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Less Than 1% Cerebrospinal Fluid Leakage in 1,803 Translabyrinthine Vestibular Schwannoma Surgery Cases

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Objective: To determine the incidence rate of cerebrospinal fluid (CSF) leak after translabyrinthine vestibular schwannoma surgery since the alteration of the surgical procedure. To compare with previous series and other series in literature.
Study Design: Database analysis.
Setting: Tertiary referral neurotologic private practice.
Patients: A series of 1,803 patients who underwent translabyrinthine vestibular schwannoma surgery between 1993 and 2009. The result of this group was compared with corresponding series.
Intervention: Translabyrinthine and extended translabyrinthine vestibular schwannoma surgery. Literature review and comparison.
Main Outcome Measures: Rates of CSF leak in this series and historical perspective of the outcome.
Results: Fifteen patients (0.8%) of 1,803 cases had CSF leaks. The method used since 1993 has shown a significant improvement compared with major case series of the last 10 years.
Conclusion: The methods used in translabyrinthine vestibular schwannoma surgery in our center can reduce CSF leakage to an absolute minimum. Compared with all large series, this could be a new era of translabyrinthine vestibular schwannoma surgery. **Key Words:** Acoustic neuroma—Cerebrospinal fluid leak—Prevention—Cranial base—Vestibular schwannoma.

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When William House (1) developed the translabyrinthine approach during the 1960s, it was a huge step forward in vestibular schwannoma surgery. Nevertheless, it resulted in a 20% cerebrospinal fluid (CSF) leak (2). Cerebrospinal fluid leakage is a serious complication because it can lead to meningitis (3), can lead to a reoperation (4), and can lead to an increased length of stay in the hospital (2,4). Many articles introducing modifications to the original technique to diminish this complication have been published. One of the most important modifications is the introduction of abdominal fat instead of temporalis muscle to close the dura and surgical cavity (5) and later strips instead of a whole piece of fat (6). Further improvements were a careful layered wound closure and a pressure head dressing (7). These modifications led to a decreased incidence from 20 to 6.8% in the same clinic (2). Still, in all publications concerning vestibular schwannoma surgery, independent of the type of approach, CSF leaks are reported. The ultimate method to avoid a CSF leak has not been published yet.

In this article, we report our experience in an attempt to solve the CSF leakage problem in the enlarged translabyrinthine vestibular schwannoma approach (ETLA). Our focus is solely on the translabyrinthine approach because each approach has different strategies to avoid complications. We present the latest data on CSF leakage in our series of 1,803 cases, which are operated on using this technique (since 1993), and review of the literature to evaluate the methods used.

MATERIALS AND METHODS

Subjects

All 1,803 charts of the patients who underwent surgery for vestibular schwannoma removal at our center (Piacenza and Rome, Italy) in the period from July 1993 to July 2009 were analyzed and incorporated with the database analysis of our previous proceedings (8,9). The database is a collection of our patient data since 1987, but since July 1993, the method of vestibular schwannoma surgery was changed in our center to reduce the amount of CSF leakage (10). Chart analysis searched for the

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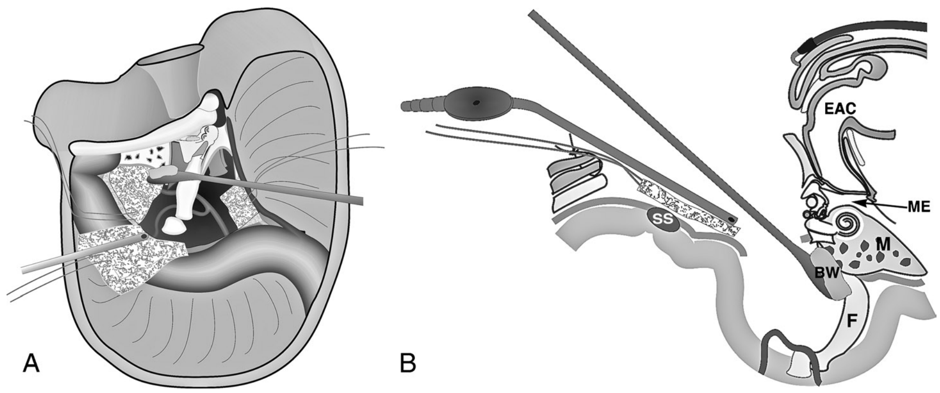

FIG. 1. *A*, Drawing of the surgical view in a translabyrinthine approach. With a small raspatory, bone wax was applied in the retrofacial cell area. If cells in this region are still open, during obliteration of the middle ear, fluid or air bubbles will come out; these cells should be closed subsequently. *B*, Drawing of the surgical view in a translabyrinthine approach. A wide exposure of the surgical field is necessary to visualize all the temporal bone cells. With a small raspatory, bone wax was applied in the retrofacial cell area. BW indicates bone wax; EAC, external auditory canal; F, facial nerve; M, mucosal cells in the petrous apex; ME, middle ear; SS, sigmoid sinus.

date of surgery, age and sex of the patient, size of the tumor, presence or absence of CSF leak, and, when present, the localization of the leakage and the way it was managed.

Literature Review

A review of the literature was done using MEDLINE and PubMed, using the following key words: "vestibular schwannoma," "acoustic neuroma," "translabyrinthine," "CSF," and "cerebrospinal fluid." Limitations were English and publications in the last 10 years. Of all publications, we selected the publications concerning vestibular schwannoma surgery with case series of at least a 100 patients operated on via the translabyrinthine approach and mentioning their CSF leakage rate. In these publications, some centers refer to earlier published series of the same clinic. These earlier published data were as also collected to have a comparable size in historical series.

Surgical Technique

The surgical technique has been published in detail previously (10) but will be summarized as follows.

Opening

The surgical incision is a standard U-shaped postauricular incision approximately 2 finger breadths superior to the pinna, 3 to 4 fingers behind the postauricular fold, and extending inferiorly up to the mastoid tip. A subcutaneous flap is elevated, exposing the temporalis fascia, and retracted away from the operative site with hooks. A T-shaped incision is made in the fasciomusculoperiosteal layer down to the bone, with the long arm of the incision extending to the mastoid tip. Anterior, superior, and posterior fasciomusculoperiosteal flaps are elevated using a strong elevator and are stitched to the skin, respectively. With a large cutting burr, remains of the periosteum are collected from the exposed bone.

A wide mastoidectomy is performed, exposing the middle fossa dura, sigmoid sinus, sinodural angle, and digastric ridge. During the bone work, as many cells as possible are exenterated from the mastoid tip, infralabyrinthine, supralabyrinthine, and zygomatic regions. Cells that cannot be exenterated completely are packed with bone wax after removing the mucosa from such cells (Figs. 1A, B). Particular care should be exercised at this stage not to open the facial and subfacial (sinus tympani) recesses, which can result in the formation of a communicating channel between the subarachnoid space and the tympanic cavity. After wide mastoidectomy, a complete labyrinthectomy is performed. The internal auditory canal is identified, and its contents are exposed to 270 degrees around its circumference. During exposure of the internal auditory canal, suprameatal (petrous apex) and inframeatal (infralabyrinthine) apical cells can be encountered, which are closed using

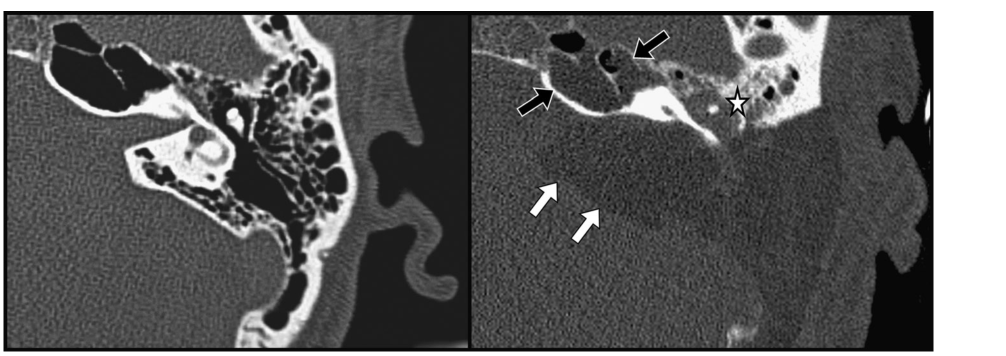

FIG. 2. *Left picture*, Preoperative computed tomographic scan (at the level of the lateral semicircular canal) of a highly pneumatized petrous bone. Note the highly pneumatized petrous apex. *Right picture*, Computed tomographic scan at the same level as the preoperative picture of the same patient on the fifth postoperative day after ETLA in which the petrous apex has been filled with bone wax (*black arrows*), the surgical field obliterated with fat strips into the CPA (*white arrows*), and the middle ear filled with periosteum (*star*). Note the air filled most apical cell, the malleus head in the middle of the obliterated middle ear, and the extension of the fat into the CPA.

bone wax as described previously. Obliteration of the cell should be performed preferably soon after it is opened and certainly before opening the dura because it has been observed that once CSF comes in contact with the mastoid cells, closure becomes more difficult and less reliable (8). Also, apical cells should be packed completely with bone wax (Fig. 2).

Closure

After tumor extirpation, the incus is disarticulated and removed from the tympanic cavity using a right-angle pick. The movement for disarticulating the incus should follow a horizontal plane, parallel to the tympanic membrane, to avoid fracture/dislocation of the stapes foot plate. Subsequently, the attic and middle ear are plugged with the dry periosteum that was collected at the start of the operation. The pieces of periosteum are pushed medial and lateral to the head of the malleus into the tympanic cavity and toward the eustachian tube opening to obliterate the middle ear space and also to achieve a watertight closure of the aditus. During this packing next to the malleus and the obliteration of the retrofacial cells, sometimes fluid, mucosa, or air comes out of other cells, which are to be filled with bone wax subsequently (Figs. 1A, B). A careful inspection of the mastoid with a small hook will ensure that all open cells can be closed with bone wax.

Obliteration of the operative site is accomplished by packing it with long strips of abdominal fat in such a manner that part of the strips protrudes into the cerebellopontine angle (CPA). The fat strips are similar to the size of the tumor (Fig. 3). No attempt is made to suture the dural edges. The fasciomusculoperiosteal flaps are sutured in a watertight fashion (Fig. 4). The skin flap is reflected back and fixed to the underlying musculofascial layer with 2 to 3 absorbable stitches; this prevents collection of blood or CSF underneath. Skin edges are sutured using black silk and a compression head bandage is applied, which is kept in place for 5 days. A lumbar drain is *not* needed using this method. One week after surgery, patients are discharged and received an outpatient follow-up appointment.

In difficult cases, such as highly pneumatized temporal bone, the posterior canal wall is lowered down, and the canal skin with the tympanic membrane and ossicles are removed. Thereafter, the mucosa is stripped from the middle ear and from the eustachian tube and then packing the eustachian tube with periosteum, obliteration of the whole cavity with fat, and, finally, closing the ear canal as described by Fish and Mattox (11). Follow-up and magnetic resonance imaging after ETLA surgery is at 2 months and 1, 3, and 5 years after surgery.

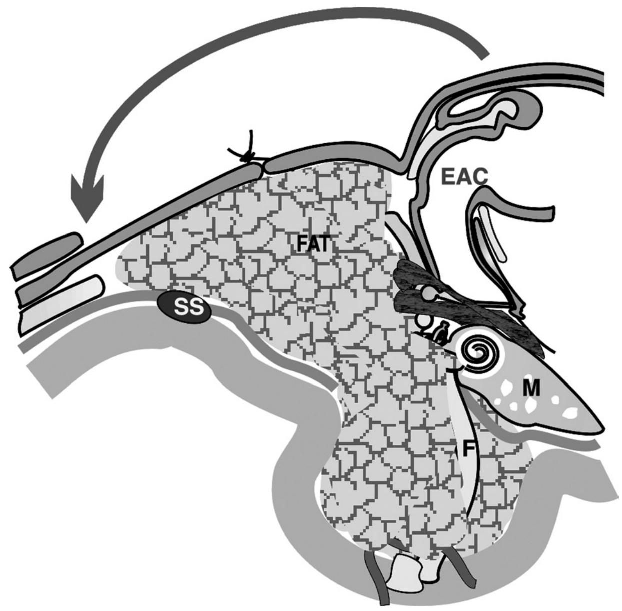

FIG. 4. Drawing of the closure of the fasciomusculoperiosteal layer to compress the inserted fat to create a second layer of closure. The skin is then closed as a third layer of closure (*arrow*).

Cerebrospinal Fluid Leak

A cerebrospinal fluid leak was defined as clear fluid drainage through the nose (rhinoliquorrhea), the wound (cutaneous), or the ear canal (otoliquorrhea). The manifestation of the leak was always clinically evident, never requiring a laboratory check by means of β_2-transferrin.

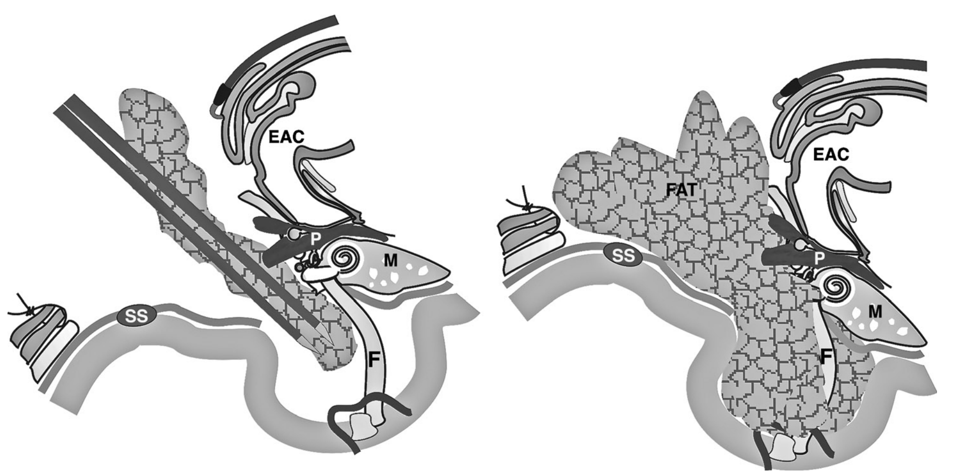

FIG. 3. Drawing of the introduction of fat strips into the CPA, axial view. The long strips of fat are grasped with a forceps (*left*) and inserted beyond the dural opening next to the facial nerve (*right*). The periosteum (*dark strips*) is used to plug the middle ear and vestibulum; the malleus head is still visible. FAT indicates abdominal fat strips; P, periosteum (in the middle ear); EAC, external auditory canal; M, mucosal cells in the petrous apex; F, facial nerve; SS, sigmoid sinus.

TABLE 1. *Patient data of series*

	1987–1994	1994–1998	1998–2002	2002–2009
Cases	129 (37 after July 1993)	200	379	1,187
CSF leak (patients)	8 (4 after July 1993)	0	2	9
CSF leak (%)	6.2	0	0.5	0.8
Literature	Celikkanat et al. (12)	Falcioni et al. (8)	Khrais et al. (9)	This study
	1993–2009 group			
Cases	1,803			
CSF leak (patients)	15			
CSF leak (%)	0.8			
Age (mean ± SD)	51 ± 12.5			
Tumor size (mean ± SD)	1.7 ± 1.2			
Sex (female/male)	834/969			

For explanation of the different periods and figures, see text.

Statistical Analysis

To compare the CSF results on our ETLA technique, we used a χ^2 test for statistical analysis.

RESULTS

Only 15 patients (0.8%) of 1,803 cases had CSF leaks. The 1,803 patients were from an annually increasing amount of vestibular schwannoma removal via the enlarged translabyrinthine approach (Table 1). The previous articles concerning the CSF leak at our center have *not* taken the change of surgical approach (July 1993) as the start or end of their calculations (8,9,12), which explains the different period of analysis in Table 1. The start and end of the calculations in the previous articles were in the summer of 1994, 1998, and 2002, explaining the referral to the same year in both series. From July 1993, there were 834 males, 969 females, age ranging from 10 to 82 years (51 ± 12.5 yr) and tumor size was ranging from intracanalicular up to 5.4 cm (1.7 ± 1.2 cm). Purely translabyrinthine, enlarged translabyrinthine, and also translabyrinthine-transotic approaches with blind sac closure of the ear canal are incorporated in this series. The patients' characteristics are listed in Table 1. The technique of surgery and closure has not been changed for 16 years.

The patients with a CSF leak were treated according to their site of leak (Table 2). Cerebrospinal fluid leakage was diagnosed between 3 and 42 days after surgery. The 15 patients had a cutaneous leak from the wound (5 patients), a leak via the ear canal (otoliquorrhea, 1 patient), or a rhinoliquorrhea (9 patients; Table 2). The only patient who developed meningitis presented 10 days after start of the rhinoliquorrhea, 5 weeks after surgery. After medical treatment of the meningitis, the rhinoliquorrhea was not present anymore. The tumor size of this group of patients ranged from intrameatal to 4.0 cm (mean ± SD, 1.9 ± 1.3 cm). The age of these 15 patients was comparable to the overall group: 47 ± 14 years.

Literature review of the last 10 years revealed 29 articles, of which 18 studies having a case series of translabyrinthine approach and included 100 patients or more (Table 3). The percentage of CSF leak in these publications ranged from 1.4 to 20%. Meningitis ranged from 0

TABLE 2. *Patients with a CSF leak: site of CSF leak, extrameatal tumor size, way of treatment, and occurrence of meningitis*

Case of CSF leak	Year	Age (yr)	Tumor size (cm)	Site of leak	Days after surgery	Treatment	Meningitis
1	1993	47	3.5	Cutaneous	5	Revision surgery	No meningitis
2	1993	35	1.2	Otoliquorrhea	12	Revision surgery	No meningitis
3	1994	36	1.0	Rhinoliquorrhea	7	Revision surgery	No meningitis
4	1994	54	3.0	Rhinoliquorrhea	3	Lumbar drain	No meningitis
5	2000	34	3.0	Rhinoliquorrhea	4	Lumbar drain	No meningitis
6	2000	26	0.0	Rhinoliquorrhea	3	Revision surgery	No meningitis
7	2003	58	3.5	Rhinoliquorrhea	30	Revision surgery	No meningitis
8	2004	27	3.0	Rhinoliquorrhea	8	Revision surgery	No meningitis
9	2004	53	0.2	Cutaneous	10	Compression bandage	No meningitis
10	2005	50	1.0	Cutaneous	4	Revision surgery	No meningitis
11	2005	64	1.0	Rhinoliquorrhea	6	Revision surgery	No meningitis
12	2007	53	4.0	Cutaneous	8	Revision surgery	No meningitis
13	2007	74	0.7	Rhinoliquorrhea	42	Revision surgery	No meningitis
14	2007	60	2.5	Rhinoliquorrhea	28	Resolved spontaneously	Meningitis
15	2008	36	1.0	Cutaneous	15	Compression bandage	No meningitis
Mean ± SD		47 ± 14	1.9 ± 1.3				

Three additional patients had subcutaneous CSF collection without a leak; they were treated successfully with a compression head bandage.

TABLE 3. *Cerebrospinal fluid leak incidence in major translabyrinthine approach series (>100 cases) in the last 10 years*

First author	Year and reference	No. cases of TLA	Period	CSF leaks (%)	Meningitis (%)	*p*
Wu	1999 (13)	277	1987–1998	19.8	2.2	
Mass	1999 (14)	258	1982–1996	7.8	1.6	
Slattery	2001 (15)	1,195	1987–1997	10.9	*1.5*	
Brennan	2001 (16)	228	1990–1999	8.7	NM	
Leonetti[a]	2001 (17)	209	1988–1999	3.8	1	$0.01 > p > 0.005$
Sluyter	2001 (18)	120	1986–1999	20.0	9	
Arriaga[a]	2002 (19)	108	NM	8.0	NM	
Becker	2003 (20)	100	1979–2000	13.0	2	
Darrouzet[a]	2004 (21)	229	1984–2000	6.9	8	$p < 0.001$
Kalamarides	2004 (22)	139	1998–2001	*12*	4	
Fishman[a]	2004 (23)	101	1995–2000	5.0	0	$p < 0.001$
Khrais[a]	2004 (9)	710	1987–2002	1.4	NM	
Sen	2006 (24)	232	1997–2002	12.5	NM	
Fayad[a]	2007 (25)	389	2003–2005	3.3	NM	$0.05 > p > 0.025$
Brackmann[a]	2007 (26)	512	2000–2004	5.5	0.6	$p < 0.001$
Jacob	2007 (27)	231	1989–2005	14.2	NM	
Hastan	2007 (28)	141	1996–2003	12.7	5	
Roche	2008 (29)	110	1991–2001	8.0	1	
Current study	2009	1,803	1993–2009	0.8	0.05	

Series are sorted by publication date. Some translabyrinthine figures are subtracted from series reporting several surgical approaches. Values in *italics* are estimations based on the available data in the article. *p* values (χ^2 test) are explained in the text.

[a]This series used fat strips into the CPA.

NM indicates not mentioned.

to 9%. In addition, we retrieved the series published earlier as a continuum of series ("Historical series," Table 4). We analyzed the site of the leak and the treatment and converted all mentioned cases into a percentage of the total number of patients with a CSF leak of that particular series (Table 5). This evaluation showed an even distribution between wound leaks (skin and ear) and leaks via the nose (rhinoliquorrhea). On average, approximately one-third (38%) of the patients needed revision surgery.

Statistical Analysis

Analysis of the CSF leak rate at our center has shown to be statistically significant compared with other CSF results; *p* values (χ^2 test) are $p < 0.05$ as listed in Table 3. We have only mentioned the *p* values compared with the 5 lowest CSF leak results of other centers as mentioned in the table.

DISCUSSION

We demonstrated in the current series that CSF leakage in translabyrinthine surgery is a complication that can be reduced to an absolute minimum. Since the introduction of this method in 1993, the amount of CSF leaks in our center has dramatically dropped and not changed ever since. In the recent meta-analysis of Selesnick et al. (3), it is stated that none of the published techniques of closure after a translabyrinthine approach are associated with a significant reduction of CSF leak compared with the pooled rate of 9.5%. Surprisingly, 2 publications of our group, with 0 and 1.4% CSF leak, respectively, are

TABLE 4. *Cerebrospinal fluid leak in historical series of different centers*

House Ear Institute, Los Angeles, CA, USA				
Period	1982–1988	1987–1997	2001–2003	2003–2005
Cases	723	1195	324	389
CSF leak rate (%)	6.8	10.9	8.7	3.3
Literature	Rodgers et al. (2)	Slattery et al. (15)	Fayad et al. (25)[a]	Fayad et al. (25)
Sunnybrook and Women's CHSC, Toronto, Canada				
Period	1975–1990	1990–1999		
Cases	203	228		
CSF leak rate	11.3	8.7		
Literature	Bryce et al. (4)	Brennan et al. (16)		
Gruppo Otologico, Piacenza, Italy				
Period	1987–1994	1994–1998	1998–2002	2002–2009
Cases	129	200	379	1187
CSF leak rate (%)	6.2	0	0.5	0.8
Literature	Celikkanat et al. (12)	Falcioni et al. (8)	Khrais et al. (9)[a]	This study

Literature marked with "*a*" indicate that the figures are subtracted from the extra information specified in the article.

TABLE 5. *Localization of the leak and management*

First author	CSF (%)	Skin and ear (%)	Rhino (%)	Revision surgery (%)	Lumbar drain (%)	Conservative (%)	Combi therapy (%)
Brennan	8.7	85	15	33	49	18	
Sluyter	20.0	66	33	25	75	0	
Fishman	5.0	60	40	60	40	0	
Darrouzet	6.9	*55*	*44*	*16*			
Wu	19.8	56	44	47			
Jacob	14.2	51	45				
Becker	13.0	50	50	38	15	23	23
Roche	8.0	50	50	38	*50*		
Leonetti[a]	3.8	*66*	*51*	63	37	0	
This study	0.8	40	60	67	13	20	
Khrais	1.4	30	70	80	20	0	20
Mass	7.8	20	80	40	25	35	0
Fayad	3.3	0	100	15	77	8	
Slattery	10.9			23	16	53	7
Brackmann	5.5			33			67
Mean	7.8	51	50	38	37	13	20

The publications presenting values on localization of the CSF leak or on the management are presented in this table. The table is sorted by the increasing number of rhinorrhea. Mean measures show an equal distribution between localization (skin versus rhinorrhea), and 38% of the patients with a CSF leak needed revision surgery.

Values in *italic* are an estimation based on the available values in the publication.

[a]Publication of several kinds of tumors via TLA.

Combi therapy indicates combination of the therapies but no revision surgery; CSF = percentage of CSF leaks reported; Revision surgery, Lumbar drain, Conservative, the percentage of the patients with a CSF leak who needed either revision surgery, lumbar drainage, or conservative therapy to stop the CSF leakage; Rhino = percentage of the patients with a CSF leak who had their leak via the nasal cavity; Skin and ear = percentage of the patients with a CSF leak who had their leak via the wound or ear canal.

not taken into account (8,9). Furthermore, we strongly believe that there is an association between the used technique (10) and a CSF leak reduction (8,9). In a careful appraisal of the literature of the last 10 years, an increasing number of publications are proving (several steps of) this technique.

Fat strips are used in several studies to close in a "corklike" fashion the dural defect. These studies (9,17,19,21,23,25) have CSF leak rates ranging from 1.4 to 6.9% with a mean rate of 3.2% (52 CSF leaks in 1,648 patients). A clear improvement compared with the suggested pooled rate of 9.5% (3), especially when all other series, using other techniques, report a rate of 7.8% or more. These figures confirm the findings that fat alone without the use of fascia or glue into the CPA defect can reduce the CSF leak rate dramatically (13). Next to the fat application in the dural opening, there are several ways of closure of the mastoid–middle ear cell complex and the musculoperiosteal and cutaneous opening.

Using fat strips together with a hydroxyapatite cement reconstruction, Arriaga and Chen (19) reduced their CSF leak rates from 12.5 to 3.7%. Fayad et al. (25) used the same fat strips combined with a titanium mesh cranioplasty and reduced their CSF leakage from 8.7 to 3.3%. They encountered only CSF draining via the nasal route, proving their watertight craniotomy closure, but lacking a tympanomastoid fluid barrier. Other studies used fat strips, but they also used bone wax to close all mastoidal cells together with a 5-day dressing to reduce their CSF leak (21,30). In their results, almost no rhinorrhea was seen, proving the viability of extensive drilling and bone wax closure of all mastoidal cells. Fishman et al. (23) used the same technique as that of Darrouzet et al. but extended the fat obliteration into the middle ear, leading to a 5% overall leak; nevertheless, they did encounter rhinorrhea hampering the use of the middle ear fat application. When no fat or bone wax is used, but muscle, bone, and glue and the dura are sutured, the CSF leak rate can be large (18).

The combination of fat strips into the dural defect and the use of extensive drilling and bone wax closure of the mastoidal cells are essential to create a good chance of CSF leakage reduction (Fig. 5). In addition, to eliminate CSF leakage from surgeries, we also advocate the removal of the incus, the use of the periosteum to obliterate the attic and vestibule, and a tight closure of the T-shaped incision of a thick fasciomusculoperiosteal layer (Table 6). We have to stress that the middle ear should be filled with periosteum and *not* with fat because fat is soft, is difficult to push in, and is easily resorbable once in contact with air. The periosteum is firm, flexible, and nonresorbable. Also, when the periosteum is pushed into the middle ear next to the malleus, the cells under the third portion of the facial nerve will "produce" some fluid or air, revealing their connection with the middle ear. A "guided" bone wax closure can be accomplished (Figs. 1A, B). Furthermore, eustachian tube packing and BioGlue do not prevent CSF rhinorrhea (24,27,31).

Historical Comparison

In the last 10 years, there have been many publications on CSF leak incidence ranging from 1.4 to 20% (Table 3) in the major series (>100 patients). Our series shows a significantly lower rate of CSF leak compared with other series, proving that CSF leakage can be expelled as a major complication in TLA surgery. Also, compared with the

FIG. 5. *Left*, Postoperative computed tomographic scan 1 year after an ETLA of a vestibular schwannoma. Note the closure of the middle ear with periosteum (*white arrow*). Also note the watertight closure of all the petrosal cells with bone wax (*black arrow*) and the completely air-filled cells anterior of the surgically opened mastoid. *Right*, Magnetic resonance image (T1-weighted image without fat suppression) of the same patient showing fat obliteration into the CPA and no depression of the skin periauricular. Note the reabsorption of the part of the fat in the CPA during the first postoperative year.

historical" sequential series (Table 4), there has been a clear improvement in all different centers, but none of the centers have comparable outcomes.

Cerebrospinal Fluid Leak Correlations

Despite the suggestion in a recent publication (25), we have to stress that there is *no* relation between the size of the tumor and the chance of a CSF leak. Many publications have proven likewise (8,9,13,14,17,20), and also in a meta-analysis, there is no relation between the size and CSF leak incidence (3). Although the volume of our CSF leaks group is small for statistical analysis, we have not seen a correlation between CSF leak and size of the tumor because the tumor size in our patients with a CSF leak ranged from intrameatal to 4 cm (Table 2). Different is the association between a CSF leak and meningitis because, in the literature, 14% of the patients with a CSF leak develop meningitis compared with the 3% chance without a CSF leak (3). In our series, we have not been able to establish a clear relation because we have only encountered a single case of meningitis in the CSF leak group and no meningitis in the group without CSF leak.

TABLE 6. *Most important surgical steps to avoid CSF leak in ETLA surgery*

- T-shaped incision in fasciomusculoperiosteal layer distant from the skin incision margin
- Wide exposure of the CPA
- Keeping the facial and subfacial recess intact
- Inspection of all cells with a hook and closure with bone wax
- Removal of the incus, pieces of periosteum put over and under the malleus
- Special attention to leakage of fluid or air from some open cells during the previous step
- Bone wax closure of these open cells (mostly infrafacial cells)
- Pieces of periosteum are put in the vestibule
- *Optional:* subtotal petrosectomy and closure of the eustachian tube and ear canal in a widely pneumatized petrous bone

After tumor removal

- No closure of the dura by any flaps or sutures
- Long fat strips put within the CPA
- Closure of the T-shaped incision watertight
- Fixation of the skin flap to the musculoperiosteal layer to avoid a dead space
- Watertight closure of the skin
- Dressing for at least 7 d

Localization of the Leak and Management

From the series reporting on the localization of the CSF leak (Table 5), it is hard to draw any conclusions because the percentage of skin leaks or rhinorrhea are equally distributed. Still, the figures of Fayad et al. (25) are appealing because of their exclusion of skin leaks by means of a titanium cranioplasty. The titanium mesh seems a good tool especially if there is no good musculoperiosteal layer to suture. Still, in the current series, we have proven that the need for such an expensive tool (US$400) is not necessary if careful opening and closure of the musculoperiosteal and skin layer are ensured. On the top side of the table (Table 5) is the low rhinorrhea rate (15%) in the series of Brennan et al. (16), which is probably due to their meticulous closure of the route to the eustachian tube. They removed the incus and head of the malleus, cut the tensor tympani tendon, pack the eustachian tube and middle ear with temporalis muscle and fascia, and the aditus is occluded with a fascia lata patch wedged in place with a spicule of bone. In their retrosigmoid cases, they also mentioned the use of bone wax to close exposed air cells, and likely, they also used this in the TLA.

In summary, we have been able to develop a surgical method to reduce the CSF leak rate to an absolute minimum. The methods used are feasible for all centers without the use of any special (expensive) device or tool. The centers who already have adapted their surgery to similar precautions report low(er) CSF leak rates. To increase the CSF leak reduction even more, proper training, frequent use of the technique, and strict discipline to follow all steps without exception are necessary. In comparison with other major series, the presented result is significantly better. Many modifications have been presented in translabyrinthine vestibular schwannoma surgery, but this will probably be the closest we can get to a negligible CSF complication.

CONCLUSION

The methods used in translabyrinthine vestibular schwannoma surgery in our center can reduce CSF leakage to an absolute minimum. Other centers using similar methods, like the fat strips into the CPA, have obtained lower CSF leak percentage. Our results and the comparison with all major series prove that the presented surgical method provides a significant improvement and could be the beginning of a new era in translabyrinthine vestibular schwannoma surgery.

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