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Original Article

Cerebrospinal Fluid Gusher in Cochlear Implantation and Its Association with Inner-Ear Malformations

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BACKGROUND: It is aimed to investigate the incidence of cerebrospinal fluid gusher in cochlear implantation and the association between cerebrospinal fluid gusher and inner-ear malformations in adult and pediatric patients.

METHODS: A retrospective case review of 1025 primary cochlear implantation procedures was performed. Patients with inner-ear malformation or cerebrospinal fluid gusher during primary cochlear implantation were included and divided into 2 groups according to age: pediatric and adult groups.

RESULTS: The incidence of inner-ear malformation was 4.19% (17/405) and 7.6% (47/620) in the adult and pediatric groups, respectively. There was a significant difference in the incidence of inner-ear malformation in the pediatric group. The incidence of cerebrospinal fluid gusher was 0.9% (4/405) and 4.1% (26/620) in the adult and pediatric groups, respectively. There was a significant difference in the incidence of gusher between the adult and pediatric groups.

CONCLUSION: The incidence of a cerebrospinal fluid gusher is higher in the pediatric group, compared to adults due to a higher rate of inner-ear malformation. Inner-ear malformation poses a risk factor for cerebrospinal fluid gusher.

KEYWORDS: Cochlear implantation, ear, inner, radiology, cerebrospinal fluid otorrhea

INTRODUCTION

Profuse clear fluid leak after opening the inner ear during surgery is called "gusher" in the literature. Gushing of cerebrospinal fluid (CSF) during cochlear implantation (CI) can lead to an increased risk of meningitis, erroneous electrode insertion, poor speech understanding, and word acquisition.[1,2] The incidence of CSF gusher in CI has been reported to be between 1% and 5%.[3] It is known that the incidence can reach up to 40% in the presence of inner-ear malformation (IEM).[4] Management of gusher is important for the safety of the patients and surgery. Both conservative and surgical treatments are used in the presence of a gusher. Although it can be managed by minor surgical intervention, it may be a life-threatening complication. Thus, the risk and management of gusher in CI should be considered.

In this study, we aimed to investigate the incidence of CSF gusher in CI with or without IEM and the association between CSF gusher and IEM in adult and pediatric patients.

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METHODS

After ethical committee approval (May 8, 2019/03), a retrospective chart review was performed on 1025 CI procedures, including children and adults, at the Otorhinolaryngology Clinic of the University of Health Sciences, İzmir Bozyaka Education and Research Hospital between 2009 and 2019. The study included only patients with profuse CSF gusher and/or IEM, during primary surgery. Cases with oozing, pulsatile perilymph, or mild leaks were excluded. Patients with CI were divided into 2 groups according to age: pediatric (≤17 years) and adult (≥18 years) patients. Cochlear and vestibular malformations were classified according to the Sennaroglu classification.[5] Then, the patients were subdivided into groups according to the presence/absence of gusher and IEM. Patients with IEM were further divided into subgroups according to the type of anomalies. The demographic characteristics of the patients, surgical results, and management techniques for CSF gusher were evaluated.

Computed tomography (CT) and magnetic resonance imaging (MRI) examinations of the patients were re-evaluated using advanced techniques. All MRI examinations were performed on a 1.5T MRI system (Philips Achieva, Philips Healthcare, Best, the Netherlands). Inner-ear structures were examined with a 3-dimensional balanced gradient echo-weighted sequence. Temporal bone CT imaging was performed using a 64-channel multi-detector scanner (Aquilion; Toshiba Medical Systems, Tokyo, Japan). Temporal bones were visualized in 3 basic planes (axial, sagittal, and coronal), and isometric reconstruction at each 0.5, 1, or 2 mm.

Statistical Analysis

For statistical analysis, we used the Statistical Package for the Social Sciences 22 (IBM SPSS Corp.; Armonk, NY, USA). Chi-square and Fisher's exact test were performed to evaluate any significant difference between the groups based on P value $< .05$.

RESULTS

A total of 1025 CIs were performed at our clinic between 2009 and 2019. Of these operations, 620 were in the pediatric group and 405 in the adult group. There were 64 patients with IEM, 17 and 47 in the adult and pediatric groups, respectively. The incidence of IEM in CI was 6.24% (64/1025), 4.19% (17/405), in the adult group and 7.6% (47/620) in the pediatric group. A chi-square test showed that there was a significant difference in the pediatric group in the incidence of IEM (Table 1). In the patients with IEM, 22 operations were performed on the left side and 42 operations on the right side. The mean age was 10.54 years (SD = 13.57). Gusher was detected in 25 of 64 (39%) ears. Despite having IEM, the gusher was not observed in 39 ears whereas it was seen in 5 of the remaining 961 patients without IEM. A comparison between the gusher without IEM (n = 5) and gusher with IEM groups (n = 25) showed that the presence of IEM was a statistically significant high risk for the gusher ($P = .002$) (Table 2).

Table 1. IEM and Gusher Rates in CI According to Age Groups

n	Pediatric (n = 620)	Adult (n = 405)	*P*	Total
IEM	47 (7.6%)	17 (4.2%)	.009	64 (6.2%)
Gusher	26 (4.2%)	4 (1%)	.003	30 (2.9%)

CI, Cochlear implantation; IEM, inner-ear malformation.

The incidence of gusher was 2.92% (30/1025) in patients with CI, and it was 0.9% (4/405) and 4.1% (26/620) in the adult and pediatric groups, respectively. A chi-square test showed that there was a significant difference between the adult and pediatric groups in the incidence of gusher (Table 1). In the gusher group (n = 30), 7 surgeries were performed on the left side and 23 operations on the right side. The mean age was 6.07 (SD = 6.79) in the gusher group, including 4 patients in the adult group and 26 patients in the pediatric group. Inner-ear malformation was detected in 25 of 30 ears in patients with gusher. The probability of detecting IEM in patients with gusher was significantly higher than in patients without gusher ($P < .001$).

In the postoperative period, the gusher persisted in 4 patients. The complaints of 2 patients were resolved with conservative methods. The remaining two patients were re-operated to avoid gusher complications such as meningitis, and the gusher was controlled.

Five patients had gusher, but IEM was not present. Radiological findings of 5 patients without IEM were re-evaluated. Two of these 5 patients had a defect at internal acoustic canal (IAC) fundus. However, there was no cochlear basal turn defect.

In patients with IEM, 5 (7.8%) patients had incomplete partition type 1 (IP1), 28 (43.7%) incomplete partition type 2 (IP2), 9 (14%) incomplete partition type 3 (IP3), 3 (4.6%) common cavity (CC), 13 (20.3%) isolated enlarged vestibular aqueduct syndrome (EVA), 5 (7.8%) cochlear hypoplasia (CH), and 1 (1.5%) isolated semicircular canal aplasia. The findings of our study showed that among 9 patients with IP3, 8 had gusher ($P = .04$). The rate of gusher in patients with IP3 was 88.8%. The analysis results and the data for all groups are presented in Table 3.

DISCUSSION

Gusher is a problem that may occur during CI and/or postoperative period. The gentle flow of clear fluid that develops during cochleostomy is called "oozing," while profuse and rapid flow is called "gusher."[6] The risk of postoperative meningitis is much higher in the presence of a gusher. Also, it may lead to difficulties during electrode insertion

Table 2. Gusher Rates in CI According to Age Groups and IEM

n	IEM (+)	IEM (−)	Total
Pediatric	21 (44%)	5 (0.9%)	26 (4.2%)
Adult	4 (23.5%)	0	4 (1%)
Total	25 (39%)	5 (0.9%)	30 (2.9%)

CI, cochlear implantation; IEM, inner-ear malformation.

MAIN POINTS

- Gusher may be seen with normal radiological anatomy during cochlear implantation.
- Inner-ear malformations increase the risk of gusher in the cochlear implantation.
- Incomplete partition type 3 patients have a higher risk of gusher compared to other inner-ear malformation subgroups.
- Conservative methods and meticulous postoperative care are generally enough to stop the gusher.

Table 3. Gusher Rates at IEM Subgroups and '*P*' Values

	n	%	*P*
Incomplete Partition 1	2/5	40	.625
Incomplete Partition 2	8/28	28.5	.076
Incomplete Partition 3	8/9	88.8	.004
Common Cavity	0		.174
Cochlear Hypoplasia	1/5	20	.271
Enlarged Vestibuler Aquaduct	5/13	38.4	.685
Isolate SCC Absence	1/1	100	.435

IEM, inner-ear malformation; SCC, semicircular canal.

causing misplacement, poor speech understanding, and word acquisition. Excessive CSF can usually access the cochlea through patent developmental pathways of the otic capsule. It has been shown that the risk of gusher may increase in IEM.[4] Preoperative radiology should be carefully examined, and postoperative follow-up should be done closely to prevent any potential complications. According to Sennaroglu et al.[5] IEM can be classified as labyrinthine aplasia, cochlear aplasia, cochlear hypoplasia, CC deformity, and incomplete partition, which, in itself, has 3 subgroups. Inner-ear malformation represents approximately 20-30% of the congenital hearing loss cases based on radiology results.[7] Ding et al[3] mentioned in a review that IEM, including cochlear ossification and round window dysplasia, had an incidence of 22.4% in CI. In our study, the incidence of IEM was 6.24% in 1025 ears with CI, which is consistent with the literature.[8,9] When patients with IEM were examined separately in the adult and pediatric groups, we found that the incidence of IEM was 4.19% and 8.38% in the adult and pediatric groups, respectively. In the literature, the gusher rate was reported between 5% and 6.7 % in CI.[3,10-12] In our study, CSF gusher rate in CI was 2.92 %, which was also consistent with the literature. The incidence of gusher was 0.9% and 4.1% in the the adult and pediatric groups, respectively. We believe that this difference is due to the higher rate of IEM in pediatric patients.

Inner-ear malformation is considered a predisposing factor for CSF gusher.[13] Merhy et al[14] previously have shown that the incidence of CSF gusher increases in the presence of IEM. Hashemi et al[15] statistically proved the presence of a correlation of IEM with the CSF gusher. In our study, gusher rate of patients who had IEM was 39.1% (25/64) in parallel with the literature.[13] It can be said IEMs increase the risk of gusher in the CI.

There were 5 (0.5%) ears with gusher in 956 patients without IEM. It has been previously reported that gusher was found in patients with bone defects at the fundus of the IAC or at cochlear basal turn.[16-18] We evaluated the radiologic examinations of our 5 patients again. They had no cochlear basal turn or IAC defect. In 2 of these 5 patients, there was isolated cochlear septal defect only. This factor might have played a role in the mechanism of gusher.[17]

Although during the preoperative radiological examinations, some patients had defects in the inner ear, which may lead to CSF leak, gusher did not occur in 3 patients with IP1, 20 patients with IP2, 1 patient with IP3, 4 patients with CH, 8 patients with EVA, and none of the ears with CC had gusher during surgery. Sennaroglu et al referring to this dilemma suggested that a fibrotic tissue, not detectable on radiological examinations, may prevent gusher during surgery.[19]

There is limited data on the incidence of gusher in IEM subtypes in the literature. It has been reported that the gusher rate was 39-45.9% in IP1, 8-15% in IP2, 100% in IP3, 27% in CH, 23-27% in CC, and 0-11% in EVA groups.[13,20-24] But no statistical analyses were performed between the groups. Sennaroglu et al[19] reported in their review that gusher rates were 100% in IP3, 39% in IP1, 15% in IP2 and there was not any gusher in CC and EVA groups. In our study, there was a CSF gusher in 8 of 9 patients (88%) who had IP3 malformation, followed by 40% in IP1, 38.4% in EVA, 28.57% in IP2, and 20% in CH groups. There was a statistically significant difference in IP3 group among other IEM groups. In a meta-analysis, Farhood et al[20] reported that the gusher rate was 45.9% in IP1 group. Despite a small sample size in our study, the gusher rate was 40% in IP1 group. It is thought that the gusher risk may be high in individuals with CC malformation, due to the frequent lateral wall anomalies in IAC. However, in our study, no patient with gusher was found in the CC malformation subgroup. Similar to our findings, in the review of Sennaroglu et al[19] and in the meta-analysis of Shi et al.[21] it was reported that the incidence of gusher was low in patients with CC malformation. Bajin et al[22] reported that the gusher rate was 8% in IP2 group. In our study, the gusher rate was 28% (8/28) in IP2 group. Bajin et al emphasized the relationship between modiolar base defect grade and risk of gusher. In our study, the reason for the higher rate of gusher in IP2 group can be explained by the presence of high-grade modiolar base defect. However, the IP2 group was not evaluated in this respect in our study. Further studies are needed to demonstrate the relationship between the level of modiolar base defect and the risk of gusher.

Our study covers a period of 10 years and all surgeons adopted the same surgical philosophy in our center. During surgery, if gusher occurs, waiting for about 10 minutes is generally enough to reduce the outflow speed of CSF. When it slows down, surgeons should perform a large cochleostomy as Graham et al[23] suggested. It makes electrode insertion easier and with the large cochleostomy, application of a piece of muscle and fascia is easier for achieving a watertight sealing. Additionally, we use Tisseel Kit fibrin sealant (Baxter, Deerfield, Ill, USA) to strengthen the seal, but not to stop the gusher outflow. Following this, the eustachian tube should be blocked temporarily with oxidized cellulose to prevent CSF from leaking to the nasopharynx. Also especially in IP groups, we use a cork-type stopper cochlear implant electrode or prepare a perichondrium stopper that covers the electrode shaft circumferentially, which was suggested by Sennaroglu et al.[24] A 3-layer wound closure is important to achieve a watertight closure. Compression head dressing is applied and head elevation during bed rest for up to 3 days is recommended for all patients. Meticulous packing of the cochleostomy with these conservative precautions was enough to stop the gusher in our patients. There was no need for further interventions like petrosectomy or lumbar CSF drainage. In all patients, complete insertion of all active electrodes was accomplished and subsequent functioning of the implants was satisfactory.

CONCLUSION

The incidence of gusher is higher in the pediatric group, compared to adults due to a higher rate of IEM. Inner-ear malfunction is a risk

factor for gusher, and in IP3 patients, there was a statistically significant higher risk of gusher compared to other IEM subgroups. Gusher may be seen with normal radiological anatomy during CI. Therefore, CI surgeons should always be prepared for the risk of gusher and know what to do for management of gusher.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of University of Health Sciences, İzmir Bozyaka Education and Research Hospital (08/05/2019 Decision no: 03).

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