CASE REPORT

Preoperative simulation unveiled undetected surgical difficulties in a case of cochlear implantation

Nozomu Matsumoto,¹ Makoto Yamashita,² Byunghyun Cho,² Makoto Hashizume²

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¹Department of Otorhinolaryngology, Graduate School of Medical Sciences, Kyushu University, Fukuoka, Japan

²Department of Advanced Medical Initiatives, Faculty of Medical Sciences, Kyushu University, Fukuoka, Japan

Correspondence to

Dr Nozomu Matsumoto, matunozo@med.kyushu-u.ac.jp

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SUMMARY

We herein report a case in which extensive preparation changed a difficult-to-treat patient into an easy one. We performed a revision cochlear implantation on a patient whose first procedure had been aborted due to unidentified difficulties. During a series of thorough three-dimensional simulations, we found that the patient in question had a normal cochlea but the cochlea was placed in an unusual position and orientation. This condition is difficult to detect on standard preoperative radiographic images. Through this simulation, we were able to propose a surgical plan to avoid making the same mistakes as the first surgeon. We present this case not as a rare difficult case of an unfortunate patient but instead emphasise the importance of performing surgical simulation and looking for non-obvious difficulties. This case is an example of the success that can be achieved with such extensive preparation.

BACKGROUND

The standard surgical procedure of cochlear implantation is called the facial recess approach. However, there are some surgical difficulties that do not allow such standard procedures to be performed.^{1,2} Known difficulties include congenital malformations, anatomical defects due to diseases or anatomy altered by previous surgeries. These difficulties are detectable and assessable before surgery through careful history taking and the evaluation of preoperative CT and/or MRI findings. Unexpected problems encountered during the surgery may result in serious complications or the decision to abort the procedure. Although most cases of inappropriate preoperative assessment of the surgical difficulty are attributable to the surgeon's lack of preparedness, some surgical difficulties are not readily detectable though typical preoperative images.

The authors were involved in research on image-guided surgery (IGS). Partly because of this area of research interest, we perform a quick preoperative three-dimensional simulation before every otological surgery. In cases with cranial malformations or previous surgery of the same site, we perform an extensive simulation with the IGS team to identify any 'hidden' difficulties. In most cases, these preoperative simulations simply confirm the feasibility of the standard procedure. However, we experienced a case in which the preoperative simulation revealed an undetected surgical difficulty and were able to also propose changes to the standard approach to avoid this issue.

Such three-dimensional simulation may help identify surgical difficulties that are otherwise difficult to predict and further enhance the safety of surgery.

CASE PRESENTATION

A 2-year-old girl with congenital profound hearing loss was referred to Kyushu University Hospital after an unsuccessful cochlear implantation procedure at another hospital. Preoperative CT and MRI revealed no anomalies nor any other accompanying diseases. The reason the previous surgeon had aborted the procedure was documented as, "because neither cochlear opening nor perilymph leakage was confirmed after cochleostomy was performed, so cochlear ossification was suspected."

Postoperative CT and MRI performed at Kyushu University Hospital also showed a normal structure of the inner ears without any sign of cochlear ossification. The previous surgery was noted to be performed as a standard procedure, with typical mastoidectomy, a wide opening of facial recess with removal of the incus and cochleostoma at the basal turn of the cochlea (figure 1A). The cochleostoma was plugged with a soft-tissue density material. Because the anatomy looked normal and the previous surgery appeared to have been performed properly, we could not determine what the difficulty that the first surgeon encountered had been. We therefore decided to perform a thorough simulation surgery with the engineers of the IGS team.

INVESTIGATIONS

We performed three-dimensional surgical simulation in the software programme that we use for IGS (3D slicer, www.3dslicer.com; and Mimics, Materialise Japan, Yokohama, Japan). We segmented and coloured the cochlea, semicircular canals and the facial nerve of the CT dataset. The cochleostoma was visible through the facial recess. We then placed a cylinder that represented the first surgeon's imaginary line of sight through the facial recess to the basal turn of the cochlea. The cylinder was found to be placed tangential to the edge of the cochlea. It was not possible to place the cylinder in the direction that goes through the facial recess, cochleostoma and inside the basal turn of the cochlea. When we placed the cylinder in the basal turn of the cochlea through the cochleostoma, the cylinder came out through the external auditory canal. The IGS team therefore proposed a surgical plan to create a small slit at the posterior wall of the external auditory

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Figure 1 (A) Snapshots during three-dimensional simulation. The cochlea and facial nerve were segmented and are coloured in blue and red, respectively. The green cylinder is the imaginary access line to the cochlea from the first surgery. The purple cylinder represents the proposed access line to the cochlea. A video of the simulation is provided as a supplementary material. (B) The revision surgery, which was performed as planned in the simulation. (C) A schematic drawing of the 'usual' cochlear and the 'unusual' placement of the cochlea of this case. EAC, external auditory canal; FN, facial nerve; SS, sigmoid sinus; TM, tympanic membrane. The arrow (a): the usual access to the cochlea and (b) the modified access angle in this case. The arrow (b) to the cochlea has the same spatial relation with the arrow (a) to the 'usual' cochlea.

canal to access the basal turn of the cochlea through the existing cochleostoma ([figure 1A](#), [video 1](#)).

DIFFERENTIAL DIAGNOSIS

Normal anatomy within the temporal bone, but the cochlea placed in a twisted position. Typical differential diagnoses of this

condition of inner ear anomalies or labyrinthitis ossificans were denied by radiographical images.

TREATMENT

The surgical navigation system was not considered necessary for this revision surgery. The surgery was performed exactly as simulated ([figure 1B](#)). The external canal skin and the eardrum were elevated. The posterior wall of the external auditory canal was drilled to create a slit 2 mm in width. The soft tissue on the promontory was unplugged. We were easily able to confirm that the perilymph leaked out from the cochleostoma when observed through the slit. An electrode array was inserted without resistance, and the proper placement of the electrode contacts was confirmed electrophysiologically and radiographically. The electrode lead was brought into the mastoid cavity through the slit. The narrow bony slit did not require reconstruction.

OUTCOME AND FOLLOW-UP

The patient returned to the standard habilitation programme of the original hospital. As of 2 years after the surgery, no postoperative complications such as a retraction pocket forming at the external auditory canal have been noted.

DISCUSSION

Surgical difficulties usually involve the absence or modification of known surgical landmarks. If surgical difficulty is detected preoperatively, surgeons have time to find a solution to avoid any issues based on personal experience, by consulting other experts or by preparing surgical navigation. However, some surgical difficulties are not readily detectable beforehand. In

Video 1 A captured video during three-dimensional simulation. The cochlea and facial nerve were segmented and are coloured in blue and red, respectively. The green cylinder is the imaginary access line to the cochlea from the first surgery. The purple cylinder represents the proposed access line to the cochlea.

such cases of unexpected difficulties, the outcome of the surgery largely depends on the surgeon's experience. This fact ultimately leads to a serious dilemma that only experienced surgeons will be allowed to experience the next surgery.

To the best of our knowledge, literatures that describe anatomically difficult cases in cochlear implantation always referred to congenital malformations, anatomical defects due to diseases or anatomy altered by previous surgeries. The presented patient's cochlea was absolutely normal. The closest report we could find about surgical difficulty of normal anatomy was a conference paper describing 'backwards and twisted cochleas'.³ In backwards and twisted cochlea cases, it is difficult to identify the round window niche in through the facial recess. If a surgeon performs cochleostomy at the imaginary promontory without identifying the round window, the drilling can easily be misdirected anteriorly to the cochlea (arrow (a) in figure 1C). The 'twisted cochlea' is not an anomaly but rather a variation of the spatial placement of the normal component structures. Therefore, this kind of anatomy is usually reported as a normal finding on preoperative CT or MRI, making it difficult to be detected beforehand especially for surgeons with less experience. In severe cases of such anatomical variation, surgeons may have to access the cochlea through the external auditory canal (arrow (b) in figure 1C). In the present case, it was possible to perform a separate cochleostomy posteriorly to the original opening through the existing facial recess opening. However, a separate cochleostomy procedure would have added another uncertainty to the original surgery, as the electrode array inserted through the new cochleostoma must go through a narrow strait at the plugged original cochleostoma. After simulating all possible revision routes, we decided to use the original cochleostoma with a modified insertion angle. Part of the posterior wall of the external auditory canal was removed to secure the access angle. Alternatively, the procedure could also have been performed under endoscope assistance.^{4 5}

An experienced surgeon could have finished this revision surgery without performing simulation and without revealing the difficulty encountered in the first surgery. However, it is important to accumulate knowledge of rare surgical difficulties, such as the present case. In addition, we report this case to further underscore the importance of extensive preoperative preparation and efforts to detect hidden difficulties. It should be noted that all the information we have used was already available in the first hospital. Computerised preoperative assessments are already employed in several institutions for different purposes, such as measuring the length of the cochlear duct preoperatively to determine the optimum size of the electrode array.⁶ Because equipment and software programme for three-dimensional

simulations have become affordable, such simulations may soon come to be included in the preoperative routine, especially in teaching hospitals. The results of computerised simulations can be discussed over the Internet, allowing for interinstitutional and even international collaboration between surgical teams and the IGS team. By sharing simulation data of difficult cases, surgery becomes less dependent on each surgeon's personal experiences. Therefore, future patients with hidden surgical difficulties will be able to experience benefits from preoperative simulations.

Learning points

- ▶ Slight variation in the placement of normal anatomical structures may cause surgical difficulty that is difficult to detect in preoperative CT and/or MRI.
- ▶ Thorough preoperative simulation helped surgeons avoid issues encountered in the previously aborted surgery.
- ▶ Computerised preoperative assessments may soon become a clinical routine so that a surgery becomes less dependent on each surgeon's personal experience.
- ▶ Collaboration between surgeons and the image-guided surgery team can be extended beyond a single institute with the use of such simulations.

Contributors NM is the surgeon who performed revision surgery on this case and wrote this manuscript. MY and BC are the engineers who performed simulation surgery and proposed multiple surgical plans for this case. MH conducted the simulation surgery process.

Competing interests None declared.

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