Preoperative Percutaneous Cranial Nerve Mapping in Head and Neck Surgery

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**Objective:** To identify and map the course of the peripheral branches of the cranial nerve preoperatively and percutaneously.

**Design:** Prospective study. Preoperative percutaneous nerve mapping performed prior to the operation under deep sedation or general anesthesia without muscle paralysis.

**Setting:** Private office surgery suite, freestanding surgery center, and regional medical centers.

**Patients:** A total of 142 patients undergoing head and neck surgery and facial plastic surgery between August 1994 and July 1999.

**Intervention:** Monopolar probe was used for nerve stimulation. Electromyographic reading was done through intramuscular bipolar recording electrodes. The equipment used was a nerve monitor.

**Results:** The mandibular divisions were tested in 142 cases, the frontal division in 60 cases, the accessory nerve in 12 cases, and the hypoglossal nerve in 3 cases. Satisfactory mappings were obtained in 115 cases of the mandibular division, 49 cases of the frontal division, 8 cases of the accessory division, and 1 case of the hypoglossal nerve.

**Conclusions:** Preoperative percutaneous nerve mapping is a new method of identifying the location of the peripheral branches of the cranial nerves. Identifying and mapping the course of peripheral branches of the cranial nerves safely assists the head and neck surgeon in the placement of incisions in a favorable location and in the dissection of the area involving the nerves. Mapping alerts the surgeon to an area containing a nerve and allows the surgeon to avoid just the specific area where a nerve is present, preventing large-scale abandonment of unmapped areas for fear of potential nerve damage.

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**Historically,** topognostic testing was the earliest attempt to diagnose weakness or absence of facial nerve function. With the introduction of the intraoperative nerve-monitoring technique, neurologic and neurosurgical procedures have been performed with enhanced safety. The intraoperative nerve-monitoring technique has also been introduced and practiced in head and neck surgery.

Preserving cranial nerve integrity is a major concern during facial plastic and head and neck surgery. While the facial nerve in the temporal bone and within the parotid gland has been explored and dissected routinely during regular surgical procedures, the peripheral branches of the facial nerve have rarely been explored during routine head and neck surgical procedures. The emphasis has been to avoid the nerve simply by limiting dissection near the anticipated course of the distal branches of the facial nerve. This is in sharp contrast to the old techniques in which the facial nerve was actively sought during mastoid surgery for preservation purposes. The surgeon’s uncertainty as to the exact course of the facial nerve may be a cause of great anxiety during surgical dissection.

While well-trained surgeons may feel comfortable operating in the area where facial nerve branches may be, many of us are reluctant to make incisions or dissections in these areas because of the possibility of injuring a nerve. Thus, many guidelines have been described to prevent nerve injury. These rules, however, create some inconvenience and limitation during surgery. A typical example can be found during submandibular gland surgery, which calls for an incision 4 cm (or 2 finger breadths) below the margin of the mandible. When the exposure is adequate with this type of incision, the argument is irrelevant. However, when sur-
tical exposure is severely compromised by the need to place incisions away from the target tissue, more than mere inconvenience results. Exposure of the mandibular angle or ramus may be extremely limited by a bulk of tissue over the area and distance from the incision site. A less ideal technique, other than making a direct incision over the mandible, would be the creation of an incision large enough to allow for sufficient tissue retraction. The same is true with surgical dissections in the temple area where frontotemporal branches of the facial nerve pose a danger.

I have developed a technique that allows the surgeon to visualize the course of peripheral branches of the facial nerve preoperatively and percutaneously. Mapping the course of the distal branches of the facial nerve aids a surgeon in placing incisions closer to the target tissue and in planning a faster, safer surgical procedure. With knowledge of the exact course of the nerve on a particular patient, the danger of nerve injury and the anxiety of the surgeon are greatly reduced. Although extra time is needed for the testing, surgical dissection time is shortened, and a more aggressive surgical dissection becomes possible. Preoperatively identifying the course of the accessory nerve enables the surgeon to quickly find the nerve during neck dissection. This information may also help in locating the shared exit point of the greater auricular nerve and the accessory nerve from the mid-posterior margin of the sternocleidomastoid muscle. I herein describe my experience in preoperative percutaneous cranial nerve mapping (PCrNM) techniques on 142 cases of head and neck and facial plastic surgery from August 1994 through July 1999.

**METHODS**

Mapping was done while the patient was under monitored anesthesia care or general anesthesia without muscle relaxation, although a short-acting muscle relaxant for intubation would be allowed. Because the test area should be completely dry, no local anesthetic or saline was injected until the mapping was completed. A Neurosign 100 nerve monitor (Smith and Nephew-Richards, Memphis, Tenn) was used to stimulate the nerve and to obtain electromyographic (EMG) readings. The monopolar probe was used to trace the nerve percutaneously. The grounding needle for the nerve-stimulating circuit was placed away from the nerve and the testing muscle, while the bipolar recording electrodes were inserted into the involved muscles 1 cm apart and parallel to each other. The reference needle for the recording was placed in the subcutaneous tissue away from the recording needles. The frontalis muscle was used to map the temporofrontal branch of the facial nerve; the orbicularis oris muscle of the lower lip was used for the mandibular branch; and the trapezius muscle was used for the accessory nerve. The needles were inserted into the tongue and strap muscles for hypoglossal nerve mapping.

Although stimulating frequencies of 3 and 30 Hz were used, 30 Hz was chosen in most of the mapping. The stimulating intensity was between 0.5 and 1 mA, depending on the individual response. Occasionally, an intensity higher than 1 mA was used. Only 1 channel was used for the testing and recording. The EMG recording was detected through an oscillating bar gram and audible pulsed signals. Once the needles were properly placed and the wires connected to the monitor, the first test stimulation was done directly over the muscle where the recording needle was in place. This was to ensure proper establishment of the electronic circuit. Occasionally, readjustment of the recording needle was necessary to prevent the needle tips from contacting each other.

The integrity of the neuromuscular response was established by applying the monopolar probe to the skin over the stylomastoid foramen or the skull base at the jugular foramen. The nerve was then stimulated by touching the probe along its anticipated course. The skin was compressed to bring the probe tip closer to the nerve. A random search found several adjacent spots of positive EMG responses, and careful repeated stimulation allowed me to choose the spot with the maximum response. Initial stimulation often produced a faint response. When the stimulation was repeated at the same spot, the response became stronger and louder. To confirm a maximum point of response, I passed the monopolar probe across the point at a right angle to the course of the nerve. The stroke with the probe must be firm, slow, and continuous while the surgeon carefully monitors the intensity of visible and audible responses. Mapping was considered satisfactory when the maximum point of response was found.

A dot was made on the skin with a marking pen to identify the underlying location of the nerve. Five to 10 dots were marked along the course of the nerve, and the dots were connected with a marking pen to reveal the entire course of the cranial nerve percutaneously and preoperatively (Figure 1). The markings are maintained during the skin preparation process.

**RESULTS**

After a 3-month trial beginning in May 1994 to establish the testing method, the study began in August 1994
and ran through July 1999. Preoperative percutaneous nerve mappings were performed in 142 procedures: 87 face-lifts, 5 resections of advanced basal cell carcinomas, 18 mandibular fractures, 1 resection of a malignant adamantinoma of the mandible, 17 submandibular gland resections, 1 resection of a metastatic parathyroid adenoma of the skull base, 1 metastatic squamous cell carcinoma of the mandibular node, and 12 radical neck dissections. The mandibular divisions were tested in all cases, frontal divisions in 60 cases, the accessory nerve in 12 cases, and the hypoglossal nerve in 3 cases. Satisfactory mapping was achieved in 115 cases of the mandibular division, 49 cases of the frontal division, 8 cases of the accessory nerve, and 1 case of the hypoglossal nerve.

The number of satisfactory mappings was higher during the last 12 months of the test period than during the entire study period. The mapping was performed in 25, 15, and 3 cases of the mandibular, frontal, and the accessory nerves, respectively, during the last year. Satisfactory mapping was achieved in 115 cases of the mandibular division, 49 cases of the frontal division, 8 cases of the accessory nerve, and 1 case of the hypoglossal nerve.

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The cranial nerves were explored and identified only where necessary to treat the original condition. Although the PCrNM was satisfactory in only 8 of 12 neck dissection cases, the positive correlation between the PCrNM and operative identification of the accessory nerve was found in 7 of 8 cases. The nerve was not found in 1 remaining case owing to the extensive involvement with the tumor. In 3 cases, the mandibular divisions were completely explored and identified: 1 case of metastatic parathyroid adenoma, 1 case of metastatic squamous cell carcinoma of the mandibular node, and 1 case of parotidectomy with radical neck dissection (Figure 2 and Figure 3). The operative findings confirmed the PCrNM result in all 3 cases. The mandibular divisions were actively sought during the face-lift procedures because the en bloc face-lift technique was used. The nerves were explored and identified only beyond the parotid gland for a short distance over and below the maseteric muscle. A positive correlation between PCrNM and operative findings was found in all 27 face-lift cases where the nerves were surgically identified. Thus, overall positive correlations were found in all 37 of the cases where the nerves were surgically identified.

Knowledge of the exact course of the cranial nerve is essential in certain surgical procedures. As the plane of dissection of a face-lift becomes deeper, the potential for facial nerve injury becomes greater. The surgeon can be prepared to make better dissections by visualizing the actual course of the nerve rather than estimating the course. In facial liposuction surgery, the jowl area is the most difficult to handle. One of the main reasons for unsatisfactory results in elimination of the jowl is the tendency
toward a conservative approach for fear of mandibular branch injury. Knowledge of the exact course of the mandibular branch would allow a surgeon to closely and safely approach the jowl area.

Mapping also allows the incision to be made closer to the body of the mandible, facilitating wider exposure of the mandibular segment. Manipulation such as plating and screwing then becomes much easier. The danger and fear of penetrating the mandibular branch during the percutaneous screw insertion of the mandible is eliminated.

With precise mapping, the incision for submandibular gland excision can be made in a more favorable location than it can without mapping (ie, higher so that exposure is simpler (Figures 4, 5, and 6). The identification and exploration of the accessory nerve is a routine part of neck dissection. Mapping of the accessory nerve in the posterior cervical triangle aids the surgeon in quickly locating the nerve, thus saving surgical dissection time (Figures 7, 8, and 9). Mapping of the hypoglossal nerve is of a more theoretical value than of any practical benefit (Figure 10). Although this technique is in no way a substitute for knowledge of surgical anatomy, preoperative PCrNM can eliminate the concerns associated with individual variations of the nerve course. While topognostic testing simply tests the strength and/or the presence of the facial nerve function, the intraoperative monitoring technique described here helps to identify a nerve fiber in the operative field.

There has never been an attempt to use a nerve stimulation technique to trace the nerve course in the periphery, percutaneously, and preoperatively. I was concerned that interference with EMG recording might result from the stimulating current delivered directly to the recording needles or the target muscle. Since it must travel through the resistant skin, subcutaneous fat, underly-

![Figure 4. Conventional incision for a submandibular gland resection. The marginal mandibularis is located above the margin of the mandible.](image)

![Figure 5. The incision for submandibular gland resection can be made closer to the mandible when the nerves are precisely mapped than when their locations are simply estimated.](image)

![Figure 6. Relationship between the mandibular nerve and modified and conventional incisions for submandibular gland resection.](image)

![Figure 7. Preoperative percutaneous accessory nerve mapping.](image)
ing muscles such as the platysma and sternocleidomastoïd, and the cervical fat pad, the required stimulating current must be higher than the intraoperative monitoring current. As it turned out, the electrical field seemed to be limited to a fairly narrow stimulating area. There was little electrical interference, even during stimulation of the distal branch close to the target muscle.

A monopolar probe proved to be an effective tool in transmitting a current through tissue mass. The bipolar probe, on the other hand, by limiting the current between 2 probes, was ineffective in percutaneous stimulation. While the limited nature of bipolar current gave it high specificity, it simply could not reach the target nerve during the percutaneous stimulation. This problem might be overcome by increasing the stimulus intensity, which in essence converts the bipolar probe into a monopolar one.

General anesthesia with a muscle relaxant blocks the muscle response. Testing without anesthesia also proved ineffective because of the interference of the baseline electric current generated by the awake muscle activities. Use of local anesthetics caused increased conductivity of the stimulating field. In this instance, the stimulating current spread so widely that the current was picked up not only by the nerve, but also by the EMG recording needle, resulting in a random, nonspecific EMG response. General anesthesia without muscle relaxation produced the most reliable response. Monitored anesthesia care provided the next best results.

The best mapping results are obtained after careful and thorough search for the nerve. As experience is gained, the search for the nerve becomes easier, and interpretation of the response becomes more accurate. At times, initial stimulation of the area containing the nerve produces only a faint response. When the probe is applied repeatedly on the same spot, the intensity of the response becomes stronger and more distinctive. For that reason, patience and repeated searches for the
maximum response is vital for proper results. There were no incidences of nerve fatigue or neuropaesthesia following the repetitions necessary to confirm the localization of the nerve. As the probe moves away from the nerve, the EMG response becomes weaker. A careful comparison of audible and visible responses between the stimulation points helps to determine the exact location of the nerve. A slow passage of the monopolar probe across the maximum stimulation point confirms the exact location of the nerve.

While it is not possible to give an exact number to evaluate the accuracy of the testing, the estimated variations between the preoperative PCRNM and the actual location of the nerve could be within 2 to 3 mm in the average thin patient. The body tissue volume, age of the skin, and the amount of water content in the tissue seem to have some influence on the stimulus/response relationship. This may explain the difference in the test results between facial and accessory nerve mapping. Further study is necessary to improve the specificity of testing in different tissues. False responses have been generated during stimulation of the auricular cartilage and the scalp. It is speculated that this may be due to the increased conductivity of those tissues, which results in a field effect.

In contrast to intraoperative monitoring, this PCRNM system requires no specially trained individual such as an audiologist to interpret the results. However, the use of the graphic EMG recording system, as interpreted by a trained audiologist, may improve the specificity of the nerve localization. Mapping of the buccal branches proves to be quite difficult. Numerous intertwining networks of the anastomosing tributaries of the buccal branches are thought to cause this nonspecificity. As the probe approaches the target muscle (eg, the orbicularis oris), the response becomes multiple and nonspecific. This is most likely due to a direct electrical stimulation of the target muscle by the stimulating probe.

During the early study period, only a single twig of the peripheral branches of the facial nerve could be mapped. With experience, however, I learned that multiple branching patterns of the peripheral nerves could be traced effectively (Figures 1 and 2). Although the mappings were quite satisfactory in 8 of 12 cases, the accessory nerve mapping was not as successful because of a higher rate of nonspecific responses. Further investigation is necessary into the placement of the grounding electrode, the intensity of stimulation, the EMG reading by the oscillograph, and interpretation by a trained individual. Hypoglossal nerve testing provides only experimental value.

Although the involved nerves were not explored and positively confirmed in each case, 37 cases showed positive correlation between the preoperative PCRNM and the findings on anatomic dissection (Figures 2 and 3). Further investigations including animal experiments and accumulation of data showing the clinical correlation between the PCRNM and anatomic dissection are necessary. Variations in outcome are expected owing to variations in the tester, the testing environment, and the test subject. There is also a certain learning curve for the procedure. However, my experiences during the past 5 years show statistically unproven but highly consistent results in mapping the course of the peripheral branches of cranial nerves.

In conclusion, PCRNM is a new method of identifying the location of the peripheral branches of the cranial nerves, which allows the head and neck surgeon to make incisions in a more favorable location and to safely dissect the area involving the nerves. Mapping alerts the surgeon to the specific area of a nerve and allows more unrestricted dissection to within that specific area.

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