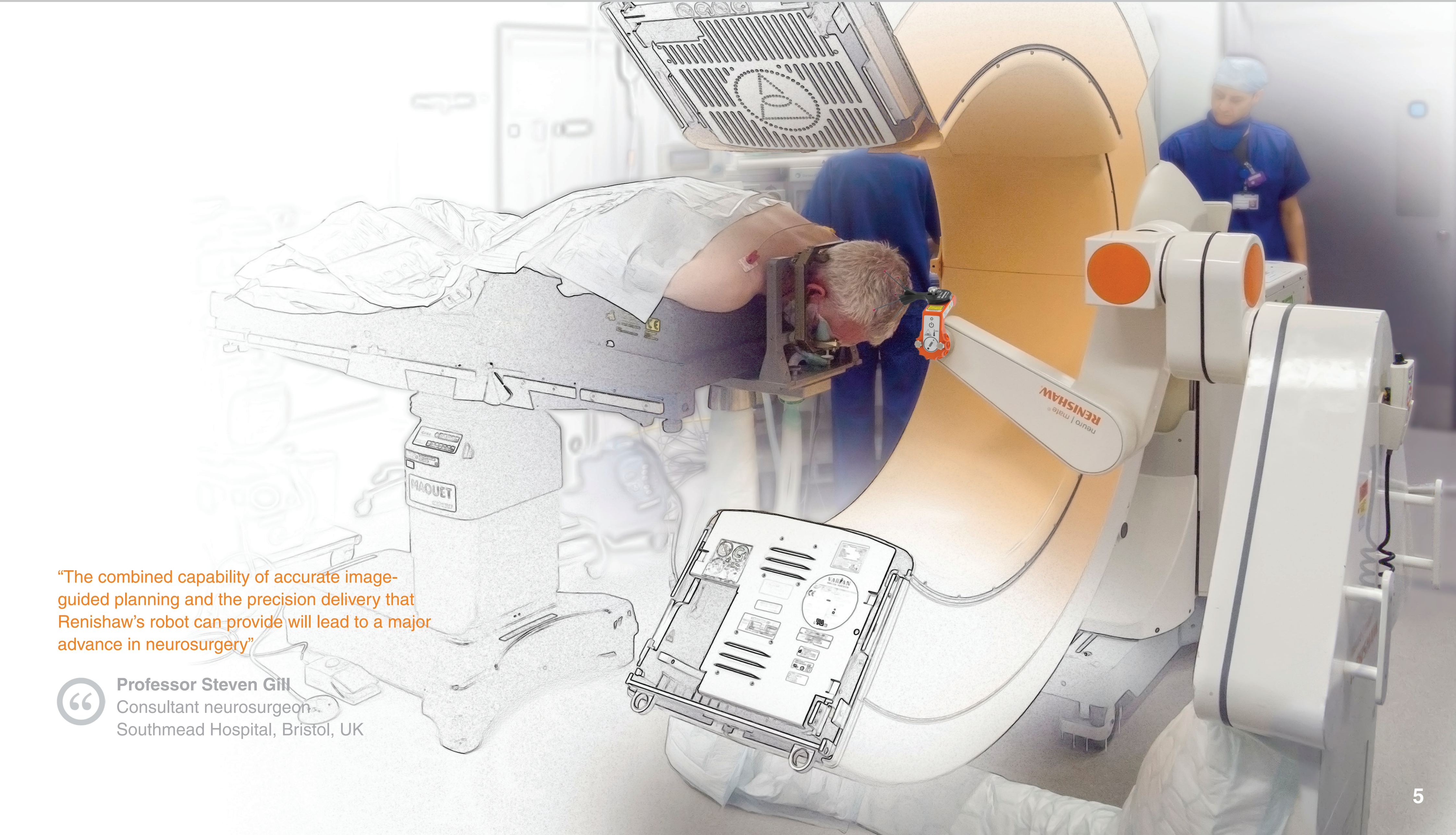

"The combined capability of accurate image-guided planning and the precision delivery that Renishaw's robot can provide will lead to a major advance in neurosurgery"

Professor Steven Gill
Consultant neurosurgeon
Southmead Hospital, Bristol, UK

System benefits

Optimises procedure times

In the case of SEEG procedures where multiple electrodes are placed, users have reported a significant reduction of the implantation procedure time.

Improved patient outcomes

Due to the potential for reduced procedure times, a robot assisted approach may offer a less stressful patient experience, a reduction in patient discomfort, as well as improving safety through a reduced risk of infection.

The robot is designed for minimally invasive surgery, inducing less trauma than open surgery.

Increases safety

A robotic surgical workflow reduces the need for manual manipulation (for example, manual setting of stereotactic frame coordinates). This can lead to a reduction of potential human errors.

Frame and frameless compatibility

The *neuromate* stereotactic robotic system has been designed to be compatible with both frame-based and frameless approaches to functional neurosurgery.

Utilising the frameless module enables a separation in time between the imaging and the surgical procedure, enabling more focus to be placed on optimising the surgical plan.

Used for both image guided and physiological procedures

The *neuromate* offers both precise image guided solution for the insertion of DBS electrodes, and a solution for microelectrode recording procedures.

Compatible with a range of imaging modalities

The *neuromate* system is compatible with a range of imaging modalities such as MR and CT for pre-, peri- and intra-operative imaging uses.

The planning software accepts tomography data that conforms to the DICOM standard, enabling the accurate planning and verification of your surgical procedures.

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Robotic workflow

Plan scan | Surgical planning | Procedure | Successful outcome

“After our first few frameless biopsy procedures with the *neuromate*, we quickly saw how it helps our workflow. The procedure is easier, allowing even difficult to reach targets to be accessed; it helps us speed up our workflow and save OR time, and last but not least, the frameless set-up improves patient comfort.”

Professor Philippe Paquis
Chief of the department of Neurosurgery
Centre Hospitalier Universitaire Pasteur, Nice, France

Applications: SEEG (stereoelectroencephalography)

Overview

Stereoelectoencephalography (SEEG) with depth electrodes allows the identification of epileptogenic zones for tailored resection surgery in patients with refractive epilepsy. During an SEEG procedure, clinicians typically insert a dozen monitoring electrodes to measure the brain's electrical activity involved during seizure.

The use of the *neuromate* greatly eases the surgical procedure for inserting these electrodes; as the burden of manually setting the coordinates of the trajectories with classical stereotactic frames approach, is removed.

neuromate in use in an SEEG procedure

Clinical literature

"SEEG is a safe and accurate methodology that is gaining popularity for invasive electroencephalography recordings aimed to identify the epileptogenic zone. The traditional Talairach methodology, recently updated by the use of the most advanced multimodal planning tools and robot-assisted surgery, allows one to directly record electric activity from every brain structure, providing valuable information in the most complex cases of refractory epilepsy."

Cardinale F et al.(2013) Stereoelectroencephalography: Surgical Methodology, Safety, and Stereotactic Application Accuracy in 500 Procedures. Neurosurgery 72(3) 353-366

"In SEEG we place up to 20 intracerebral electrodes in order to identify the epileptogenic zone and map eloquent structures. Thanks to the use of the *neuromate* system, every target can be reached with a combination of speed and sub-millimetric accuracy."

Dr. Francesco Cardinale
Neurosurgeon
Epilepsy and Parkinson Surgery Centre 'Claudio Munari',
Ospedale Niguarda Ca'Granda, Milan, Italy

Applications: DBS (deep brain stimulation)

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Overview

Deep brain stimulation (DBS) can provide remarkable therapeutic benefits for otherwise treatment-resistant movement disorders such as Parkinson's disease, essential tremor and dystonia.

It is a technique that relies on precise placement of electrodes, targeting structures deep within the brain. Reduction in the risk of human error combined with a very stable, rigid platform makes *neuromate* ideal for DBS lead delivery.

Clinical literature

"The in vivo application accuracy of the *neuromate* neurosurgical robot, measured with a system independent from the robot, in frame-based DBS procedures was better than 1 mm. This accuracy is at least similar to the accuracy of stereotactic frame arms and is compatible with the accuracy required in DBS procedures."

Daniel von Langsdorff et al (2014) In vivo measurement of the frame-based application accuracy of the Neuromate neurosurgical robot. Journal of Neuroscience October 31, 2014; DOI: 10.3171/2014.9.JNS14256

neuromate in use in a DBS procedure

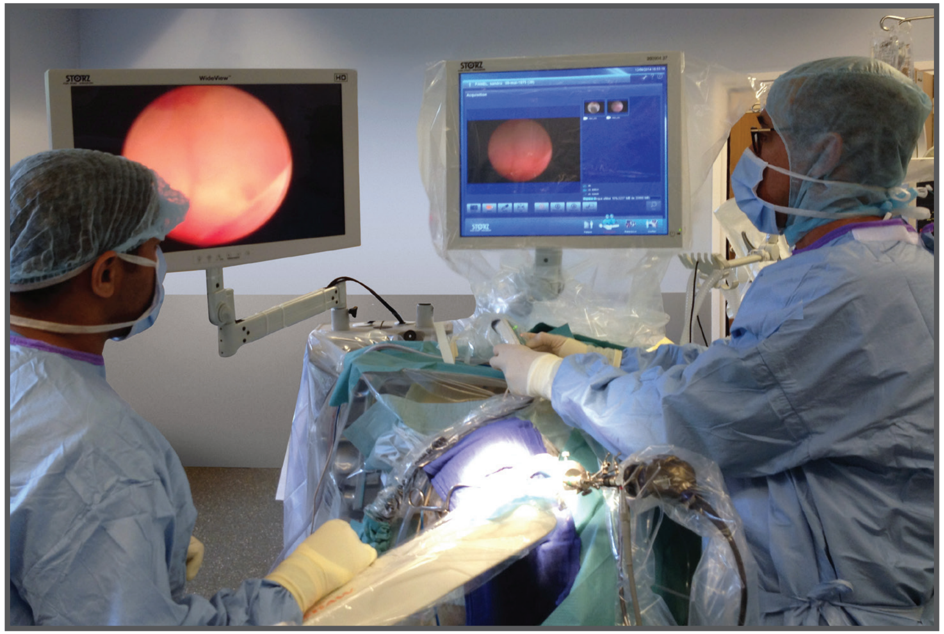
"Stereotactic procedures can be hampered by inaccurate positioning for many reasons, of which human error is only one. The robot reduces the degree of error by precisely positioning the tools to pre-programmed co-ordinates, with a high degree of accuracy and reproducability."

Professor Bertrand Devaux
Consultant neurosurgeon
Sainte-Anne Hospital, Paris, France

Overview

Progress in medical imaging and treatment modalities for brain tumours are driving a re-evaluation of the role of stereotactic biopsies. Their appeal derives from their reliability enabling a confident diagnostic, without clinical aggravation for delay in treatment. From this, a suitable, often multi-modal therapeutic approach can be developed.

The *neuromate* endoscopy module provides access to the ventricular system and deep brain structures. Image-guided planning with a user-defined safety corridor and accurate manoeuvring with a remote control, can enable a surgeon to perform accurate surgeries with potentially safer access and a firm instrument support.



neuromate in use iin a neuroendoscopy procedure

neuromate in use in a biopsy procedure

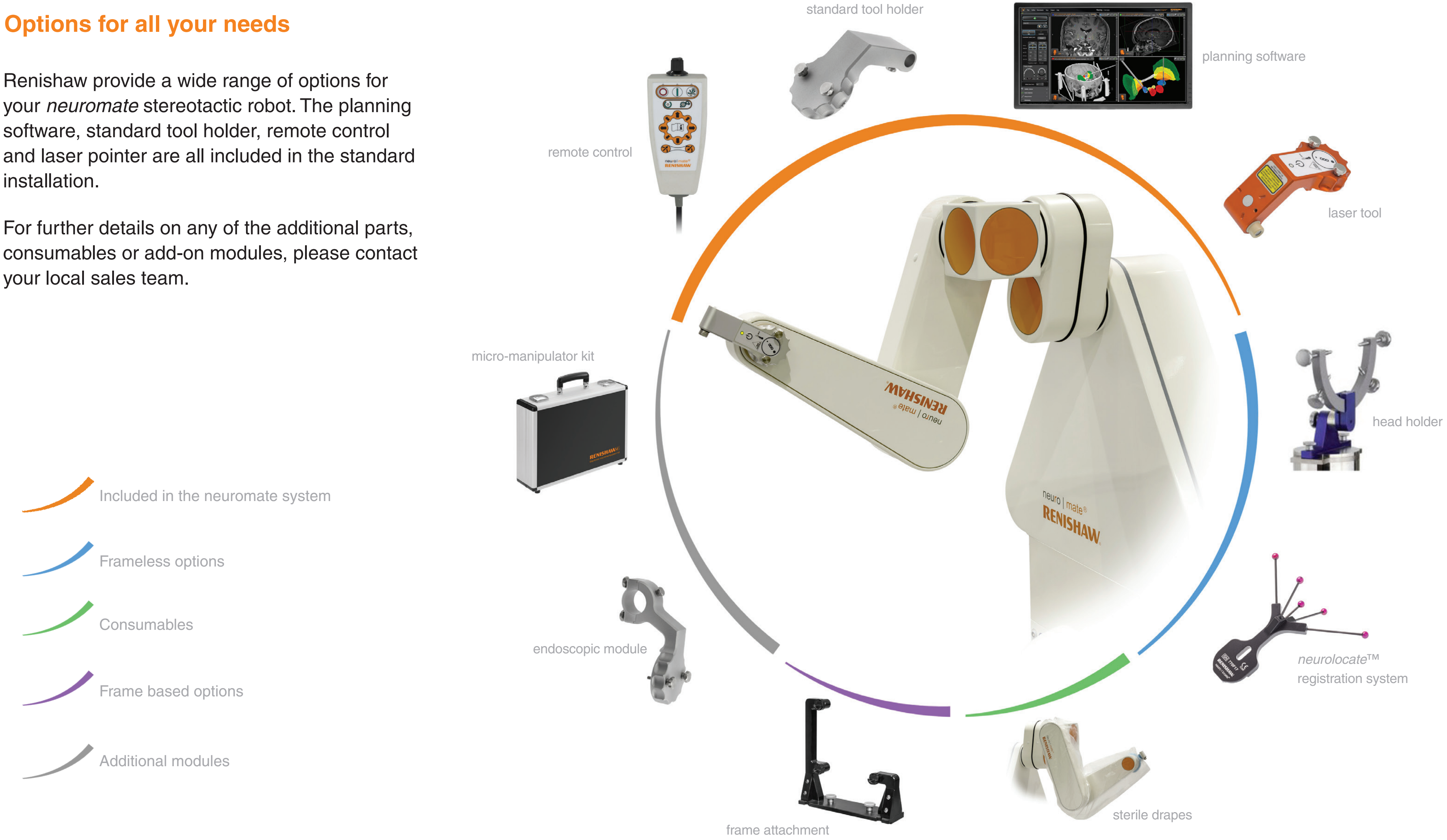
"Using the *neuromate* for endoscopic procedures provides us with multiple advantages in the execution of our surgical procedures. Most notably, as a result of the robotic navigation of the endoscope, we observed a significant reduction of the stress applied to the surrounding brain tissue compared with manual or mechanically supported procedures which my lead to better outcome."

Prof Philippe Decq
Chief of the Department of Neurosurgery
Hopital Beaujon, Clichy, France

Options for all your needs

Renishaw provide a wide range of options for your *neuromate* stereotactic robot. The planning software, standard tool holder, remote control and laser pointer are all included in the standard installation.

For further details on any of the additional parts, consumables or add-on modules, please contact your local sales team.



The value in robotic neurosurgery

Renishaw recognises that acquiring state-of-the-art technologies requires an investment for hospitals to undertake. That's why we offer flexible financing options that allow clinics to align the benefits that they realise against the costs of acquisition.

Our support is based on a bespoke approach that addresses the needs and concerns locally.

We will work with your management team to ensure that the business plan you need is robust, credible and quantifies your vision to continue to develop as a centre of excellence.

We are committed to work in partnership with you now and into future supporting your vision for robotic neurosurgery and improving patient outcomes.

Advancing medicine through innovative technologies

Our products

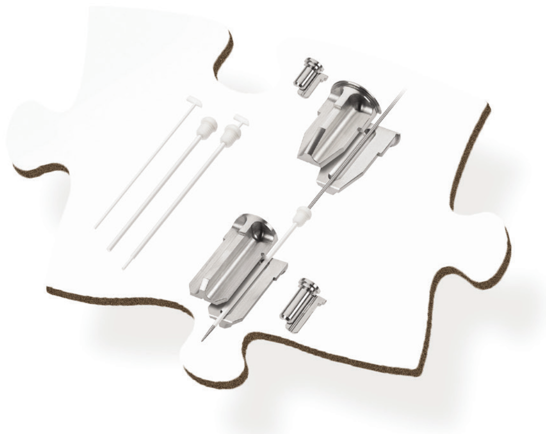
Renishaw is applying precision engineering technology to the challenges of functional neurosurgery. Our aim is to help leading clinicians to enhance the safety and cost-effectiveness of their procedures, improving patient outcomes through accurate delivery of implantable devices.

Service and support

Renishaw recognises that hospitals rely upon our products to keep their neurosurgical departments running smoothly. For this reason, we offer full service and support to our customers, ensuring that interruptions to service are kept to the absolute minimum.

neuro | inspire™ surgical planning software

neuro | guide™ DBS electrode delivery system



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Research

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