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No Cerebrospinal Fluid Leaks in Translabyrinthine Vestibular Schwannoma Removal

Reappraisal of 200 Consecutive Patients

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Objective: The objective of this study was to validate measures taken to reduce the number of cerebrospinal fluid (CSF) leaks after removal of vestibular schwannomas to 0.
Study Design: This study was a retrospective case review.
Setting: The study was conducted at an otology/neurotology tertiary referral center (Gruppo Otologico, Piacenza, Italy).
Patients: Three hundred thirty-one vestibular schwannoma patients were studied.
Interventions: The enlarged translabyrinthine approach (TLA) was used in all cases, with a number of modifications in the last 200 patients. It was extended in 22 patients with blind sac closure of the external meatus, removal of the posterior bony canal wall, and obliteration of the Eustachian tube and middle ear.
Main Outcome Measures: Whether patients had a leak through the wound, the nose (rhinoliquorrhea), or the ear (otoliquorrhea) was assessed.
Results: In an early group, the percentage of CSF leaks was 6.9%. On the basis of the evaluated causes, as time went by, technical modifications evolved. They consisted of 1) the total conservation of the fascioperiosteal flap, 2) obliteration of all petrosal cells possibly communicating with the middle ear, 3) removing the incus in a correct way, 4) closing the attic with periosteum, 5) obliterating the surgical cavity, leaving strips of abdominal fat with their medial ends inside the cerebellopontine angle, 6) suturing the musculo-periosteal layer in a correct way, and 7) fixing the skin flap to the underlying surface. The application of these modifications resulted in a total absence of CSF leaks in 200 consecutive patients thereafter. Also, no cases of meningitis were encountered.
Conclusions: To our knowledge, this is the first series of 200 consecutive vestibular schwannoma patients operated by means of the enlarged TLA without a single CSF leak. When the appropriate measures are taken, the number of CSF leaks after removing tumors through the enlarged TLA must and can be reduced to 0. **Key Words:** Acoustic neuroma—Vestibular schwannoma—CSF leaks—Translabyrinthine approach.
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A cerebrospinal fluid (CSF) leak has been a constant complication in vestibular schwannoma (VS) surgery. In the literature, the percentages vary from 6.2% to 20% (1–8). Leakage results from a persisting communication between subarachnoidal space and temporal bone and may not cause problems itself. It does, however, provide a potential entry for infection. Meningitis, with significant morbidity and even mortality, may evolve (9,10). The conservative management of these leaks requires placement of a spinal drain and immobilization of the patient (with an increased risk of pneumonia, pulmonary embolus, and delayed vestibular compensation), which results in associated discomfort, headaches, an increased risk of infection, and a prolonged hospital stay (6,11).

After VS surgery, a CSF leak can follow three different routes: the skin wound (wound leak), the nose through the Eustachian tube (rhinoliquorrhea), and the external auditory canal (EAC) through a tear of the tympanic membrane (otoliquorrhea). The latter is rarely encountered and its percentage is insignificant in the largest series reported in the literature.

The translabyrinthine approach was developed by William House during the sixties (12). At that time, the incidence of a CSF leak was 20% (1). Since then, many papers have been published introducing modifications to the original technique. One of the important modifications was the introduction of abdominal fat instead of temporalis muscle to close the dura and surgical cavity (13). Later, using strips of fat instead of a whole piece was advocated (14). Other improvements were layered wound closure, beginning with the mastoid periosteum, as well as careful

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placement of a pressure head dressing (9). As a result of these modifications, the incidence of CSF leaks decreased from 20% to 6.8% in the same clinic (1,2). Thus, although decreased in frequency, postoperative CSF leaks still occur in all published series. An important drawback of a number of studies is that they fail to mention the precise (intratemporal) site of the leaks (6). Therefore, it is difficult to learn how they develop and consequently can be prevented in the future.

This study reports the experience of the Gruppo Otologico, Piacenza, Italy, in the treatment of postoperative CSF leaks in a series of 131 consecutive VS cases. Most of these patients have been described earlier (3). Moreover, the causes by which these leaks developed and the surgical modifications which led to the total absence of CSF leaks in the consecutive 200 cases thereafter (during the last 4 years) are described. All patients were operated on between April, 1987, and September, 1998, through the enlarged translabyrinthine approach (TLA).

SURGICAL TECHNIQUE

The main steps of the surgical technique are similar to those originally described by William House (12). However, modifications have been progressively introduced, with the aim of making tumor removal easier and decreasing the risk of a postoperative leak.

The first step consists of preserving the fascial layer while creating the skin flap. The same care is taken in preserving the periosteum during development of the musculo-periosteal flap. In our technique, this periosteal incision is T-shaped, with the long arm ending at the level of the mastoid tip. Preservation of both the fascial and periosteal layer gives more consistency to the musculo-periosteal flap. In this way, during the closure at the end of operation, tears are prevented (3).

During the bonework, as many cells as possible are removed at the level of the mastoid tip, in the infralabyrinthine, supralabyrinthine, and zygomatic regions. All these cells may communicate with the tympanic cavity and/or the proximal portion of the Eustachian tube. If complete removal of the pneumatized cells is not possible, the remaining cells are obliterated with bone wax, after the mucosal layer has been removed. Particular care is taken not to open the facial and subfacial recess, to prevent any direct communication with the tympanic cavity. Bone wax obliteration is also used in this area. When present, cells of the petrous apex are opened superiorly and inferiorly to the internal auditory canal (IAC) and then also plugged with bone wax. To avoid leaving some cells open, it is advisable to perform the obliteration immediately after the cells have been opened, certainly before dural incision. The reason for this is that when CSF has come in contact with the mastoid cells, closing of these cells with bone wax becomes less reliable.

After the tumor has been removed, the incus is disarticulated and taken out. The movement of removing the incus must follow a horizontal plane, parallel to the tympanic membrane, to avoid a fracture or dislocation of the footplate. Thereafter, the attic is plugged with pieces of periosteum collected during the beginning of the surgery. These are pushed medial to the malleushead, superiorly to the cochleariform process in the direction of the protympanum, and inferiorly to the cochleariform process in the direction of the tympanic cavity. Pieces of periosteum are also put lateral to the malleushead to fill up the rest of the attic space to close any communication between the middle ear and surgical cavity. Obliteration of the latter is performed by leaving long strips of abdominal fat with their medial parts in the cerebellopontine angle (CPA). In this way, the fat almost completely fills the space previously occupied by tumor. No attempt is made to suture the dural margins. Fibrin glue is rarely used.

The musculo-periosteal layer is then sutured in a watertight fashion. Before suturing the skin, the skin flap is fixed to the underlying layer with two or three absorbable stitches to avoid collection of CSF or blood. A tight dressing, applied in the operating theater, is maintained until the day of discharge (5 days) and is then substituted with a smaller one, which is kept in place for another 3 days. Antibiotic coverage (Piperacillin 2 grams intravenously 6 times/day) is started 1 hour before the beginning of the operation and continued for 24 to 48 hours, depending on the length of the operation and, particularly, the intradural procedure. Starting from the second postoperative day, the patient is often required to bend the head down to check if there is rhinoliquorrhea.

Since July 1993, after a case of postoperative rhinoliquorrhea in a patient with a highly pneumatized temporal bone, a modification of the basic technique has been adopted when facing this particular anatomic condition. It consists of closing the EAC as a blind-sac, which is medially reinforced with a little flap derived from the musculo-periosteal layer. The posterior bony wall of the EAC is drilled away and the mucosa of the tympanic cavity and the Eustachian tube is removed together with malleus and incus. The Eustachian tube is plugged with pieces of periosteum, and finally the residual cavity is obliterated with abdominal fat. The wound closure is performed in a way similar to the previously described technique. The only difference is that in the modified technique a flap is created from the musculo-periosteal layer to avoid a residual opening at the level of tissue previously used for the medial reinforcement of the blind-sac closure (16).

MATERIALS AND METHODS

In this study, all the files of 329 patients undergoing a VS removal through the enlarged TLA in the Gruppo Otologico between April, 1987, and September, 1998, were retrospectively analyzed. Two patients affected by neurofibromatosis type 2 were operated on bilaterally, raising the total number of cases in the study to 331. The study group included a total of four patients with neurofibromatosis type 2 (6 tumors) and seven patients with residual tumors who were previously operated on in other centers through the retrosigmoid approach. Most patients were operated on through the technique described below. However, in 18 patients a modified technique was adopted, consisting of removal of the middle ear and blind sac closure of the EAC. Ten of these patients had a highly pneumatized petrous apex. In the remaining patients, the choice of the modified technique was because of the recording of endocochlear potentials (three patients) (15) and the concomitant occurrence of an ipsilateral tympanic membrane perforation (one patient). Also, the patients in whom the VS was removed by means of a transotic (three patients) and transcochlear (one patient) approach were included in this modified group, because the surgical steps performed to reduce the risk of a postoperative CSF leak in these approaches are in fact the same. A case of perioperative death due to a CPA hemorrhage was excluded from the total number of cases.

We also did not include all tumors operated on during the same period through the retrosigmoid and the middle cranial fossa routes, because problems related to postoperative CSF leak in these approaches are usually different when compared with the enlarged TLA. Most of the patients of the group in which the CSF leaks occurred have been described in a previous study (3).

A CSF leak was defined as clear fluid drainage through the nose, the wound, or the EAC. The manifestation of the leak was always clinically evident, never requiring a laboratory check by means of Beta-2-transferrin.

Parameters taken into consideration in this study were the number of CSF leak cases, leak route, postoperative day of appearance, probable site and reason for its development, and way in which each case was managed. To identify potential risk factors that may predispose to the development of these CSF leaks, a comparison was made between the CSF leak and non-CSF leak group. Statistical analysis was performed using the nonparametric Mann–Whitney U test, because of unequal group size and lack of homogeneity of variance. Statistical significance was defined as $P < 0.05$.

TABLE 1. *Patient data in 331 translabyrinthine vestibular schwannoma removals*

	Mean	SD	Minimum	Maximum
Age (years)	50.3	12.62	13	79
Size (cm)	2.2	1.11	i.c.	5.4

SD, standard deviation; i.c., intracanalicular tumors.

RESULTS

Age and tumor size are summarized in Table 1. Among the 329 patients (331 tumors), 161 were women and 168 men, with a mean age of 50.3 years (range, 13–79 years). The right CPA was involved in 171 cases, whereas the left was involved in the remaining 160. The mean tumor size, calculated as the largest extracanalicular diameter, was 2.2 cm (range intracanalicular, 5.4 cm).

A CSF leak was recorded in 9 of the 131 early cases, corresponding to 6.9%. The last one was recorded in July, 1994. Since then, among the 200 patients operated on consecutively through the enlarged TLA, no more leaks occurred (Table 2).

In seven patients there was a rhinoliquorrhea and in one a wound leak, whereas in the last patient, the leakage occurred from the blind-sac closure of the EAC and was therefore also considered a wound leak. The mean tumor size of the tumors in which a postoperative leak occurred was 2.43 cm (range, 1–3.4 cm), whereas in the remaining group, the mean size was 2.19 cm (range intracanalicular, 5.4 cm) (Table 3). The difference regarding tumor size and age between the 'leak' and 'nonleak' group was not statistically significant. In addition, in the total series (n = 331), no case of meningitis was found.

Most of the leaks (six cases, corresponding to 66%) happened between the second and the fourth postoperative day (Table 4). The leak was recorded after discharge from the hospital in only one patient, exactly 30 days after the operation. In one patient, the leak stopped after the insertion of a lumbar drainage, which was kept in place for 3 days. The other eight patients needed a surgical revision. In two of them, a previous attempt to stop the leak with a lumbar drainage did not succeed.

During revision surgery, additional fat was left in the surgical cavity in two cases, coupled with suturing of a musculo-periosteal defect in the patient with the wound leak. In the case of the leakage from the EAC, the blind-sac closure was revisited. The other five patients required a middle ear obliteration; two were performed through the facial recess and three in association with a blind-sac closure of the EAC.

TABLE 2. *Comparison of the group with and without CSF leaks*

	First group (in which 9 leaks occurred) n = 131				Second group (without leaks) n = 200				Sign
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Age (years)	48.7	12.7	17	79	51.3	12.5	13	79	NS
Size (cm)	2.35	0.99	i.c.	5	2.11	1.17	i.c.	5.4	NS

TABLE 3. *Comparison of total number of cases with and without CSF leaks*

	CSF leak n = 9 (2.7%)		No CSF leak n = 322 (97.3%)		Sign
	Mean	SD	Mean	SD	
Age (years)	43.9	10.7	50.4	12.6	NS
Size (cm)	2.43	0.98	2.19	1.11	NS

SD, standard deviation; i.c., intracanalicular tumors; Sign, significance; NS, not significant; CSF, cerebrospinal fluid.

TABLE 4. *Patients with CSF leaks: route of leak, day of appearance, cause, and treatment*

No.	Route	Day postop.	Cause	Treatment
1	r	3	Incomplete obliteration facial recess	Middle ear obliteration
2	w	4	Defect in musculo-periosteal flap	Additional fat and resuturing
3	r	2	Insufficient obliteration surgical cavity	Additional fat
4	r	30	Incomplete obliteration facial recess	Middle ear obliteration
5	r	9	Infralabyrinthine communication	Middle ear obliteration #
6	r	4	Fracture of stapes footplate	Middle ear obliteration #
7	r	4	Infralabyrinthine communication	Middle ear obliteration #
8	r	2	Unknown	Lumbar drain
9	w	13	Wrong closure external auditory canal	Blind sac closure revision

r, rhinoliquorrhea; w, leak through wound; #, obliteration of the middle ear *with* blind sac closure; CSF, cerebrospinal fluid.

For six patients who had revision surgery, a surgical mistake was considered the probable reason of the leak. The mistakes were a wrong execution of the blind-sac closure of the EAC, with incomplete removal of the cartilage and loss of medial reinforcement with a flap sculptured from the musculo-periosteal layer (one patient); opening of the facial recess for end-to-end facial anastomosis without complete obliteration of the tympanic cleft (two patients); fracture of the footplate (one patient); incomplete attic obliteration (one patient); and a hole left during suture of the musculo-periosteal layer (one patient). In the remaining two patients who underwent a surgical revision, the leakage was probably determined by the high pneumatization of the bone, with a communication between infralabyrinthine and hypotympanic cells.

No case of bacterial meningitis requiring antibiotic therapy has been recorded. However, in all CSF leak cases antibiotic therapy was given until 2 days after the leak ended.

DISCUSSION

This study shows that the percentage of CSF leaks in the enlarged TLA may eventually reach 0. In our early cases, this percentage already was relatively low (6.9%) in comparison with that in the literature (Table 5) (1–8). In the past decades, different percentages can be found depending on the year of publication (in the sixties more leaks were reported than in the nineties), surgical approach (the middle fossa approach is known to have less CSF leaks than TLA and suboccipital approach), and experience of the neuro-otological center (6). To learn from previous failures, careful examination of the site and probable origin of the CSF leaks during revision surgery took place. In the international literature, many papers regarding CSF leaks fail to mention these data nor is the surgical approach after which the leaks developed always properly described (17–21).

In our early cases, two of nine leaks (22%) presented with an incisional leak. This is not consistent with the literature: in 1994, a survey, revising six studies that specified a total of 244 CSF leaks, showed that liquorrhea through the wound was reported more frequently (59%) than through the nose (37%). Combined leaks (3%) and leaks through the ear canal (1%) were seldom encountered (6). The reason for this inconsistency may be the meticulous way in which we preserve and afterward suture the fascio-periosteal layer. We consider it particularly important to preserve fascial and periosteal layers, so that they add resistance to the flap, allowing the surgeon to suture without tearing the flap. This represents a strong barrier for the CSF and also helps in maintaining the fat correctly positioned in the cavity. We consider it also very important to fix the skin flap to the underlying surface, avoiding leaving a dead space, easily detachable and so theoretically a place for CSF accumulation. Moreover, one of the two patients with a wound leak showed leakage from the blind sac closure which, as was proved by revision surgery, was not carried out correctly.

TABLE 5. *Studies of CSF leaks and meningitis after translabyrinthine vestibular schwannoma surgery*

Author	Year	No. of cases	Leaks (%)	Meningitis (%)
House et al. (1)	1979	251	20	15
Tos et al. (7)	1988	400	11	4
Ekvall (8)	1992	215	10	0
Rodgers et al. (2)	1993	723	6.8	2.9
Hoffmann et al. (6)	1994	146	21	3
Celikkanat et al. (3)*	1995	129	6.2	0
Lacombe et al. (4)	1996	102	6.89	0.9
Fishman et al. (5)	1996	83	13	1.2
Falcioni et al. (current study)	1998	200	0	0

*Most of the patients of our early group (in which the CSF leaks occurred) have been described in the study of Celikkanat et al. (3).
CSF, cerebrospinal fluid.

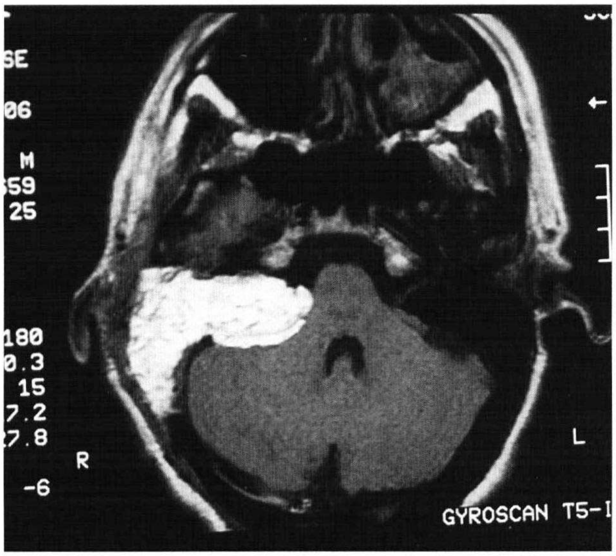

FIG. 1. A magnetic resonance imaging test performed 3 days after removal of a vestibular schwannoma through the enlarged translabyrinthine approach. Note the medial ends of the fat strips located inside the cerebellopontine angle, filling the space previously occupied by the tumor.

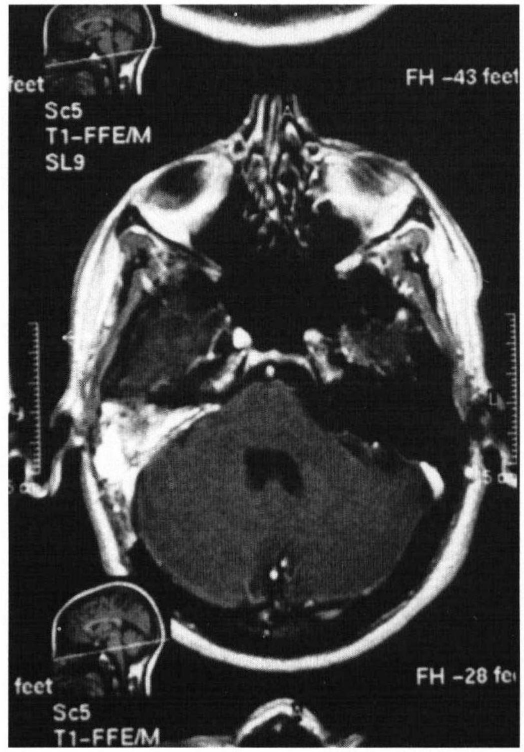

FIG. 2. Same patient as in Fig. 1. Magnetic resonance imaging test performed 1 year after the surgery. The fat has shrunk to approximately 50% of the original volume. The brain tissue has reexpanded to its normal position.

Regarding the patients with rhinoliquorrhea, the causes were variable. Insufficient obliteration of the surgical cavity was found to be the origin of the leak in one case. Closing of the surgical cavity has been a matter of debate since the introduction of the TLA. Modifications consisted of introducing abdominal fat instead of temporalis muscle (13), later improved by putting abdominal fat in strips (14). It was histologically shown that this adipose tissue remained viable and adhered to the walls of the mastoid cavity (13). Temporalis fascia was later used to put in between fat and contents of the posterior fossa. However, also in these series, CSF leaks still prevailed (22,23). A reason for this might be that the fascia prevents the fat from adhering to the mastoid walls, as has been suggested by Kartush (24). Moreover, we believe a fundamental step is hampered by the use of fascia, namely, positioning the abdominal fat strips deeply into the CPA. In all our cases, the fat filled the residual cavity, taking the place of the tumor (Fig. 1). We did not record any problems due to possible fat compression on the brainstem. At the same time, a theoretical stretching of the facial nerve is easily avoided by leaving the monitoring system on until the fat has been placed. Shrinking of the fat in time was clearly visible during the radiologic follow-up (Fig. 2).

The effectiveness of fibrin glue in reducing postoperative CSF leaks is not clear. Some authors recommend its routine use (10), whereas others do not find any advantage from its application (6,9,23). We used fibrin glue only in a few cases; therefore, it was impossible to evaluate its efficacy in a scientific way. However, the outcome of this series proves that fibrin glue is not necessary when all the technical steps to close off the cavity have been performed correctly.

In two patients, infralabyrinthine communication was the origin of the leak. In this regard, particular attention has to be paid to petrous bone pneumatization, which presents a wide range of individual variability (25). The existence of an infralabyrinthine tract is particularly dangerous because of the possible communication with hypotympanic cells. High pneumatization was believed to be the reason for the leak in two of our patients. To avoid this problem, we presently drill away as many pneumatized cells as possible, packing the remaining cells with bone wax after removal of the mucosal layer.

In the case of extremely pneumatized bones, when it is not possible to remove and/or pack every cell, since July, 1993, we have adopted a modified technique, as proposed by Fisch (26), but without cochlear removal, and Ekvall (27). It consists of taking out the posterior wall of the EAC together with the ossicles, closing the EAC as a blind-sac, and obliterating the tympanic cavity and the Eustachian tube. This procedure, if correctly performed, reduces the risk of CSF rhinorrhea to zero; however, it takes 50 to 60 minutes and is therefore not routinely adopted.

In another patient, the leakage was coming from the oval window, through an accidental fracture of the footplate, as has been previously described (28,29). This possibility should be taken into consideration during obliteration of the attic and the tympanic cleft. Whenever the obliteration is performed through a facial recess, particular care is needed, because the facial recess itself represents a possible route for the leakage. This technique has never been adopted by our team, but in a few initial cases when it was performed because of the rerouting of the third portion of the facial nerve with end-to-end anastomosis. In two of those patients, the reason for the CSF leak occurrence was probably an incomplete obliteration of the tube and the tympanic cavity. Our study confirmed data on the absence of a relationship between tumor size and percentage of CSF leak (2,10,21,30). These data are in disagreement with other studies in which the largest tumor size has been related to a high risk of postoperative leakage, probably because of the larger opening of the dura (17,31). We did not close the dura at all; therefore, the fact that we did not find any relationship between tumor size and the number of CSF leaks fits in well with our technique of closing the surgical cavity by putting abdominal fat deeply in the CPA, regardless of the size of the tumor. Moreover, it is our contention that any attempt to close the dura carries an additional CSF leak risk; the smaller the opening in the dura, the harder it is to put fat through this opening.

Another postoperative measure, already recognized as important in diminishing the risk of a CSF leak, is the tight dressing applied in the operating theater and left in place for at least 5 days (9). This bandage exerts pressure on the adipose tissue that closes the dural defect. In our practice, this dressing is substituted with a smaller one when discharging the patient; this latter bandage is removed at home after 3 additional days.

The occurrence of a leak was most frequently recorded between postoperative day 1 and 4. This is the period with the highest risk, because the intracranial pressure, after having been decreased during surgery, comes back to its normal values, while at the same time, the fat used for obliteration is not yet completely adherent to the cavity walls. However, some drops of fluid from the nose during the first day may be related to the washing fluid used during surgery, and therefore should be reevaluated after some hours.

In the case of postoperative CSF rhinorrhea, we think that an attempt to solve the complication with conservative management (tight dressing, bed rest, and lumbar drainage insertion) is advisable for not more than 2 to 3 days. In fact, in other skull base approaches we verified that this conservative procedure was not very effective when a fistulous route was established inside the temporal bone. This bony fistula is not "compressible," and its spontaneous closure is a rare occurrence. The risk of meningitis related to the presence of a lumbar drainage should also be taken into account (6). In the case of surgical revision, the technique most frequently adopted in the last cases was the removal of the tympanic cleft with obliteration of the residual cavity and the Eustachian tube and blind-sac closure of the EAC. Removal of the mucosal layer also seems to guarantee a better adhesion of the fat to the cavity walls. This procedure offers the highest guarantees and, in case of a TLA, has no other disadvantages, because the patient already has a dead ear. For this reason, it is preferred over closure of the Eustachian tube by obliteration through the middle cranial fossa (32–34).

Conservative treatment has a high success rate in the management of wound leaks. In these cases, the temporary decrease of CSF pressure obtained with the lumbar drain combined with the pressure dressing allows the surgical cavity to close. This is true if the treatment is not delayed for too long; otherwise, the fistulous tract is generally covered with a pseudocapsule that makes further adherence of the tissues impossible. Early surgical revision is one of the most important factors in avoiding the occurrence of a postoperative meningitis complicating a CSF leak.

CONCLUSIONS

Postoperative CSF leak has always been and is yet one of the most dangerous complications of VS surgery. It is present with different rates in the largest series presented in the international literature. Retrospective analysis of the CSF leak cases occurred at the Gruppo Otologico between April, 1987, and July, 1994, allowed the identification of some risky steps during the operation. On this basis some surgical modifications of the enlarged TLA were progressively adopted, resulting in no leaks in the last 200 cases consecutively operated on. These data allow the claim that by using these modifications, the incidence of postoperative CSF leaks after a VS removal through a enlarged TLA can and must reach 0.

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