Robotic Assistance in Neurosurgery

Last updated: February 5, 2024

TABLE 3. Reported Ex Vivo and In Vivo End-Target Accuracies of Robotics Systems

System	Repeatability (mm)	Ex Vivo TE (mm)	In Vivo TE (mm)
PUMA	0.05-0.10[6]	1.0[47]	–
Minerva	0.10-0.15[10,52]	1.3[10]	–
Zeiss MKM	0.23 ± 0.14[53]	1.47 (0.28-2.14)[53]	3.3-4.5 FL[17]
NeuroMaster	±0.013[18]	1.3 (0.4-2.4)[18]	–
Neuromate	0.15[49]	0.86 ± 0.32 FB[49]	1.77 (1.25-2.51) FL[24,54]
		1.95 ± 0.44 FL[49]	
Pathfinder	0.31 (0-0.48)[19]	0.44-0.50[19,35]	–
SurgiScope	0.05[55]	0.23 ± 0.13[48]	1.6 ± 3.0 FL[31]
ROSA	0.10[36]	0.30[36]	0.81 ± 0.39 FB[39]
			1.22 ± 0.73 FL[39]
Renaissance	–	0.65 ± 0.32[51,56]	1.0-1.5 FL[44]
iSYS1	0.10[45]	0.6 (0.1-0.9)[45]	1.5 (0.3-6.7) FL[45,46]

FB: frame-based; FL: frameless.

ROSA™ (MEDTECH, MONTPELLIER, FRANCE)

ROSA™ = robotized surgical assistant

Most common approach by experts for SEEG!

Version for spine – ROSA Spine

IMAGING REQUIREMENTS

- there are no formal requirements on slice thickness (not recommended > 2.5 mm); if resolution is too high, software will downsample it.
- CT has to be "zero degree" gantry of else 3D will be reconstructed incorrectly.

SOFTWARE

Tutorial how to use "Zones" (brain segmentation) >>

HARDWARE

INSTRUMENT ADAPTORS

Available adaptors at UAMS

Material	Diameter	Length	Purpose
Drill adaptor	4.5 mm	82 mm	Monteris LITT bolt
Drill adaptor	3.2 mm	82 mm	
Drill adaptor	2.45 mm	82 mm	SEEG (PMT, Ad-Tech; also works for DIXI*)
PEEK adaptor	2.2 mm	38 mm	DBS
PEEK adaptor	2.1 mm	38 mm	RNS depth cannula (slotted, Ad-Tech), SEEG (PMT)
PEEK adaptor	1.8 mm	38 mm	Biopsy (Nashold biopsy needle), DBS cannula

There is the ability to custom make PEEK adaptors to the desired size, though this takes a bit of time.

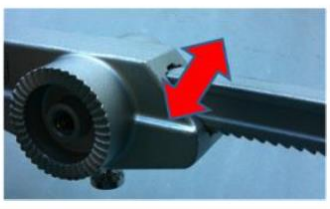
*DIXI drill for bolts is 2.45 mm diameter (vs. 2.4 mm for PMT, Ad-Tech) – ideally, needs 2.5 mm adaptor

PATIENT HEAD FIXATION

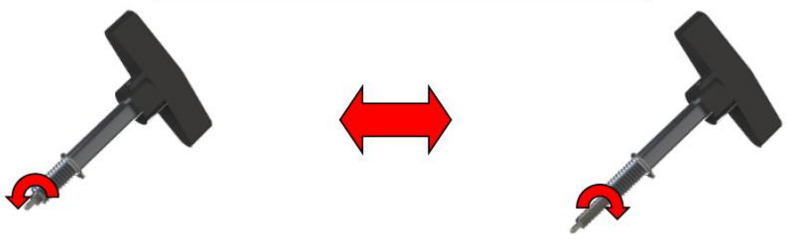
ROSA accuracy is the same at any (1-4) arm extension! (e.g. may use 3.5-4 for DBS to give ergonomic access to the top of the head).

Head can be fixed in:

A. **Mayfield frame** – gives wobble at two points; make sure to tighten extra bolt to avoid wobble:



Observed mechanical play

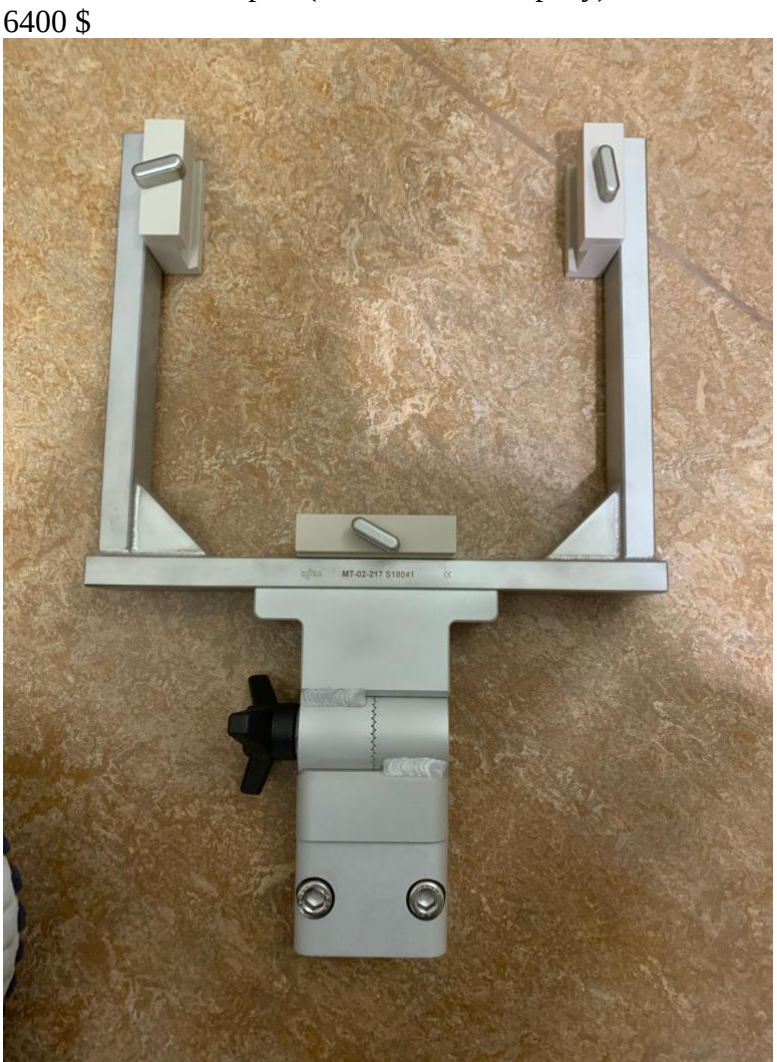


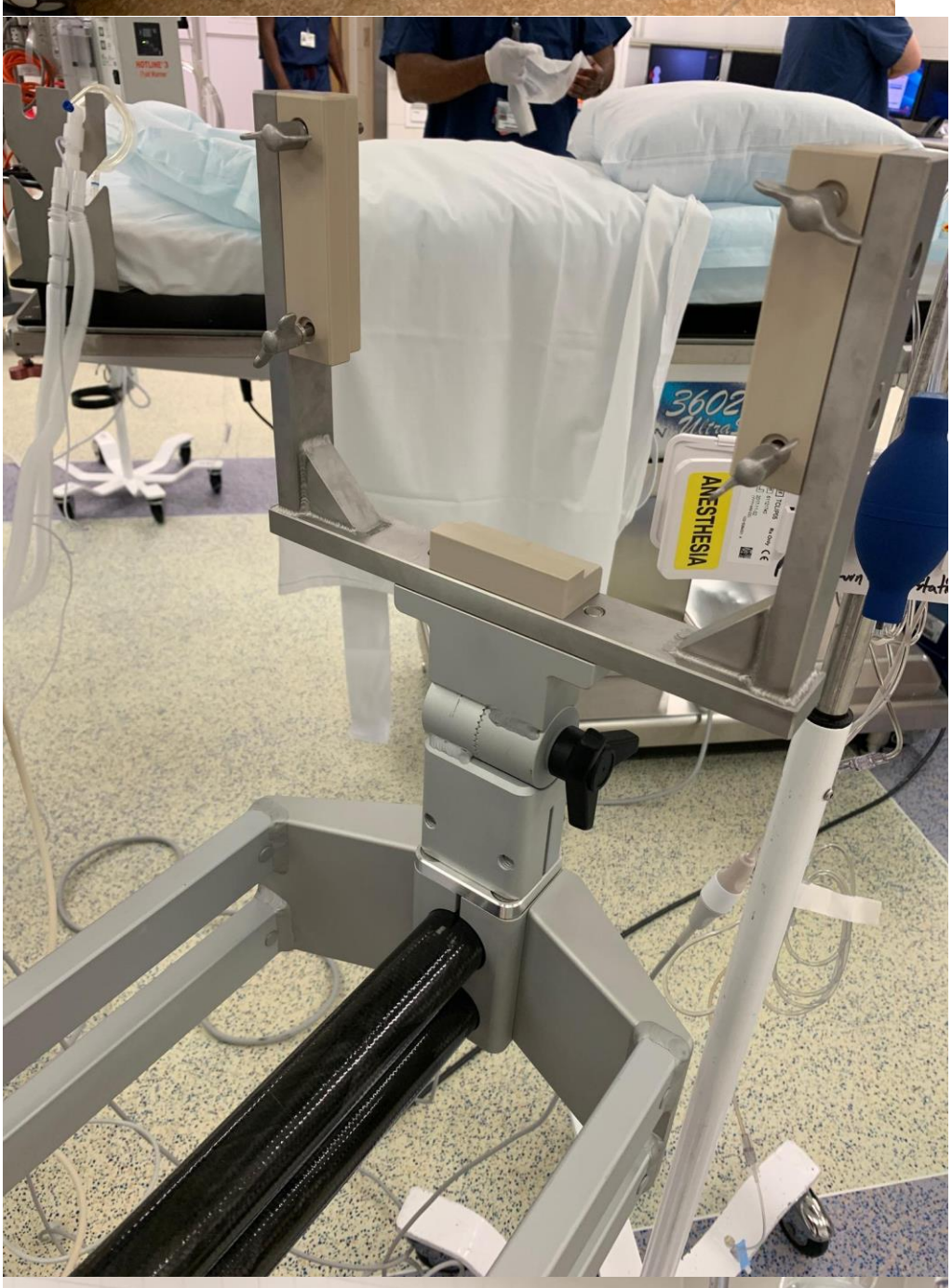
Adjustement of the head-holder screw

B. **Stereotactic frame base** (distance between left and right pins where they engage into skull – approx. 90 mm – check skull for a thin bone) then it can be attached to ROSA via same "starburst" adapter or frame adapter:

Best, most rigid fixation – frame base with frame adapter

Leksell Frame Adapter (from ROSA company)
6400 $




ANESTHESIA

INTRAOPERATIVE REGISTRATION

Laser facial scan – worst accuracy
Bone fiducial ("marker point") **manual registration** – need intraop CT (e.g. O-arm) – do it before attaching to robot (ROSA arm gives bad CT artefacts); some use radiolucent board to hold the head during O-arm scan (ask anesthesiologist to hold respiration during scan to avoid head motion artefcats).

Procedure for SEEG

PLANNING TRAJECTORIES

- load three images:
  1) CTA – use for reference image to merge all other images
  2) MRI T1w
  3) hybrid (MRI T1w + MEG)
- create custom contrast settings for CTA:
  1) vessels
  2) bone
  3) scalp soft tissue
- create trajectories with 6 mm diameter – mimics bolt cap diameter (easy to check for collisions on 3D window)
- create anatomical trajectory on MRI T1w + MEG; if near MEG cluster, then adjust trajectory to sample MEG (but check vascularity on T1w and CTA)

INTRAOPERATIVE

- general anesthesia.
- A-line is not needed.
- use VANCOMYCIN (and CEFTRIAXONE) for prophylaxis.
- may consider adding TXA.
- insist on head shave – saves from lots of trouble, can use ChloraPrep, postop will not need to be with bloody hair for 1-2 weeks in EMU.
- ***head in flat position*** (else the risk of bad pneumocephalus).
- head is secured into Mayfield or conventional frame* attached to ROSA; once head is secured, unplug OR bed from power source so no one accidentally does move it (→ C-spine injury).
  *frame gives 4-point stability and easy access to both temporal areas; Mayfield could be used in Mohawk configuration (two pins at occipital line, one pin in mid-forehead) – leaves nonsterile bar so each side has to be draped separately (not practical).
- registration using:
  a) **laser based facial skin** surface scanning (imaging has to have nose tip) has enough accuracy (approx. 2 mm) for SEEG needs.
  b) **bone fiducials** (3-5) → intraop CT for registration; if using frame, may purchase (50K USD) optional frame registration plates and software – also needs CT for registration.
  c) probably the best - **Leksell frame pin sockets** as fiducials (but need to use nonsterile registration [may also place fiducials nonsterile]; with O-arm, it is impossible to see all 4 pins unless using 40 cm FOV with newer O-arm)
  N.B. frame and bone fiducials have the highest registration accuracy!
- no Ioban is needed.
- regularly reprep the scalp to minimize risk of infection; also keep instruments between uses immersed in Betadine 10% bowl (rinse in saline right before use).
- desired trajectories are selected on the touch screen interface.
- arm movement is initiated through the use of a foot-pedal.
- robotic arm automatically locks the adapter as a working platform / instrument holder into a stable position once reaching calculated position for the selected trajectory.
  N.B. robot does not drive anything inside the skull (and most patients do not like idea of "robot doing surgery")
- move platform axially next to skin → inject local anesthetic (e.g. using long spinal needle through ROSA adapter) → using DIXI "bone starter" create puncture skin hole down to bone.
- get ready to drill twist hole; drill bit (e.g. 2.4 mm) on handheld power drill (Stryker) is introduced through ROSA adapter (e.g. 2.45 mm, 82 mm length).
  N.B. irrigate adapter lumen while drilling, then flush from bone dust (else SEEG bolt will get stuck inside) with Betadine and bacitracin solutions.
- practical advice how to avoid frequent drill stop adjustments: if bone+scalp thickness < 18 mm*, set drill depth stop to 10 cm for once (i.e. 100 mm minus 82 mm ROSA adaptor length = 18 mm for bone+scalp thickness); then move platform axially to distance to target = trajectory length** + 10 cm; then drill; if not through bone, advance platform (slow axial) by 1-2 mm deeper and drill again (safer and easier than adjusting drill depth stop each time); may avoid depth stop use at all if using a shorter drill bit (such as DIXI) – just set drill bit to 10 cm (and mark with permanent marker on drill bit shaft to additional visual control):

  *place all SEEG trajectories that are < 18 mm (so no need to adjust drill bit between trajectories); then move to thicker trajectories (e.g. for bone+scalp = 18-28 mm, set to 11 cm, etc)
  **trajectory length is target-to-inner table
- dura is opened with disposable insulated DIXI **dural perforator*** using monopolar cautery at low settings or with simple metal stylet (careful not to burn the skin).
  *mark 10 and 11 cm on it so will know when tip is touching dura and then goes beyond (same concept as for drill bit length)

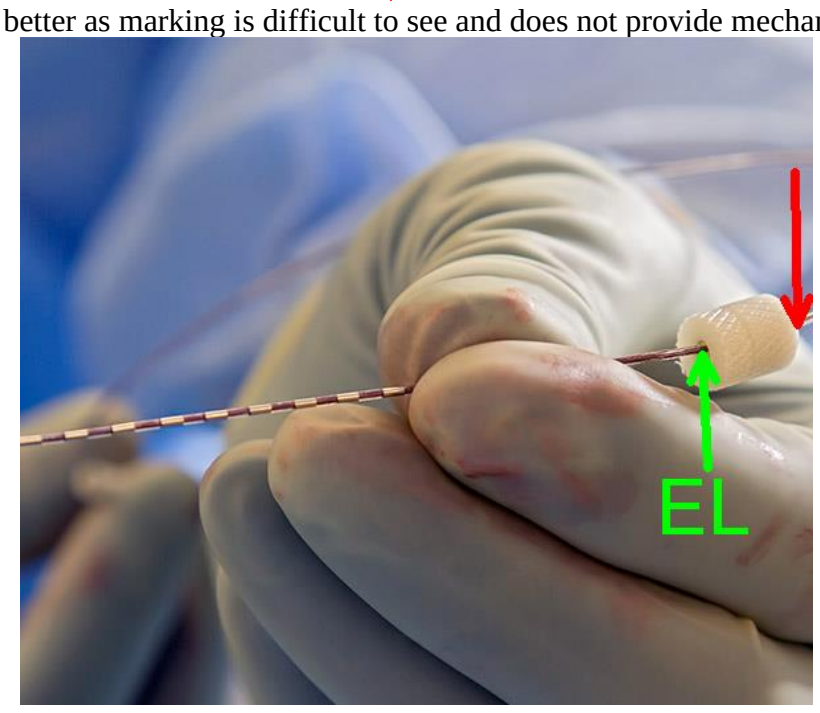
SEEG part

- guiding **titanium bolt** is screwed firmly into skull twist pinhole; skull thickness does not matter as bolt does not need to go full thickness of skull but needs to purchase at least 3 mm (ideally, 5 mm) of bone.
  N.B. for thin temporal squama bone plan trajectory entry to have at least 3 mm of bone (use different entries, go at the angle to skull – longer bone pass).

N.B. do not overtighten bolt – the tip will snap off (will get stuck inside screw driver tip; plus, plastic cap will not secure lead and there will be CSF leak).

- touch with the tip of ROSA adapter the top of bolt – ROSA calculates the distance **X** from the target to the top of adapter; then may subtract 82 mm (adapter length) from **X** = ***length*** from target to the top of bolt ← practically, don't need this (see below), i.e. only need to know is **X** for electrode length set up (see below).
- create brain path with **stylet**;
    a) set length of **stylet** distance **X** with slider on metal ruler; place stylet into ruler groove and adjust depth stop for stylet.
    b) more practical way – use reusable **Elekta Luer Connection Needle** 1020173 stylet – it has 217 mm length – can go through adapter! (vs. short PMT stylet) – so path is created using bolt+adapter guidance – longer and more accurate than just bolt guidance; move ROSA axially to "distance to target 217 mm" and insert very gently and slowly the Elekta stylet (rotating between fingers while inserting - tip displaces blood vessels):

    c) same as method b) just using **DIXI stylet** (advantage – it is a disposable stylet so comes fresh and not bent vs. Elekta needle stylet can get bent during many cycles of cleaning and sterilization in the tray) - move ROSA axially to "distance to target [stylet length] mm"
    - do not pull stylet out until ready to place electrode.
- determine ***electrode length*** **(**EL**)***: subtract 5 mm from the tip of bolt to *accommodate cap threads*, i.e. subtract 87 mm from **X**; practically, EL = **X** + 13 - 100
    *that is distance at cap bottom (easy with ruler – just lay electrode into groove and slide cap to the end of ruler); mark lead (↓) at cap top with permanent marker or Steri-Strip (even better as marking is difficult to see and does not provide mechanical stop):



- electrode is secured in place by a plastic cap.
    PMT, DIXI – plastic cap comes already mounted on electrode: screw half-way, pull* stylet out (for PMT; for DIXI – stylet is nonremovable), final tighten cap.
    Ad-Tech – metal cap is barely screwed on the bolt, lead is inserted, pull* stylet out, final tighten, slide plastic cap over:
        *electrode has tendency to back out during stylet removal, but this may be minimized with practice.

The depth electrode shaft is wrapped in the threading of the head of the anchor bolt (arrow). A second anchor bolt (and depth electrode) has been capped with liquid Silastic and a Silastic cap (Ad-Tech):

- test each electrode immediately after insertion (much more efficient than test them at the end) – thus, have sterile cables of each size (8, 10, 12, 14, 16 contacts) available on sterile field.
- before placing the next electrode, reprep the scalp area with chlorhexidine / Betadine.
- after all electrodes are placed, each bolt is wrapped with Xeroform gauze (maybe soaked with Betadine).
- take all electrode tails together (may separate left and right sides), make pigtail and suture to scalp, then may place Tegaderm on top.
- insert needle grounding electrodes to forehead (staple to scalp); attention – those are incompatible with MRI.
- place bulky gauze over bolts.
- wrap whole head into Kerlix (don't do too tight – patient discomfort, especially over ears), put stockinette over (cut the top off so cable can come out).

PROCEDURE FOR DBS

<u>If using microdrive, need:</u>

1. ROSA DBS MICRODRIVE HOLDER ($8000)

Catalog Number: ROSAS00344
DEVICE: ALPHA OMEGA MICRODRIVE HOLDER FOR CRW ADAPTOR (03760244031365)
or
Catalog Number: ROSAS00497
DEVICE: MCRDRV Ø25.4 HLD (03760244032096)

ROSA Part #: ROSAS00344
ROSA DBS Microdrive Holder

2. CRW frame non-X/Y adapter

Non-X/Y frame adapter		Autoclave

Photo of different adapters
top right - **non-XY CRW adapter**.
bottom right - **non-XY Leksell adapter** - ROSA does not have an adapter that can hold it!
left - **XY frame** adapter (either Leksell or CRW) - allows adjustments to the bengun in the X and Y direction without the need to adjust the frame at all.

ALPHA OMEGA

Cannulas – see p. Op360 >>

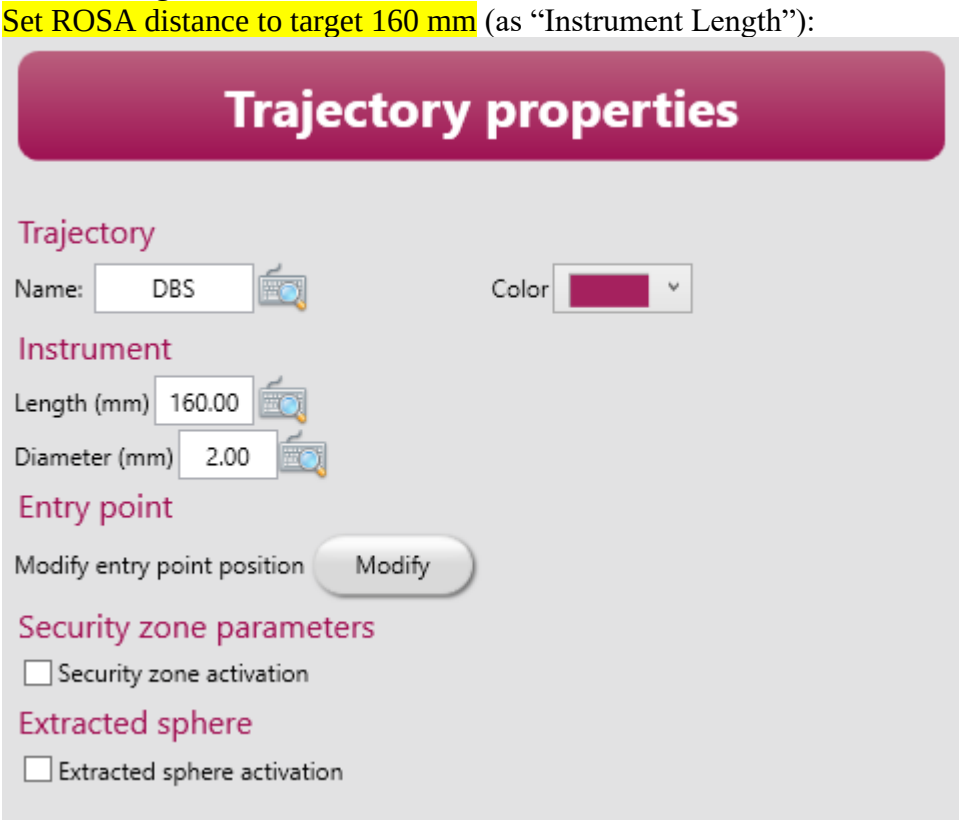
Microdrive:

A. Autoclavable manual system (has no electronics, thus, lighter in weight)
B. Electronic system:

Acceptable registration accuracy is ≤ 0.6 mm RMS (Dr. Sameer Sheth) – enough for DBS accuracy; spin confirmatory CT after both DBS leads are in.

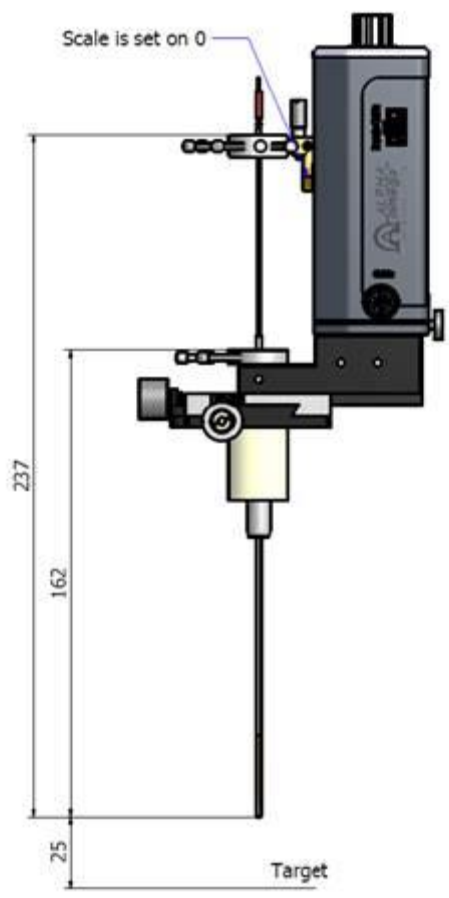
Implanting DBS lead at target:

Set ROSA distance to target 160 mm (as "Instrument Length"):



Set microdrive scale at 25 mm.

"25 mm above target" cannula is in:



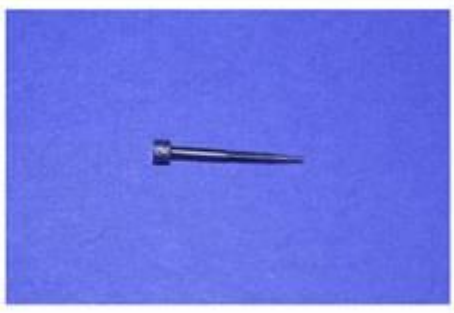
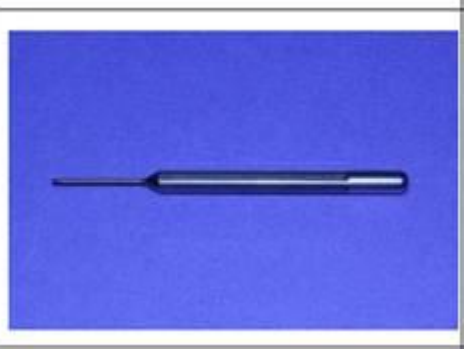
1	AutoClavable Headstage	

DBS Ruler	

- ruler has marking (*) where the bottom of the most distal contact should be (that is when microdrive is set to 25 mm and ROSA distance to target 160 mm, distal contact will be at the target).

DBS holder		Autoclave	Remove lead holder base 
Bengun			
Electrode Holder			

- length of the bengun is 6 cm and each cannula slot on the bengun has a diameter of 1.8 mm (with 2 mm between slot centers)

Microelectrode holder and Bengun screws	
Screwdriver	

FHC

see >> and also >>

Lead Holder SKU: 70-CN-DB
The Lead Holder is a temporary support attached to the microTargeting™ STar™ Drive carriage to hold the lead depth stop during insertion. It provides clearance for raising the insertion tube above the scalp while maintaining lead position.

Depth Stop Adapter SKU: 66-AC-DS(1.8)
The Depth Stop Adapter is used to hold the lead at a specific distance from target during lead insertion procedure.

Lead Measuring Fixture SKU: 70-AC-MT
The DBS Lead Measurement Fixture is used with the lead holder to allow easy and accurate placement of the depth stop cap on a DBS lead at the correct location for use with standard stereotactic frames (375mm) or the microTargeting™ Platform (319mm).

STar Adapter for ROSA Surgical Robot SKU: C0305
The STar™ Adapter for ROSA® is the latest addition to the STar Drive frame adapters, making the microTargeting™ STar Drive compatible for use with industry stereotactic systems. This solution adds the capability of remote advancement and retraction of up to 5 microelectrodes in a Ben-Gun array

configuration, along with automatic reporting of current position to FHC's microelectrode recording systems, to any ROSA Brain or ROSA ONE® Brain surgical robotic platform.

NEUROMATE (Renishaw)

Brochures >>
User Manual >>

EXCELSIUS GPS, S. "GLOBOT" (Globus Medical)

see p. Op41 >>

MAZOR X → MAZOR X STEALTH (Medtronic)

see p. Op42 >>

SPINE ROBOTICS - PRINCIPLES

- tactile feedback is different than with freehand.
- use drill resistance and feeling passing sclerotic bone seen on robot screen.
- if in doubt, use ball-probe to feel trajectory (may even stimulate screws before placing rod).