Neurosurgery
Issue: Volume 37(2), August 1995, p 348-350

Publication Type: [Instrumentation, Technique, and Technology]
ISSN: 0148-396X
Accession: 00006123-199508000-00026

[Instrumentation, Technique, and Technology]

The NeuroStation System for Image-Guided, Frameless Stereotaxy

Germano, Isabelle M.

Author Information
New York, New York

The NeuroStation System for Image-Guided, Frameless Stereotaxy

The NeuroStation system (Fig. 1) can be used for image-guided, frameless stereotaxy. The system consists of a computer workstation and monitor, software and a digital audio tape (DAT) driver, a digitizer, a registration probe and microforceps, a reference arc and Mayfield attachment, a system of optical cameras, a portable system cart, a surgical breakout box, and a foot switch connected to the surgical instruments and the digitizer. The expected total price, including all these components, is $250,000. The NeuroStation is manufactured by Surgical Navigation Technologies, Inc., 530 Compton Street, Broomfield, CO 80020; Tel: (303) 439-9709; Fax: (303) 439-9711. Service contracts will be available. FDA clearance has not yet been obtained.

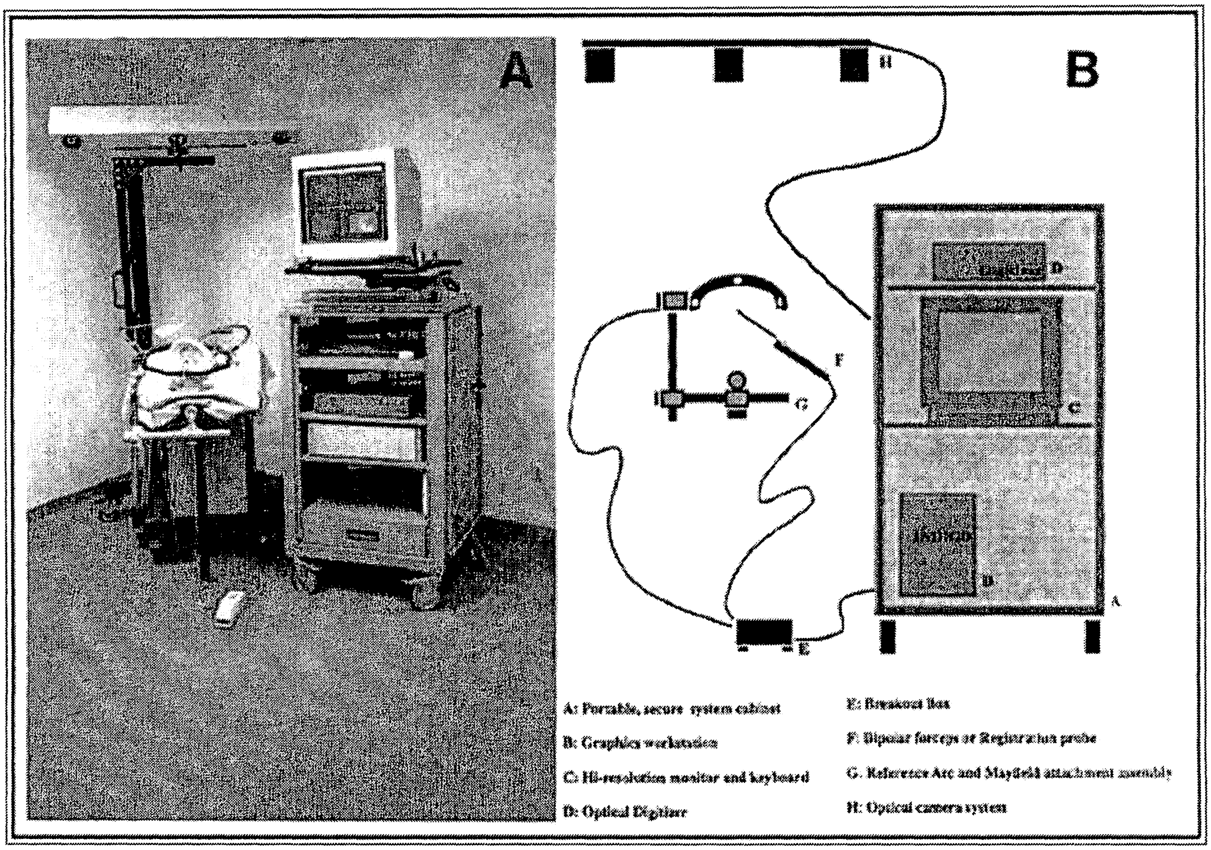

Figure 1. *A*, photograph of the NeuroStation system for image-guided, frameless stereotaxy. *B*, schematic representation of the NeuroStation.

Description of the system

The NeuroStation is an image-guided, frameless stereotactic system that incorporates Bucholz Free-Hand technology (Fig. 1A). The system is based on infrared light-emitting diodes (LEDs) attached to the surgical instruments. The position of the LEDs is constantly monitored by three cameras that send real-time feedback to the computer. At any given time, the surgeon can check the location of the surgical instruments in relation to the anatomic structures of interest displayed on the computer screen. When the pedal is pressed, the real-time position of the probe is displayed on the computer screen (Fig. 1B).

Use of the system

Image acquisition

Before any images are acquired, at least four markers are placed on the patient's head; the manufacturer recommends that seven markers be placed on the patient's head. Currently, the markers for computed tomographic (CT) scanning are made of Silastic; those for magnetic resonance (MR) imaging are made of vitamin E. The markers are affixed with tape and kept in place until the time of surgery or, if the surgery is scheduled >24 hours after the imaging study, the markers can be removed and replaced by marks made by an indelible pen. Images with a 1.5-mm section thickness are obtained and archived on a DAT tape. The tape is brought to the computer workstation, and the images are loaded onto the NeuroStation. With the newest CT scanners or MR imagers, images can be acquired in approximately 20 minutes. It takes about 15 minutes to archive the images onto the tape, and about 20 minutes to transfer them to the workstation. However, a local area network can be used to transfer the images directly to the workstation, a process that eliminates the need to retrieve them from the DAT tape.

Computer graphics

The images can be displayed in a standard format (i.e, reformatted axial, sagittal, and coronal [triplanar] images); in surgical views (i.e., reformatted according to the position and trajectory of the probe); or as three-dimensional (3D) images. To create the 3D images, the operator selects a gray-scale threshold to encompass the outer margin of the image (i.e., the skin); the computer does the 3D reconstruction of the CT or MR image in <3 minutes. No editing of the images by the operator is required. To show the content of the 3D object, the 3D image can be "cut" by a wedge orthogonal to the instrument; however, a 3D model of separate structures, such as the brain or lesion, is currently not possible. Nine different types of windows can be displayed simultaneously on the screen. The real-time location of the intraoperative instrument is indicated on the triplanar images by two crossed red lines and on the 3D images by a simulated probe.

Stereotactic registration

After the images have been reformatted and reconstructed by the computer, the markers are used as registration fiducials. The computer cursor is placed on the first marker, and a number appears on the screen indicating that marker as the first registration fiducial. The other markers are then selected in consecutive order on the screen. These registration fiducials will be matched by locating the position of the corresponding markers on the patient's head at the beginning of the operation. This process is called *registration*.

After the patient is in the operating room and has been positioned for surgery, with the Mayfield headholder in place, the reference arc is attached directly to the headholder and is connected to the digitizer by a cable. There are five LEDs on the reference arc that provide a constant emission of infrared light as a fixed reference point for the camera system. The optical camera system connected to the digitizer is placed 1 m (~3 ft) above the patient at the level of the knees. A pointer with three LEDs is also connected to the digitizer. The status of the LEDs is indicated on the monitor at all times; if the camera's view of the LEDs is obstructed, a red light appears on the screen. The probe is then used to touch each of the markers on the patient's head in the sequence indicated on the monitor by the previously chosen registration fiducials. At the end of the registration, the computer calculates the registration error, which should be <2 mm. If the error is >2 mm, the registration process should be repeated.

A high registration error may be caused by moving the markers after the images are obtained or by selecting the markers inaccurately. The success of the registration should be confirmed by checking the position of the probe with several markers in real time.

After the registration has been completed, the position of the probe in relation to the lesion and the selected entry point can be displayed by holding the probe on the patient's head and then pressing and releasing the foot pedal. The computer then shows the real-time position of the probe on the reformatted and 3D images displayed on the screen. The probe can therefore be used to plan the craniotomy window. At this point, the surgical planning program can be used to determine the entry point and the target on the reformatted images.

Craniotomy

When registration has been completed successfully, the reference arc and the camera system are draped with a sterile transparent drape. The probe used for the registration is replaced with an appropriate surgical instrument, such as a microbipolar coagulator with LEDs (Bucholz forceps). The soft tissues are opened in the usual fashion. Before the bone work is started, three divots are made with a power drill in the calvaria around the craniotomy window. These divots are used as references for a second precautionary registration. Should the head move during the elevation of the bone flap, the divots can be used as reference points for re-registration. The bipolar coagulator with the LEDs is then used during the opening of the dura and during microsurgical dissection. Each time the surgeon presses the foot pedal, the real-time location of the bipolar tip in relation to the target is shown on the computer display of the selected image formats.

Applications

The NeuroStation is ideally suited for locating small, deep-seated vascular lesions and tumors and for reducing the extent of microsurgical dissection. Its use obviates conventional stereotaxy, which is often uncomfortable for the patient and cumbersome for the surgeon. The NeuroStation is also useful for identifying boundaries between normal brain and large supratentorial gliomas, which may be clearly shown on the scans but difficult to see. In such cases, microcottonoid markers can be placed at the boundary of the tumor as displayed on the monitor before the resection is started. When the resection is extensive, the brain can shift position significantly, and currently there is no method to compensate for that position shifting. However, Stealth Technologies is now testing an intraoperative brain-shift monitor that uses ultrasound technology. The placement of ventricular catheters for shunts, ventriculostomy, or reservoirs is facilitated by the use of the NeuroStation, especially in the patients who have small ventricles or who have underlying coagulopathy (e.g., liver failure, acquired immunodeficiency syndrome) that makes a single pass desirable. The system can also be useful for performing stereotactic biopsies.

Advantages and limitations

Several image-guided, frameless intraoperative navigational devices based on various localization techniques are being used with increasing frequency (1-3,5-10,12). All these devices seek to provide accurate intraoperative localization of structures or lesions of interest and to eliminate the use of a frame on the patient's head, which is uncomfortable for the patient and may obstruct the surgeon's working space.

The NeuroStation is accurate to within 2 mm; when tested on a plastic head phantom containing fiducial rods, the error in localizing the fiducials after registration was <2 mm (11). Two types of movement error may occur during surgery. The first type of movement error occurs because the patient's head moves during the bone opening. If such movement occurs, re-registration by using the bone divots is necessary. The second type of movement error occurs after the retraction or the removal of the brain tissue. At that point, the reconstructed images do not provide real-time feedback to update the anatomic information because these images show only the preoperative anatomy.

Advantages of the using the NeuroStation include the resulting smaller craniotomy that is perfectly centered on the lesion; also, the microsurgical dissection time is shorter than in conventional stereotaxy because the NeuroStation helps the surgeon to find the lesion quickly. Less time is required to load and unload the images and to create 3D images in the NeuroStation system than in other navigational systems (5). Furthermore, with this system, the LEDs can be applied to one of the instruments used for microsurgical dissection, which obviates the surgeon's switching back and forth between the instrument and a pointer.

Disadvantages of using the NeuroStation include the requirement for a clear line of sight between the cameras and the instruments with the LEDs; however, the use of redundant LEDs minimizes this drawback. To avoid blocking the line of sight, the scrub nurse, the assistant, and the other operating room personnel must always be aware of their positions with respect to these components of the system. The major limitation of this system is the lack of real-time feedback after the brain has been retracted and resected. This limitation is common to most of the navigational systems, unless ultrasound techniques are used (4). Stealth Technologies has been awarded a grant from the National Institutes of Health (Bethesda, MD) to develop an intraoperative brain-shift monitor that uses ultrasound technology. This addition to the NeuroStation is expected to be released by the end of 1995. Further advances include incorporating the use of the NeuroStation with open MR imagers or CT scanners.

REFERENCES: (1-12)

1. Barnett GH, Kormos DW, Steiner CP, Weisenberg J: Use of a frameless, armless stereotactic wand for brain tumor localization with two-dimensional and three-

dimensional neuroimaging. **Neurosurgery** 33:674-678, 1993. **Ovid Full Text** | **Mount Sinai Serials** | **Bibliographic Links** | [Context Link]

2. Berger MS: Ultrasound-guided stereotaxic biopsy using a new apparatus. **J Neurosurg** 65:550-554, 1986. [Context Link]

3. Brown RA: A computerized tomography-computer graphics approach to stereotaxic localization. **J Neurosurg** 50:715-720, 1979. **Mount Sinai Serials** | **Bibliographic Links** | [Context Link]

4. Bucholz RD: Three-dimensional intraoperative ultrasonography using an optical digitizer, in *Proceedings of the American Association of Neurological Surgeons Meeting, Boston, MA*, April 1993, p 148. [Context Link]

5. Germano IM, Olivier A, Cukiert A, Peters T: Frameless stereotaxy for surgery of the epilepsies. **J Neurosurg** 81:629-633, 1994. **Mount Sinai Serials** | [Context Link]

6. Guthrie BL, Kaplan R, Kelly PJ: Free-hand stereotaxy: Computer assisted neurosurgery, in *Proceedings of the Neurosurgical Society of America*, 1989, pp 59-61. [Context Link]

7. Kato A, Yoshimine T, Hayakawa T, Tomita Y, Ikeda T, Mitomo M, Harada K, Mogami H: A frameless, armless navigational system for computer-assisted neurosurgery. **J Neurosurg** 74:845-849, 1991. **Mount Sinai Serials** | **Bibliographic Links** | [Context Link]

8. Koivukangas J, Louhishalmi Y, Alakuijala J, Okarinene J: Ultrasound-controlled neuronavigator-guided brain surgery. **J Neurosurg** 79:36-42, 1993. **Mount Sinai Serials** | **Bibliographic Links** | [Context Link]

9. Roberts DW, Strohbehn JW, Hatch JF, Murray W, Kettenberger H: A frameless stereotaxic integration of computerized tomographic imaging and the operating microscope. **J Neurosurg** 65:545-549, 1986. **Mount Sinai Serials** | **Bibliographic Links** | [Context Link]

10. Shelden CH, McCann G, Jaques S, Lutes HR, Frazier RE, Katz R, Kuti R: Development of a computerized microstereotaxic method for localization and removal of minute CNS lesions under direct 3D vision. **J Neurosurg** 52:21-27, 1980. **Mount Sinai Serials** | **Bibliographic Links** | [Context Link]

11. Smith KR, Frank KJ, Bucholz RD: The NeuroStation: A highly accurate, minimally invasive solution to frameless stereotactic neurosurgery. **Comput Med Imaging Graph** 18:247-256, 1994. **Mount Sinai Serials** | **Bibliographic Links** | [Context Link]

12. Watanabe E, Mayanagi Y, Kosugi Y, Manaka S, Takakura K: Open surgery assisted by the neuronavigator, a stereotactic, articulated, sensitive arm. **Neurosurgery** 28:792-800, 1991. **Ovid Full Text** | **Mount Sinai Serials** | **Bibliographic Links** | [Context Link]

COMMENTS

The ideal systems for a frameless stereotaxy has not yet been developed. So far, all such systems have problems. The articulated arms with optical encoders are cumbersome and carry a considerable nuisance factor during surgical procedures. Neurosurgeons may not adopt them if more convenient systems are available. Systems that are connected by cords are similar to many of the instruments we use and may be more easily incorporated into neurosurgical instrument arrays and neurosurgical procedures. The Stealth System works by light-emitting diodes point sources, which are detected by a three-camera array. A reference frame corrects for table movement with respect to the camera array. The problem with this technology is its line of sight; if anything or anyone stands between the light-emitting diodes and the cameras, the image registration will fail.

In the next few years, many more systems for frameless stereotactic surgery may become available. Several other technologies based on magnetic field digitizers, inertial navigation systems, and radiofrequency time-delay systems are in the prototype and design stages.

As they perform stereotactic tumor resection surgery, all neurosurgeons should be aware of the intracranial shifts that can occur during tumor removal. For example, spinal drainage and mannitol should not be used in such surgery because they will cause shifts, and the tumor position will differ from that indicated by the preoperative database. Many of these problems can be avoided by using the proper technique and by positioning the patient correctly.

Patrick J. Kelly

New York, New York

IMAGE GALLERY

Select All

Export Selected to PowerPoint

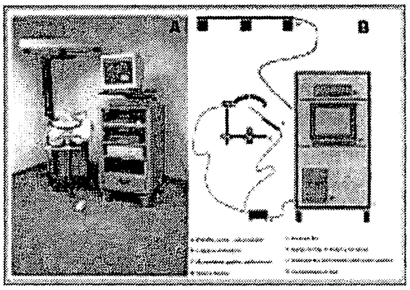

Figure 1

Back to Top