Impact of Routine Plain X-ray on Postoperative Management in Cochlear Implantation

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OBJECTIVES: To determine the benefit of a routine plain radiography (X-ray) for confirming the optimal electrode position in cochlear implant surgery.

MATERIALS and METHODS: In total, 245 patients (135 males and 111 females) who underwent cochlear implantation in a single tertiary referral center were included in this study. Postoperative plain X-ray findings and electrophysiological tests were retrospectively analyzed.

RESULTS: The mean age was 11.4±14.6 years (range, 1–70 years). Overall, 196 (80%) patients were pediatric patients (age, <18 years) and 49 (20%) were adults (age, ≥18 years). The mean rotation of electrode arrays was 1.03±0.17 turns. The plain X-ray revealed that electrode misplacement was present in 5 patients (2%); incomplete insertion in 3 patients, and tip rollover and electrode migration in 1 patient each. A revision was performed for the last patient who had an extracochlear electrode position in the plain X-ray.

CONCLUSIONS: Postoperative imaging is mostly used to confirm the electrode array position after cochlear implant surgery. In addition, intraoperative evaluations have low positive predictive value and sensitivity. Thus, this study revealed that postoperative radiological imaging should be considered even when all intraoperative electrophysiological measures and surgical reports are normal.

KEYWORDS: Cochlear implant, electrodes, radiography

INTRODUCTION

Cochlear implants (CIs) are electronic hearing devices that transform mechanical sound energy into electrical signals and enable hearing by directly transmitting the signals to the cochlear nerve via an electrode array inserted in the cochlea.

The most suitable position of the electrode to provide more acceptable clinical outcomes is in the scala tympani [1–3]. To confirm the intrascalar placement, a plain radiography (X-ray) scan is generally preferred as a standard method by many CI centers. The modified Stenvers’ view, in which the central beam in the temporal bone is positioned 45° posteriorly and 12° caudally [4], is often preferred to check the position and insertion depth of the electrodes [5].

Furthermore, the other choice for the corroboration of appropriate electrode placement is electrically evoked compound action potentials (ECAPs), which have proven to be an efficient method in the intraoperative and postoperative periods [6]. The evoked stapedius reflex (ESR) and impedance are other objective measures that can be intraoperatively or postoperatively performed [7, 8]. Alternatively, electrophysiological measurements do not substitute radiological imaging to identify the cases of device failure that is due to displaced or migrated electrode.

Electrode array misplacement is a rare complication with incidence rates between 0.2% and 5.8% [9–13]. In this case, plain X-ray can be an easy and useful diagnostic method [14].
Radiological imaging is a golden standard method to confirm the electrode positions in CI. However, to avoid radiation exposure, some surgeons advocate performing routine X-ray only in cases with abnormal anatomy or inappropriate intraoperative findings; for example, an increased resistance during electrode insertion. In this study, we aimed to determine the value of routine postoperative plain X-ray in retrospective cases with CI.

MATERIALS and METHODS

Subjects
Patients who underwent CI owing to bilateral profound sensorineural hearing loss in the Department of Otorhinolaryngology of a tertiary hospital between October 2011 and October 2015 were considered for the study. All demographic data of the patients were obtained from clinical records. The patients who underwent primary CI surgery were included in the study. The patients with a cochlear anomaly and revision surgeries were excluded. The study was approved by the local Institutional Review Board (ref number: 2016/92). Written informed consent was obtained from the patients who participated in this study and from the parents of the patients who were <18 years of age.

Surgical technique
Subperiosteal pocket technique was used in all CIs. Mastoidectomy and a posterior tympanotomy were performed, and a round window or anteroinferior cochleostomy approach into the scala tympani was applied to access the cochlea. The fat or fascia grafts were used for packing around the electrode at the cochleostomy site in most cases. All CIs were performed by three different surgeons in a single center.

Intraoperative assessment
An audiologist was routinely present during each operation; he measured the impedance levels for all electrodes during the closure of the incision and before ECAP measurements using the manufacturers’ default modes. The impedance levels between 1 and 30 kilohms (Short circuit [SC] <1 kilohms and open circuit [OC] >30 kilohms) were considered to be normal. ECAP and ESR were evaluated on three different parts of the array: apical, middle, and basal. If no response was obtained in all parts, it was considered to be an abnormal ECAP. Further, if a response was not received at any part of the electrode, it was considered to be a partial ECAP abnormality. Additionally, it was assumed as negative ESR when ESR was not visualized on three different impulses.

In addition to these parameters, the surgeon’s suspicion of misplacement (i.e., uncertain or difficult insertions) or intraoperative estimation of array insertion were noted.

Radiologic assessment
At our clinic, a plain Stenvers’ view X-ray is routinely performed for all patients on the first postoperative day. All plain radiographies are evaluated for possible electrode misplacement by a blinded radiologist. In our study, radiologic images were retrospectively analyzed to assess the placement, position, and depth of insertion using the digital radiology Picture Archiving and Communication System (ExtremePACS; Ankara, Turkey). Additionally, archived written reports of the radiographies were retrospectively investigated.

The rotating electrode array along the cochlea was categorized as follows: 0.5, 0.75, 1, 1.25, and 1.5 turns (Figure 1).
postoperative plain X-ray showed tip rollover of the electrode array in the cochlea for only 1 patient (0.4%; Figure 2). In this patient, the impedance levels and ESR were found to be normal, but a partial response (present only on basal arrays) was recorded in ECAP and no revision was required. In another patient, the postoperative plain X-ray revealed that the whole electrode seemed to be out of the cochlea (0.4%), whereas all intraoperative electrophysiological tests (ECAP, ESR, and impedance) were found to be normal (Figure 3). This patient underwent revision surgery on the first postoperative day, and the findings in the revision surgery showed that the misplacement was due to posterior migration of the internal receiver in the subperiosteal pocket, resulting in electrode displacement (Brand name and model was Cochlear (Cochlear Ltd., Sydney, Australia)-straight banded array CI422).

The surgeons suspected an inappropriate position of the electrode array in four patients. In three of these patients, the X-ray showed the partial insertion as a 0.5 turn of the electrode array. The postoperative plain X-ray showed complete and proper insertion in only one suspected case. The positive and negative predictive values of surgical suspicion in electrode placement were 75% and 99.1%, respectively. Moreover, the sensitivity and specificity of surgical suspicion were 60% and 99.5%, respectively (Table 2).

**TABLE 1. Comparison of radiological and electrophysiological tests**

<table>
<thead>
<tr>
<th>POSTOPERATIVE PLAIN X-RAY RADIOPHGRAPHY FINDINGS (N:256)</th>
<th>MANUFACTURER</th>
<th>INTRAOPERATIVE ESTIMATION OF ARRAY INSERTION</th>
<th>INTRAOPERATIVE IMPEDANCE LEVELS</th>
<th>INTRAOPERATIVE ECAP</th>
<th>INTRAOPERATIVE ESR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 TURN (1.2%) (N:3)</td>
<td>C:3</td>
<td>Partial insertion in 3 patients</td>
<td>SC on basal electrode in 3 patients</td>
<td>Basal electrode abnormality in 3 patients</td>
<td>2 normal 1 negative</td>
</tr>
<tr>
<td>0.75 TURN (7.3%) (N:18)</td>
<td>C:16</td>
<td>Full insertion</td>
<td>17 normal</td>
<td>SC on basal electrode in 1 patient</td>
<td>16 positive 2 negative</td>
</tr>
<tr>
<td>1.00 TURN (74.2%) (N:182)</td>
<td>C:143</td>
<td>Extracochlear misplacement in 1 patient</td>
<td>180 normal</td>
<td>All normal in 176 patients Mid-basal electrode abnormality in 6 patients</td>
<td>176 positive 6 negative</td>
</tr>
<tr>
<td>1.25 TURN (6.9%) (N:17)</td>
<td>C:8</td>
<td>Full insertion</td>
<td>All normal</td>
<td>All normal in 16 patients Mid-apical electrode abnormality in 1 patient</td>
<td>15 positive 2 negative</td>
</tr>
<tr>
<td>1.5 TURN (10.2%) (N:25)</td>
<td>C:19</td>
<td>Full insertion</td>
<td>24 normal</td>
<td>All normal in 24 patients Mid-basal electrode abnormality in 1 patient</td>
<td>25 positive</td>
</tr>
</tbody>
</table>

**TABLE 2. Value of surgeon’s suspicion and intraoperative electrophysiological tests versus radiological imaging**

<table>
<thead>
<tr>
<th></th>
<th>PPV (%)</th>
<th>NPV (%)</th>
<th>Specificity (%)</th>
<th>Sensitivity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgeon’s suspicion</td>
<td>75</td>
<td>99.1</td>
<td>99.5</td>
<td>60</td>
</tr>
<tr>
<td>ECAP</td>
<td>66.6</td>
<td>99.5</td>
<td>96.6</td>
<td>80</td>
</tr>
<tr>
<td>ESR</td>
<td>10</td>
<td>98.2</td>
<td>95.8</td>
<td>20</td>
</tr>
<tr>
<td>Impedance</td>
<td>42.8</td>
<td>99.1</td>
<td>98.3</td>
<td>60</td>
</tr>
</tbody>
</table>

ECAP: Evoked compound action potential; ESR: Evoked stapedius reflex; PPV: positive predictive value; NPV: negative predictive value

DISCUSSION

Many studies have reported on the misplacement and migration of the CI electrode array [9–13, 15]. The average incidence rate of extracochlear misplacement is 0.37% [16] based on various possible causes such as inner ear malformations, temporal bone fracture, otosclerosis, labyrinthitis ossificans, or lack of surgeon experience [11, 16–18].

**Figure 2.** Red arrow indicates tip rollover of electrode array, which does not require immediate revision surgery.
Additionally, it acts as a reference in the future of confirmation to confirm the appropriate placement of the electrode array in activation. Caused by the air bubbles that were solved between the surgery and of the devices with a minimum of 1 abnormal electrode impedance.

The impedance measurements are influenced by the electrode–tissue interface, the resistance in the fluid/tissue environment, and the resistance of the electrode contact and lead wires. The sensitivity and specificity of impedance for identifying electrode functions in CI users were reported to be 91.7% and 97.9%, respectively. Impedance abnormalities, including SC (low impedance, approximately ≤1 kilohm) or OC (high impedance, usually >30 kilohms) are not uncommon findings in the intraoperative or postoperative periods. These abnormalities may adversely affect the performance of the implant and should be defined at the earliest for proper clinical management. Goehring et al. reported that the total incidence of the devices with a minimum of 1 abnormal electrode impedance value was 12.4% and 8.2% at the intraoperative and postoperative intervals, respectively. It was assumed that the abnormalities were caused by the air bubbles that were solved between the surgery and activation.

Intraoperative or postoperative plain X-ray is another common application to confirm the appropriate placement of the electrode array in the cochlea. Additionally, it acts as a reference in the future of electrode migration and provides the surgeon with feedback on the intracochlear position of the array. There is no universally accepted protocol for imaging, but postoperative plain X-ray is routinely performed as a part of CI.

The average skin radiation exposure dose was reported as 1.69–7.25 mGray for plain skull X-ray. Nevertheless, since a minimum of 1000 X-rays would be required to reach 1 gray (malignancy risk level), it seems very difficult to reach the minimum amounts for complications in CI patients. Additionally, in an era of decreasing reimbursements, the cost and labor requirements of plain X-ray are not insignificant. In our country, the cost of a single skull X-ray ranges from approximately 10 to 30 $. Therefore, this application seems to be an area in which some health care cost savings may be realized. However, many surgeons believe that the implications of overlooking extracochlear electrode misplacement are too high to justify neglecting a relatively simple, low radiation exposure and cost saving.

The limitations of the study are the retrospective design of the study and the lack of information on the postoperative device performance.

CONCLUSION
Postoperative imaging is often used to confirm the electrode array position after CI surgery. Although some authors propose to perform routine X-ray only in cases with abnormal anatomy or inappropriate intraoperative findings, this study showed early electrode migration in one case with normal anatomy despite normal intraoperative electrophysiological tests and a surgical note stating full insertion. Therefore, radiological imaging should be used in all cases after CI surgery because of intraoperative non-radiological evaluations that have high specificity but low sensitivity.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Istanbul Faculty of Medicine (No: 2016-92).
Informed Consent: Written informed consent was obtained from the patients who participated in this study and from the parents of the patients who were <18 years of age.

Peer-review: Externally peer-reviewed.


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REFERENCES