Cerebrospinal fluid leak during stapes surgery: Gushing leaks and oozing leaks, two different phenomena

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Abstract

Cerebrospinal fluid (CSF) leak is an uncommon event that can occur during stapes surgery. Such leaks can be classified as gushing *leaks (stapes gushers) and* oozing *leaks. A stapes gusher is a massive flow of CSF through the perforated footplate that fills the middle ear suddenly, while an oozing leak is a slower and less profuse flow. We conducted a retrospective, observational, multicenter study of 38 patients—23 men and 15 women, aged 23 to 71 years (mean: 47)—who had experienced a CSF leak during stapes surgery. Patients were divided into various groups according to the type of surgical procedure performed and the type of postoperative complications they experienced. Audiometric and clinical evaluations were carried out pre- and postoperatively. Correlations among surgical variations (total or partial stapedectomy, placement of a prosthesis), hearing outcomes, and the incidence of postoperative complications (postoperative CSF leak and vertigo) were studied. Our statistical analysis revealed that gushing leaks and oozing leaks result in different degrees of hearing impairment and different rates of complications. We recommend that an individual approach be used to manage these complications.*

Introduction

Cerebrospinal fluid leak (CSF) is an uncommon complication of stapes surgery. Such leaks can be classified as *gushing* leaks (stapes gushers) and *oozing* leaks. A stapes gusher is a massive flow of CSF through the perforated footplate that fills the middle ear suddenly. This phenomenon generally occurs as the result of an abnormal communication between the perilymphatic and subarachnoid spaces.[1] The abnormal communication with the subarachnoid spaces might involve the cochlear duct or internal auditory canal.[2,3] An oozing leak is a slower and less profuse flow of fluid.[4]

Jackler and Hwang carried out a study on the enlargement of the cochlear aqueduct.[5] They found that radiologic evidence of an enlargement of the cochlear aqueduct is not a relevant finding in cases of stapes gushers and transotic CSF leaks. They concluded that a defect of the fundus of the internal auditory canal is more likely to produce a perilymph gusher. Other authors have reached the same conclusion.[1,4] On the other hand, it seems that a patient with an intraoperative oozing leak could be affected by an enlargement of the cochlear aqueduct.[1,4]

Most reported cases of CSF leaks related to stapes surgery are congenital (X-linked progressive mixed deafness), although adults affected by otosclerosis can also experience this complication during surgery.[6,7] The reported incidence of stapes gusher has ranged from 1 in 500 to 1 in 3,300 stapes operations.[8,9] A survey by the American Otological Society published in 1993 found that 46% of surgeons had observed one or two episodes of stapes gusher in their practice.[10]

In this article, we describe the results of our study of CSF leaks during stapes surgery.

Patients and methods

We conducted a retrospective, observational, multicenter study of 38 patients—23 men and 15 women, aged 23 to 71 years (mean: 47)—who had experienced a CSF leak during stapes surgery between 1960 and 2005. These surgeries had been performed at three institutions:

- From 1960 through 1985, 32 patients had experienced a CSF leak at the Salvá Clinic in Barcelona,

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Spain (approximately 20,000 stapedectomies had been performed during this period).[11-13]

- At Vall d'Hebron University Hospital in Barcelona, 4 patients treated between 1980 and 1990 had experienced a CSF leak.[14]
- Two patients treated at the Policlinico Universitario in Messina, Italy, between 1995 and 2005 had experienced a leak.

In addition to accumulating demographic data, we reviewed the patients' charts for information on their preoperative history, the surgical technique, postoperative complications, and hearing outcomes. Our inclusion criteria were a diagnosis of otosclerosis based on a clinical history of progressive hearing loss, normal otoscopic findings, an audiogram showing a mean conductive hearing loss greater than 20 dB nHL in the range of 0.5 to 4 kHz, the absence of cochleostapedial reflexes, surgical findings of otosclerosis, and an intraoperative CSF leak.

Surgical technique. Thirteen patients underwent a total stapedectomy and 25 a partial stapedectomy.

Among the 32 patients operated on at the Salvá Clinic, 16 received a polyethylene prosthesis, 7 a tantalum prosthesis, and 4 a Shea Teflon (polytetrafluoroethylene) piston prosthesis; 5 patients did not receive a prosthesis. All 4 patients operated on at Vall d'Hebron University Hospital received a polyethylene prosthesis. Of the 2 patients seen at Policlinico Universitario, 1 received a polyethylene prosthesis and the other did not receive a prosthesis.

All patients underwent intratympanic placement of Gelfoam, packing of the external auditory canal, postoperative antibiotic prophylaxis, and postoperative elevation of the head at a 45° angle.

The 6 patients who did not receive a prosthesis all had experienced a massive intraoperative flow of CSF that did not allow the surgeons to insert a prosthesis. In these cases, closure of the oval window with an autologous graft (perichondrium or muscular fascia) and intratympanic placement of Gelfoam were performed. Catheterization of the subarachnoid space, as described by Shea,[15] was not needed in any of our cases.

Evaluations. Audiometric and clinical evaluations were performed preoperatively at least 48 hours before surgery and postoperatively between 4 and 6 weeks after surgery. The audiometric evaluations were carried out according to the guidelines of the American Academy of Otolaryngology–Head and Neck Surgery's Committee on Hearing and Equilibrium.[16] We did not evaluate speech audiometry. Audiograms obtained before 1995 were also interpreted according to these guidelines.

In all patients, a four-frequency pure-tone average (PTA) was measured for both air- and bone-conduction values. We compared the mean pre- and postoperative PTAs for air conduction, bone conduction, and air-bone gap (ABG) at 0.5, 1, 2, and 3 kHz.

Complications. We documented the incidence of two complications—CSF leak and vertigo (any vertigo, mild vertigo, and severe vertigo). CSF leak was considered a postoperative complication only if it arose or persisted after surgery; intraoperative leaks were not considered a postoperative complication. Vertigo was defined as severe when characterized by long duration (i.e., days), nausea, and vomiting.

Comparison groups. Patients were assigned to various groups according to the type of surgical procedure performed and the type of postoperative complication.

Patients were assigned to four groups according to the extent of surgery—total stapedectomy (n = 13) or partial stapedectomy (n = 25)—and according to whether a prosthesis was placed (n = 32) or not placed (n = 6).

As for postoperative complications, we designated patients into eight groups: any vertigo (n = 29), no vertigo (n = 9), mild vertigo (n = 19), no mild vertigo (n = 19), severe vertigo (n = 10), no severe vertigo (n = 28), postoperative CSF leak (n = 5), and no postoperative CSF leak (n = 33).

Statistical analysis. Statistical analyses were performed with an open-source R3.0 software package.[17] The Wilcoxon signed-rank test was used for pre- and postoperative intragroup analyses, and the Mann-Whitney *U* test was used for intergroup analyses. The chi-square (χ^2) test was used to define the presence or absence of postoperative complications within groups formed according to the type of surgery. Statistical significance was set at $p < 0.05$.

Results

We compared pre- and postoperative air-conduction, bone-conduction, and ABG values within and between groups (data available in table form upon request from the corresponding author):

- From the intragroup analysis, we found a statistically significant difference between pre- and postoperative values for all three measurements in patients who had undergone a total stapedectomy and placement of a prosthesis (a reduction in air-conduction and ABG values and an increase in bone-conduction values).
- Likewise, we found a significant difference in pre- and postoperative values in those who did not undergo a total stapedectomy and placement of a prosthesis (a reduction in bone-conduction values and an increase in ABG values).
- There was a significant difference in patients who did not experience any vertigo, severe vertigo, and CSF leak. There was a significant difference in patients who experienced mild vertigo.

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Table. Correlations among postoperative complications and surgical variations

	No	Yes	Total	χ^2 Value	*p* Value
Total stapedectomy					
Postoperative CSF leak				1.499	0.2208
No	20	13	33		
Yes	5	0	5		
Total	25	13	38		
Mild vertigo				1.871	0.1714
No	15	4	19		
Yes	10	9	19		
Total	25	13	38		
Severe vertigo				0.512	0.4745
No	17	11	28		
Yes	8	2	10		
Total	25	13	38		
Prosthesis placement					
Postoperative CSF leak				12.725	<0.001*
No	2	31	33		
Yes	4	1	5		
Total	6	32	38		
Mild vertigo				4.948	0.0261†
No	6	13	19		
Yes	0	19	19		
Total	6	32	38		
Severe vertigo				15.693	<0.001*
No	0	28	28		
Yes	6	4	10		
Total	6	32	38		

* $p < 0.01$
† $p < 0.05$

- Testing revealed a significant difference in bone-conduction (an increase) and ABG (an increase) values in patients who experienced any vertigo, mild vertigo, and severe vertigo.
- We found no significant differences in air-conduction, bone-conduction, and ABG values in patients who experienced a postoperative CSF leak.
- Patients who did not experience any vertigo or postoperative CSF leak showed a significant increase in bone-conduction values and a reduction in ABG values.
- From the intergroup analysis, we found significant differences in pre- and postoperative air-conduction, bone-conduction, and ABG values between those who did and did not receive a prosthesis (lower values in those who did), between those and those who did not experience a postoperative CSF leak (higher bone-conduction values in patients who did), and between those who did and did not experience severe vertigo (higher bone-conduction values in those who did). Also, significant differences were found in air-conduction and bone-conduction values between those who did experience mild vertigo and those who did not.

The correlations among surgical variations and postoperative complications were statistically significant. In particular, patients who did not undergo placement of a prosthesis reported a higher incidence of mild and severe vertigo and postoperative CSF leak (table). No other correlations were statistically significant.

Discussion

To the best of our knowledge, ours is the largest study of patients who experienced an intraoperative CSF leak during stapes surgery.[11-14]

Radiology can help surgeons prevent and evaluate stapes gushers. Suggestive signs of a possible gusher are dilation of the internal auditory canal fundus, dilation of the vestibule, widening of the vestibular aqueduct (diameter: >1.5 mm), widening of the cochlear aqueduct, cochlear dysplasia (widening of the upper cochlear canal >2.2 mm, an incomplete cochlear partition, or modiolus abnormalities), and dilation of the first portion of the facial canal.[18-20] However, gushers have occurred even in patients whose preoperative imaging was normal, particularly in those undergoing cochlear implant surgery.[21,22] McFadden et al[23] and Krouchi et al[24] reported some cases of stapes gushers occurring during stapes surgery in patients with a normal preoperative computed tomography (CT) scan.

Since stapes gushers are rare and preoperative CTs are not completely reliable in the prevention of this event during stapedectomy, obtaining a CT scan for each patient appears to be excessive. On the other hand, in a review published in 2013, Virk et al reported that CT does have a useful role in the diagnosis and management of otosclerosis.[25] Nevertheless, patients who have a history of perilymphatic gusher and boys with a suspected congenital stapes fixation (congenital otosclerosis appears to be related to sex) should undergo CT before surgery.[26]

Causse et al described two intraoperative anatomic alterations that might suggest to a surgeon the possibility that a stapes gusher might occur: a congenital avascu-

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larization of the middle ear and an abnormally anterior insertion of the posterior crus into the footplate.[9]

Based on the pre- and postoperative air-conduction, bone-conduction, and ABG values, our study found a general gain in hearing and a worsening in bone conduction, although some patients experienced a relevant hearing loss. Most patients who presented with more severe postoperative hearing loss complained of postoperative vertigo; only a few of them experienced a postoperative CSF leak.

Patients who had undergone placement of a prosthesis reported significantly better hearing outcomes than did those who had not received a prosthesis, as would be expected. Conversely, the decision to perform a total stapedectomy rather than a partial stapedectomy did not appear to influence hearing outcomes significantly. With regard to postoperative complications, patients who had not received a prosthesis had a significantly higher incidence of postoperative CSF leak and severe vertigo. CSF leak arose or persisted postoperatively in 5 of the 6 patients who had not undergone prosthesis placement. In these patients, a successful second-look surgery was performed and the leak was stopped by placing a prosthesis or by adding an autologous graft of perichondrium or muscular fascia with Gelfoam. Other surgical variations did not seem to influence the onset of postoperative complications significantly.

Patients who experienced a postoperative CSF leak and those who complained of vertigo, especially severe vertigo, had significantly greater hearing loss, which suggested that irreversible damage to the inner ear had occurred. The worst hearing outcomes and the highest incidence of complications were seen in the 6 patients who had not received a prosthesis.

Several cases of stapes gusher have been reported in the literature. Some authors performing stapedectomy have reported intraoperative stapes gushers in patients who did not experience hearing gain, as well as those who experienced progressive hearing loss.[7,27-29] Conversely, Dornhoffer et al described 10 gusher patients who were operated on successfully.[30] Voelter et al presented 4 cases of gusher without postoperative sensorineural hearing loss.[31]

Some authors have focused their attention on surgical management and prevention of gushers. Farrior and Endicott proposed a technique for closing the aqueduct of the cochlea; they believed that the communication with the subarachnoid space was located at that level.[27] Rebol recommended that stapedectomy not be performed in patients at high risk of gusher; instead, he preferred a small-hole stapedotomy.[32] The use of laser technology might also help decrease the incidence of gusher.

The technique used to repair a CSF leak varies according to the source of the leak, the size of the defect, and the status of the patient's hearing. In general, the goal is to isolate the CSF from the middle ear space, or at least from the eustachian tube orifice, thus preventing retrograde infection and troublesome headaches from decreased CSF pressures.[4]

Although our retrospective study did not include a long-term follow-up and the value of the audiometric evaluations was limited, it seems that gushing and oozing leaks are associated with different degrees of hearing impairment and complications.

In our opinion, an individual surgical approach should be used for every patient. In the case of a heavy gusher, surgery should be discontinued and a waterproof repair of the oval window should be made with an autologous graft. On the other hand, oozing leaks can often be controlled by a quick insertion of the prosthesis and sealing with connective tissue.[33]

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Continued from page 300

sound is effectively transmitted to the contralateral ear via bone conduction.

At the effective masking level, a significant difference was not observed between the contralateral ear and the BAHS ear without overmasking. The participants could discriminate the speech by hearing with the contralateral ear when the ipsilateral ear was masked with an insert earphone. When a mask was administered above the effective masking level (overmasking), the discrimination of the contralateral ear decreased, although this decrease was not found to be statistically significant. The obtained data suggest that unilateral BAHS application could prevent or slow the neural deprivation of the contralateral ear.

Although there were 28 BAHS patients at the beginning of the study, we had to perform this study with 5 patients. As we noted previously, the patients were tested for masking to avoid insufficient masking or overmasking, and most of the patients excluded from the study had a masking dilemma (ipsilateral masking was not sufficient or caused overmasking). The limited number of patients may be a weakness of the current study, so the findings should be considered preliminary. Further clinical investigations with more subjects on this topic are needed.

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