Facial nerve monitoring during robotic cochlear implementation: first patient experience

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Purpose

The first clinical application of image-guided cochlear implantation lacked facial nerve (FN) monitoring (NM) as part of the proposed surgical system and clinical workflow [1]. This was due to insufficient sensitivity and specificity of standard NM systems. Lately, a NM approach that enables sufficient sensitivity and specificity to discriminate nerve proximity (<1 mm) was verified in an animal model [2]. The proposed method relies on application of a multipolar FN stimulation through the facial recess. A first clinical implementation of robotic cochlear implantation (RCI) is currently undergoing in the University Hospital of Bern (Switzerland) [3]. Utilization of NM as one of various safety mechanisms during the RCI approach has been recently proposed [4]. Herein, we present the first experience using our proposed NM approach during RCI. We hypothesize that multipolar NM through the facial recess enables sensitive and specific drill-FN safety distance assessment for decision making during RCI.

Methods

NM system & approach

A multipolar stimulating probe is attached to a medical grade NM system (ISIS, inomed GmbH). The system sends stimulating current among 4 channels of the probe and elicited electromyogram (EMG) signals from facial muscles are monitored. Via a proprietary NM software different functionalities can be controlled during the RCI operation: 1) Free-running EMG is used to facilitate monitoring of no electrically triggered EMG signals. 2) A positive control is utilized to verify sensitivity of the NM stimulating and measuring loop. 3) FN stimulation is achieved through the facial recess to provide safe and unsafe drill-FN distances based on multipolar stimulus thresholds.

RCI drilling and EMG-based NM

With approval of the local ethics commission (IRB Bern, Switzerland, KEK-BE Nr.156/13) a first RCI operation was achieved in summer 2016. Prior to start the RCI procedure four fiducial screws (2.2mm × 5mm, M-5243.05, Medartis) were implanted in the right mastoid of a 51 year old female patient. A CT scan was acquired (SOMATOM, Siemens) and a trajectory planned to the entrance of the cochlea. The patients head was accommodated into a non-invasive head-rest, and EMG electrodes were located in orbicularis oris and oculis facial muscles. Surface stimulating electrodes were located on the superficial branch of the FN (positive control). A reference marker was fixed in the patient’s mastoid to enable tracking of head movements during the procedure. After physical registration of the patient’s mastoid to the preoperative plan [5], robotic drilling was started using optimized protocols to reduce temperature. At to 3 mm before the FN radiologic safety confirmation of the drilled axis relative to the FN using intraoperative CT imagery (xCAT, Xoran, USA) was achieved [5]. Thereafter, a total of 5 NM measurement points (0.5 mm axial increments) were assessed through the facial recess. For each NM measurement point up to ten monophasic pulses (0.2 to 2 mA, 250 µs) were applied through each of four channels (3 bipolar and 1 monopolar) of the stimulating probe. The NM algorithm was used to assess drill-FN distance based on stimulus thresholds from previous in-vivo studies [2]. NM data were recorded for postoperative analysis and final drill-FN distances were determined from postoperative CT images of the mastoid acquired after the RCI procedure.
Fig. 1. (Left) RCI system drilling the planned trajectory towards the round window in the cochlea entrance. (Right) The preoperative plan with the planned trajectory passing between the FN and the chorda tympani (CT), and near the ossicles and the external auditory canal (EAC).

Results

NN measurements through the facial recess assessed safe drill-FN distances (stimulus thresholds ≥ 2 mA, drill-FN distance > 0.7 mm) (Table 1). Free-running EMG during facial recess drilling indicated mechanical activity with no signs of nerve irritation (no neurotonic discharges).

Conclusion

The developed NM approach was sensitive and specific to determine drill-FN proximity during the first clinical application of RCI. To determine if our NM approach is sufficiently sensitive and specific in the critical FN distance range (<0.3 mm) further validation in patients is required.

Table 1: Stimulus threshold values and drill-FN distances from NM and postop CT image assessment.

<table>
<thead>
<tr>
<th>NM measurement point</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned distance from FN (mm)</td>
<td>1.71</td>
<td>1.34</td>
<td>1.04</td>
<td>0.82</td>
<td>0.72</td>
</tr>
<tr>
<td>Stimulus threshold bipolar (mA)</td>
<td>&gt; 2</td>
<td>&gt; 2</td>
<td>&gt; 2</td>
<td>&gt; 2</td>
<td>&gt; 2</td>
</tr>
<tr>
<td>Stimulus threshold monopolar (mA)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Predicted FN distance from NM (mm)</td>
<td>&gt; 0.7</td>
<td>&gt; 0.7</td>
<td>&gt; 0.7</td>
<td>&gt; 0.7</td>
<td>&gt; 0.7</td>
</tr>
<tr>
<td>Postoperative distance CD (mm)</td>
<td>1.81</td>
<td>1.47</td>
<td>1.21</td>
<td>1.01</td>
<td>0.82</td>
</tr>
</tbody>
</table>
Fig. 2. Postoperative safety assessment to critical structures of the first RCI implanted patient. The RCI drilled tunnel (red) relative to the preoperative co-registered FN and chorda tympani is depicted. The minimum drill-FN distance is indicated (CD). The CI electrode is depicted within the drilled tunnel.

Reference


