

Video Article

Surgical Implantation of Chronic Neural Electrodes for Recording Single Unit Activity and Electrocorticographic Signals

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Abstract

The success of long-term electrophysiological recordings often depends on the quality of the implantation surgery. Here we provide useful information for surgeons who are learning the process of implanting electrode systems. We demonstrate the implantation procedure of both a penetrating and a surface electrode. The surgical process is described from start to finish, including detailed descriptions of each step throughout the procedure. It should also be noted that this video guide is focused towards procedures conducted in rodent models and other small animal models. Modifications of the described procedures are feasible for other animal models.

Video Link

The video component of this article can be found at <http://www.jove.com/video/3565/>

Protocol

1. Pre-implant Procedures (Common)

1. Shave the top of the animal's head from between the eyes to well behind the ears. Use electric barber's clippers to shave the head. Scrub head first with isopropyl alcohol, then betadine (repeat 3x). Apply eye lubricant.
2. Mount the animal in stereotaxic ear bars. Direct the fixed tip of the right stereotaxic ear bar into the auditory canal of the animal's right ear by moving the head sideways against the canal. Extreme care must be taken to assure that each ear-bar tip is properly positioned in the auditory meatus. Next, push the loosened left ear bar into the auditory canal and apply slight inward pressure. Grasp the animal's nose and wiggle it back and forth firmly. If the animal is mounted properly the head will feel rigidly mounted.

2. Pre-implantation Surgery (Common)

1. With a pair of fine scissors, cut two half circles from the midline outwards, partially removing the scalp
2. Scrape and remove the periosteum connective tissue that adheres to the bone. Scraping with a blunt edge such as the back of a scalpel blade or the tip of a sterile cotton swab will minimize bleeding because the capillaries will be crushed rather than cut smoothly. Control bone bleeding using bone wax or a cauterizing iron.
3. Disinfect and clean the bone surface using hydrogen peroxide. Dry the bone to make the cranial sutures more clearly visible. The Bregma and Lambda points should be noted and used to level the head. The location for craniotomy and electrode implant should be measured with respect to Bregma and can be temporarily marked with a pen or by drilling shallowly into the surface. The craniotomy location will depend on the experimental aims of the study (i.e. motor, sensory experiments)¹.
4. Drill screwholes into the bone and place the ground and stabilizing screws. Always use stainless steel or titanium screws. Small jeweler's screws (for example #2-56, or #00-80) with as many threads per inch as possible are desirable.

3. Silicon Electrode Implant Procedures

1. Drill the craniotomy after implanting screws. Drill four shallow pilot marks for the corners of the craniotomy. Using pilot marks as a guide drill out the perimeter of the craniotomy. Remove the center mass of bone that was not drilled using a pair of sturdy forceps. The edge of the open craniotomy may need to be cleaned with further drilling. Thin pieces of bone may be clipped with a pair of microrongeurs. Plan your surgery carefully to avoid major blood vessels such as the Sagittal Sinus, which may appear within 0.5 mm of the midline longitudinal suture¹. Puncturing the Sagittal sinus can cause extensive bleeding. Exposed dura should be kept hydrated with aCSF or Saline.

2. To pierce the dura mater you will need to fashion a small hook using a sterile hypodermic needle of small gauge (e.g., < 28 gauge). Take the bevel of the needle and press it flat against a firm surface (such as the flat part of a scalpel) tilting slightly to form a 90 degree bend at the point. Use this hook to catch the surface of the dura, and lift upwards from the brain surface. The dura can be cut using micro scissors or may be torn using lateral movements of the dura hook. Take care to avoid blood vessels on the surface of the brain when using the dura hook. You should notice CSF leaking out when dura is resected and a difference in color from the surface of the dura.
3. Carefully attach the ground wire of the silicon electrode around the base of the ground screw, and tack in place with dental cement. The silicon electrodes should be placed carefully so that the electrodes cable leads are arched over the craniotomy.
4. Implants will be placed using a linear motor actuator placed on a stereotaxic apparatus. To attach the electrode to the insertion device, Polyethylene glycol (PEG) is heated with a soldering iron and applied to insertion rod and the recording electrode.
5. With the electrode secured, manually lower the tip of the electrode to the desired stereotaxic location on the surface of the brain.
6. Using the software interface to the linear actuator, move the electrode into the desired depth within the brain tissue.
7. Secure the recording electrode in the brain by attaching PEG from an adjacent screw to the electrode cable. You can now remove the electrode from the insertion device by adding saline to dissolve the PEG bound. Raise the insertion device away from the craniotomy and repeat for each electrode.
8. Cover the exposed craniotomy with saline soaked Gelfoam. A silicone polymer is then used to cover the electrode cable and protect it from the dental acrylic. Position the connector in the final location, then apply dental acrylic to make a robust headcap.

4. MicroECoG Electrode Implant Procedures

1. Implantation of the microECoG electrode will involve a slightly larger craniotomy. For a 5 x 5 mm device, a 6 x 6 mm craniotomy must be made. Before drilling the craniotomy, UV-curable dental acrylic is applied to the periphery of the craniotomy site while it is still dry and not in danger of touching the dura or pia.
2. A sterile surgical drill is used with a #107 burr to drill off the surface of bone in the general shape of the craniotomy. The smaller #106 burr can then be used to drill out the rest of the bone down to a thin transparent layer. Rongeurs will then be able to lift off the remaining piece of bone. The microECoG can be implanted epidurally or subdurally. Again, keep the dura well hydrated with artificial CSF or Saline.
3. In order to implant the microECoG, place a stereotaxic arm over the open skull, and secure the electrode to the arm using sterile tape. The electrode can now be lowered down into the craniotomy. Make sure the electrode sites are facing downward and will be making contact with the dura or pial surface. If kept moist, the electrode should slide onto the tissue and will stay in place.
4. The ground wire is connected to the ground screw by wrapping around at least three times over and under itself. The ground screw can be any screw that has come into contact with the dura. The reference wire can also be tied to the reference screw in the same manner.
5. Small pieces of saline soaked Gelfoam should be placed surrounding the electrode where there is dura or pia exposed. A small amount of saline soaked Gelfoam should also cover the top of the thin film electrode. UV-curable dental acrylic can be applied to the top of the Gelfoam and can be used to create a stable head cap. The acrylic is applied directly to the thin film cable covering it until the connector is reached. Be careful not to cover beyond the bottom of the connector cap.
6. Alternatively, the implantation of the microECoG in 4.3 can be immediately followed by the implantation of a silicon microelectrode array (steps 3.2-3.6) through small holes that are manufactured in the microECoG substrate. This allows for simultaneous recording of both single units at various depths along with high resolution field recordings from the surrounding brain surface.

5. Postoperative Recovery

1. After the cement has completely hardened, suture the skin tightly around the head-cap and remove the animal from the stereotaxic frame.
2. Apply antiseptic powder or antibiotic ointment copiously around the wound. If there is any bleeding from the ears, place some antibiotic well into the ear canal.
3. Keep the animal warm as barbiturates prevent the animal from maintaining its body heat. House each chronically implanted animal in a separate cage. It usually takes four to seven days for the animal to recover completely from the surgery.

6. Representative Results

A successful silicon electrode implant surgery will have recording sites with impedances measuring between 500kOhm-2MOhm, and thin-film electrodes between 10kOhm-50kOhm (at 1kHz). The neural signal can be checked immediately post surgery as well. You should be able to see spikes on the implanted electrodes and see slow wave oscillations on the thin film surface electrode (Figure 1).

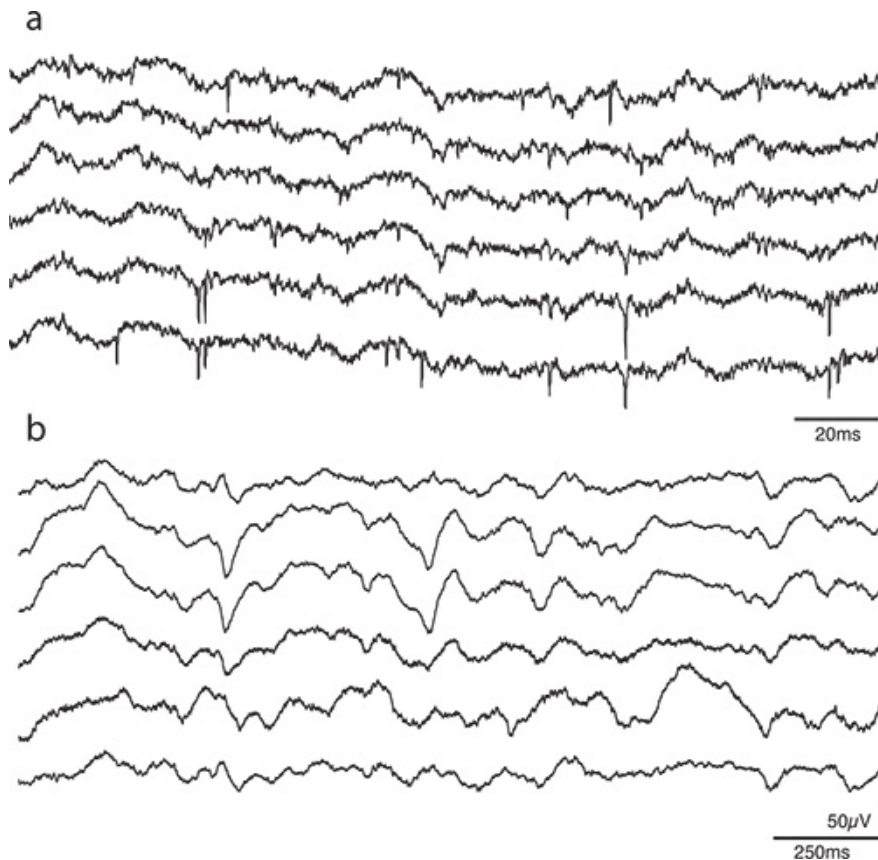


Figure 1. Representative results of single unit activity and ECoG oscillations. a) Wide-band data from 6 simultaneously recorded channels of a chronic silicon electrode implanted in the neocortex. Note that spikes can often be seen across recording sites. b) ECoG oscillations from 6 channels of a 16-channel thin-film uECoG electrode array on the surface of the brain. The mean of all 16 signals were removed from each trace (common average referencing), and a 500 Hz digital low pass filter was applied.

Discussion

There is an increasing interest in using intracortical and surface multichannel recording interfaces for researching brain function², providing microstimulation³, or control signals for neuroprosthetic systems^{4,5}. The methods outlined in this video demonstrate how to implant chronic penetrating and surface electrode systems. While other silicon chronic electrode systems exist⁶, we have focused on implanting planar electrodes developed by NeuroNexus Technologies^{7,8}. Techniques for the implantation of other electrode systems will vary considerably.

Of the surgical steps described, mounting the animal in the stereotaxic ear bars may be the most difficult and the most important step in determining the accuracy of placement of the implanted electrodes. Extreme care must be taken, therefore, to assure that each ear-bar tip is properly positioned in the auditory meatus. After assurance that the ear-bar tip is in the auditory meatus of the animal's right ear, release the animal's neck with your right hand while your left thumb and forefinger continue to support the head and apply pressure of the head against the ear-bar tip. With your right hand, push the loosened left ear bar into the auditory canal and apply slight inward pressure. Move the left side of the animal's head down and forward and all around until you can feel the left ear-bar tip slip into the auditory meatus. With your right hand, continue to apply pressure on the left ear bar. Release the animal's head and, with your now free left hand, tighten the set screw of the left ear bar.

Disclosures

DRK is part-owner of NeuroNexus Technologies.

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