Preoperative percutaneous mapping of the frontal branch of the facial nerve to assess the risk of frontalis muscle palsy after a supraorbital keyhole approach

Clinical article

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Object. Although a supraorbital keyhole approach utilizing an eyebrow incision and supraorbital minicraniotomy is one of the most commonly used keyhole approaches for treating cerebral aneurysms, the risk of frontalis muscle palsy due to an injury of the frontal branch of the facial nerve remains a serious drawback to a supraorbital keyhole approach as a minimally invasive surgical technique. Therefore, the authors attempted to evaluate the risk of frontalis muscle palsy by mapping the frontal nerve branch in the lower forehead using a nerve conduction study in individual patients.

Methods. Percutaneous mapping of the frontal nerve branch was performed preoperatively on 52 patients who underwent supraorbital keyhole approaches for aneurysmal clipping. The maximal compound muscle action potentials (CMAPs) in the lower forehead were observed at 5 points along a laterally inclined line angled 30° from the midpupillary line, in which the points were 1.0, 1.5, 2.0, 2.5, and 3.0 cm as measured from the supraorbital margin.

Results. Severe frontalis muscle palsy was observed in 11 patients (21.2%), yet recovery occurred 2–5 months after surgery. No patients experienced permanent palsy. The incidence of severe palsy was 7.4% in those patients showing clear CMAPs with a high location (exclusively at 2.0, 2.5, or 3.0 cm), 14.3% in those with a bimodal distribution, 40.0% in those with a low location (exclusively at 1.5 cm), and 83.3% in those with an extremely low location (exclusively at 1.0 cm).

Conclusions. Percutaneous mapping of the frontal branch of the facial nerve using a nerve conduction study can be used to assess the risk of postoperative frontalis muscle palsy following a supraorbital keyhole approach. The patients with the highest risk of postoperative palsy showed a clear CMAP exclusively at 1.0 cm along the inclined line measured from the supraorbital margin.

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Key Words • cerebral aneurysm • electrodiagnosis • facial nerve • minimally invasive surgery • treatment outcome • surgical technique

Abbreviation used in this paper: CMAP = compound muscle action potential.

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The frontal or frontotemporal branch of the facial nerve is especially vulnerable to injury during neurosurgical procedures such as cranioorbitozygomatic, pterional, and supraorbital keyhole approaches that involve an incision and soft-tissue dissection in the frontal and temporal regions. In the case of pterional and cranioorbitozygomatic approaches, dissection of the temporal muscle using an interfascial, subfascial, or submuscular method, following an incision beginning 1 cm anterior to the tragus at the root of the zygomatic arch, is a technical precaution to avoid injury to the frontal branch of the facial nerve.1,7,27

A supraorbital or superciliary keyhole approach utilizing an eyebrow incision and supraorbital minicraniotomy is a minimally invasive alternative to a pterional approach and is commonly used for treating cerebral aneurysms.3,5,8,11,13,16,21,26 In recent years the use of a supraorbital keyhole approach has increased due to the application of proper surgical indications, usage of specialized surgical instruments, and technical advancements.9,17–19

However, the risk of disfigurement caused by palsy of the frontalis muscle due to an injury of the frontal branch of the facial nerve remains a serious drawback to a supraorbital keyhole approach, because the frontal branch can course closely above the location of the eyebrow incision. Reisch and Perneczky22 previously reported a 5.5% incidence of permanent palsy of the frontalis muscle. Therefore, instead of using nonspecific knowledge of the facial...
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nerve course based on statistics from cadaveric study,\textsuperscript{6,20} the unique anatomical location of the frontal branch in an individual patient is a crucial factor determining whether there is postoperative injury to the frontal branch. However, no studies have yet focused on such localization in the case of a supraorbital keyhole approach. Accordingly, we performed electrophysiological mapping of the frontal branch of the facial nerve in the lower forehead before a supraorbital keyhole approach to evaluate the risk of frontalis palsy.

\textbf{Methods}

\textit{Patient Population}

Between November 2010 and October 2011, a total of 52 patients with 55 unruptured intracranial aneurysms were enrolled in this prospective study. Patients underwent preoperative percutaneous mapping of the frontal branch of the facial nerve in the lower forehead using a nerve conduction study, followed by a suprachilar keyhole approach for aneurysmal clipping. The patient population consisted of 22 men and 30 women with a mean age of 55.1 ± 9.7 years (range 34–70 years). The locations of the clipped aneurysms included the supraclinoid internal carotid artery (n = 7), anterior communicating artery (n = 16), and middle cerebral artery (n = 32). The study was reviewed and approved by an institutional ethics committee. Informed consent was obtained in all patients.

\textit{Mapping the Frontal Branch of the Facial Nerve}

Before surgery, percutaneous mapping was performed using a nerve conduction study to evaluate the course of the frontal branch of the facial nerve in the lower forehead. The electrodiagnostic test was performed by an expert electromyographer (S.H.L.) using a Medelec Synergy electromyograph (Oxford Instruments Medical).

The patient lies back on an examination table and relaxes. A laterally inclined line angled 30° from the midpupillary line is then drawn, and 5 points are marked along the line at 1.0, 1.5, 2.0, 2.5, and 3.0 cm as measured from the supraorbital margin (Fig. 1). The active electrode is sequentially placed at all 5 points, while the reference electrode is placed in the middle of the contralateral frontalis and the ground electrode is applied to the midline of the forehead just below the hairline. A monopolar needle is used as the active electrode, and a surface electrode is used as the reference electrode.

The CMAPs of the frontal branch of the facial nerve are recorded by applying surface stimulation to the anterolateral side of the tragus. A definite response is represented by the presence of a clear initial negative deflection of the CMAP when recorded at each of the 5 points. The CMAP is produced by the muscle’s motor point, which is the most electrically excitable area of the muscle and located where the motor nerve enters the muscle. Thus, when a clear CMAP is recorded, this indicates the close presence of the frontal branch of the facial nerve.

\textit{Supraorbital Keyhole Approach}

For the supraorbital keyhole approach a skin incision is made in the upper half or along the upper margin of the eyebrow, starting from the midpupillary line and extending laterally (Fig. 2A). The incision is located within 1 cm of the supraorbital margin and measures 3.5 cm in length. The frontalis muscle is then cut using a monopolar cautery. In the lateral part of the incision, the temporalis muscle is cut 1 cm, exposing a site for a frontobasal lateral bur hole. Adequate undermining of the skin allows the creation of a 2 × 2.5−cm supraorbital bone flap using a high-speed drill with a footplate attachment. The incised skin and frontalis muscle are then retracted using 3 stay sutures on each side (Fig. 2B). The inner edge of the craniotomy above the orbital rim is drilled and the frontal floor prominences are flattened. After the dural incision, the intradural procedures start with draining the CSF from the optic nerve and carotid cisterns.

In the present patient series the duration of the operative wound traction from the creation of the bone flap to its fixation was approximately 1 hour. The detailed intradural procedures and the closure of the operative wound have been previously reported by the current authors.\textsuperscript{18,19}

\textit{Postoperative Evaluation of Frontalis Muscle Palsy}

A physical examination of the frontalis muscle was performed during admission and 1 month postoperatively. Those patients with palsy of the frontalis muscle were then evaluated using blinded observers every month until complete or near-complete recovery. The tone of the frontalis muscle was inspected first, followed by the patients raising their eyebrows to note the excursion of the brows and degree of forehead wrinkling.

\textit{Statistical Analysis}

The statistical analyses were performed with the aid of an SPSS package (version 14 for Windows; SPSS, Inc.). To compare the 4 groups based on the location of the frontal branch of the facial nerve in the lower forehead, the Fisher exact test was used for the incidence of postoperative severe palsy of the frontalis muscle, whereas a 1-way ANOVA was used for patient age. The results were considered significant for probability values less than 0.05.

\textbf{Results}

\textit{Mapping the Frontal Branch of the Facial Nerve}

Based on the nerve conduction study at the 5 points along the inclined line above the supraorbital margin, a definite CMAP was recorded at 1 point in 32 patients (61.5%), 2 points in 18 patients (34.6%), and 3 points in 2 patients (3.8%).

The patients exhibited 4 types of distribution of the frontal branch of the facial nerve in the lower forehead based on the location of the CMAPs between 1 and 3 cm along the inclined line from the supraorbital margin: 1) high location (n = 27, 51.9%), with definite CMAPs at 1 or multiple points between 2 and 3 cm along the line from the supraorbital margin (Fig. 3A); 2) bimodal distribution (n = 14, 26.9%), with definite CMAPs at both a higher (2.0, 2.5, and 3.0 cm) and lower (1.0 and 1.5 cm) location
(Fig. 3B); 3) low location (n = 5, 9.6%), with a definite CMAP exclusively at 1.5 cm (Fig. 3C); and 4) extremely low location (n = 6, 11.5%), with a definite CMAP exclusively at 1.0 cm.

In the 14 patients showing CMAPs with a bimodal distribution, the lower CMAP was observed at 1.0 (n = 12) or 1.5 cm (n = 2) along the inclined line, while the higher CMAP was observed between 2 and 3 cm along the inclined line. The ages were comparable among the 4 patient groups based on the distribution of the frontal branch according to the location of the CMAPs (Table 1).

Postoperative Palsy of the Frontalis Muscle

Among all 52 patients, no patient experienced permanent palsy of the frontalis muscle postoperatively. However, 11 patients (21.2%) experienced severe palsy of the frontalis muscle with no movement postoperatively, followed by recovery after 2–5 months (mean 3.2 ± 1.4 months). In addition, mild to moderate palsy lasting less than 2 months was observed in 15 patients (28.8%), and no frontalis palsy was observed in 26 patients (50.0%).

Table 1 summarizes the incidence and severity of the frontalis palsy according to the location of the frontal branch of the facial nerve, determined by the presence of definite CMAPs. For severe palsy of the frontalis muscle with recovery 2–5 months after surgery, the incidence increased according to the proximity of the frontal branch of the facial nerve to the eyebrow incision above the supraorbital margin. Thus the incidence of severe frontalis palsy of the frontal branch was 7.4% (high location), 14.3% (bimodal distribution), 40.0% (low location), and 83.3% (extremely low location), as demonstrated by the occurrence of CMAPs, representing significant differences between all 4 groups (p = 0.001).

Discussion

The facial nerve exiting the skull base at the stylo-mastoid foramen and traveling within the substance of the parotid gland shows several extraparotid branching patterns with 5 major facial branches. The path of the uppermost branch, the frontal (frontotemporal) branch of the facial nerve, has already been roughly estimated in the literature.2,10,23,25 Pitanguy and Ramos30 plotted the
course of the frontal branch as a line starting from a point 0.5 cm below the tragus and passing 1.5 cm above the lateral extremity of the eyebrow. Correia and Zani located the frontal branch between two diverging lines extending from the region of the earlobe to the lateral end of the eyebrow and the lateral end of the highest forehead crease, respectively. However, the current use of percutaneous mapping with a nerve conduction study allowed exact localization of the frontal branch of the facial nerve above the eyebrow in each patient.

If an eyebrow incision is limited in length and location, it can avoid transecting the frontal branch of the facial nerve. In the current patient series, a skin incision along the superciliary arch, starting from the midpupillary line and extending laterally, located within 1 cm from the supraorbital margin and measuring 3.5 cm in length.

**Fig. 3.** Results of percutaneous mapping of the frontal branch of the facial nerve. A: Frontal branch of the facial nerve with a high location. A definite CMAP is exclusively recorded at 3.0 cm along the inclined line as measured from the supraorbital margin. B: Bimodal distribution of the frontal branch. Definite CMAPs are recorded at 1 and 2.5 cm along the inclined line measured from the supraorbital margin. C: Frontal branch of the facial nerve with a low location. A clear CMAP is exclusively recorded at 1.5 cm along the inclined line measured from the supraorbital margin.
neuropraxia or axonotmesis. Severe injury to the nerve to the operative wound in the forehead, resulting in tranverse palsy of the frontalis muscle, encoun­
tered in the present patient series was considered to be related to stretch-induced nerve injuries that occurred during the operative wound traction. The severity of the nerve injury is primarily determined by the proximity of the nerve to the operative wound in the forehead, resulting in neuropraxia or axonotmesis. Severe injury to a nerve close to an operative wound invariably induces axonotmesis, which occurs when there is complete interruption of the nerve axon and myelin, although the surrounding perineurium and epineurium are preserved. However, recovery is excellent due to sprouting axons in the remaining mesenchymal latticework. Mild injury to a nerve far from the operative wound invariably induces neurapraxia, which does not involve loss of nerve continuity and causes transient functional loss.

None of the patients in the present series developed permanent palsy of the frontalis muscle or severe palsy lasting more than 6 months. However, permanent palsy of the frontalis was reported by Reisch and Pernecky with a 5.5% incidence, while prolonged frontalis palsy of more than 6 months was reported by the present authors in an earlier surgical series with an incidence of 5.9%. Thus, it may be surmised from these data that the chances of permanent injury to the frontal branch of the facial nerve are higher when it runs adjacent to the eyebrow incision.

Although the current study is limited based on a case series from a single institution, the use of percutaneous mapping of the frontal branch facilitates a preoperative assessment of the risk of frontal muscle palsy when using a supraorbital keyhole approach. This risk assessment can then enhance technical precautions, such as using a slightly lower skin incision or avoiding the use of monopolar cautery while undermining the skin of the forehead.

Moreover, this risk assessment can even affect the acquisition of informed consent from patients, who should be fully aware of the predicted risks and benefits of the procedure, as well as alternative available treatments such as endovascular coil embolization, a conventional ptoral approach, or other keyhole techniques such as a sphenoid keyhole approach.

Conclusions

Percutaneous mapping of the frontal branch of the facial nerve with a nerve conduction study can be used to assess the risk of postoperative frontalis muscle palsy following a supraorbital keyhole approach. The patients with the highest risk of postoperative palsy showed a clear CMAP exclusively at 1.0 cm above the supraorbital margin.

Disclosure

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