Cerebrospinal Fluid Leakage During Temporal Bone Surgery: Selecting Intra-operative Dural Closure with a Dumbbell-Shaped Muscle Graft as a Surgical Approach

Nasrin Yazdani¹ · Mohammad Taghi Khorsandi-Ashtiani¹ · Hamed Tashakorinia¹ ·
Mahtab Rabbani Anari² · Narges Mikaniki²

Received: 10 June 2016 / Accepted: 17 July 2017 / Published online: 22 July 2017
© Association of Otolaryngologists of India 2017

Abstract Cerebrospinal fluid (CSF) leakages of the temporal bone may arise during mastoid surgery. The leakages can have multiple potential etiologies, for instance, using a cutting burr near the bony tegmen or monopolar electrocautery on the surface of the dura mater. In this paper, we introduced an effective and simple technique for the management of CSF leakages of the temporal bone. In a prospective case series, 36 patients (16 males and 20 females) who have had an experience of incidental or inevitable CSF otorrhea or otorhinorrhea during temporal bone surgery were selected. All patients were treated using a muscle graft in a dumbbell-shaped design through the dura defect at the Amir-Alam University Hospital between April 2005 and November 2008. The mean size of the defects was 5 mm (a range of 2–10 mm). A dumbbell-shaped autologous muscle graft was immediately successful in sealing the leakage in all patients. Only five patients (13.8%) had some evidence of leakage remaining on the day after the operation, which was subsequently resolved by conservative management in four of them (11.1%). Only one patient (2.7%) was subjected to a second operation for a new defect. Recurrence of CSF leakage or other related complications were not observed during about 7 years of follow up. A free autologous muscle graft, using the dumbbell technique through a small to moderate dura

defect is an effective, easily performed, and safe method to seal iatrogenic leakages of the temporal bone.

Keywords Temporal bone · Cerebrospinal fluid · Muscle graft · Leakage · Ear surgery

Introduction

Cerebrospinal fluid (CSF) leakage of the temporal bone poses certain diagnostic and management challenges, and requires meticulous and well-timed intervention. The leakage occurs when the barriers of the CSF around the brain are breached [1]. CSF leakage can be categorized into traumatic (including iatrogenic injuries), non-traumatic, and spontaneous. CSF leakages of the temporal origin most commonly occur as a result of trauma and iatrogenic injury [2–4]. Other etiologies include congenital malformations, infectious diseases, cholesteatomas, and neoplastic invasion of the skull base [5, 6].

Even the most skillful surgeon can experience an incidence of CSF leakage while carrying out different types of surgery on the complex skull base. Iatrogenic CSF leakages occur most frequently, secondary to either functional endoscopic sinus surgery (FESS) or neurosurgical procedures [7].

CSF leakage can also arise iatrogenically as a complication of mastoid surgery. The use of cutting burr or diamond burr close to the bony tegmen and monopolar electrocautery on the surface of the dura mater and the absence of preoperative CT scans to visualize a thinned temporal bone may result in injury leading to CSF leakage [8].

Prevention and repair of CSF leakages are challenging. Irrespective of the cause, surgical intervention is strongly recommended to manage CSF leakage. The skull base is a crowded and complex area, and it is always challenging for

✉ Mahtab Rabbani Anari
Mahtab_rabbani@yahoo.com

¹ Otorhinolaryngology Head and Neck Surgery Department, Amir Alam University Hospital, Otorhinolaryngology Research Center, Tehran University of Medical Sciences, Tehran, Iran

² Department of Otorhinolaryngology-Head and Neck Surgery, Imam-Khomeini Hospital Complex, Tehran University of Medical Sciences, Tehran, Iran

a surgeon to manage and seal a leakage in such a critical spot. The management of a leakage often requires a lot of skill since routine methods such as suturing is not possible in such a small narrow and complex field. There are different techniques available for dural repair, however the success rate varies among the previous published studies and a standard closure method has not yet been established.

This study presents a simple and efficacious method for managing small to moderate (up to 10 mm) dural defects that occur during surgery on the base of the skull. A free muscle graft is employed in a sand clock (dumbbell shaped) fashion through the defect. This procedure makes it feasible for the surgeon to close the defect and stop the leakage, even in anatomically difficult areas such as those commonly found while working on the base of the skull.

Materials and Methods

In a prospective study, patients who had experienced an incidental or inevitable cerebrospinal fluid otorrhea or otorhinorrhea during temporal bone surgery were treated at

the Amir-Alam Teaching Hospital between April 2005 and November 2008.

Surgical Technique

The senior author (M.KH.A.) managed all patients. The patients were subjected to different surgical approaches based on their primary condition. Dural defect and CSF leakage were detected during the procedure. After localization and adequate exposure of the defect, a free muscular graft was harvested from temporalis or sternocleidomastoid muscle by sharp dissection. The largest diameter of muscle graft should be twice the width of the defect. Under microscopic guidance, 80–90% of muscle mass was inserted gently into the defect site using forceps and there after pulled out. The muscular graft was fashioned in a dumbbell-shaped design to plug the dural defect (Fig. 1). At the end of the procedure, a perfect closure of the dura mater was confirmed with valsalva maneuver. Meticulous multilayered soft tissue closure was performed in the standard way. A mastoid pressure dressing was placed after surgery and removed on the 2 days

Fig. 1 “Dumbbell-shaped” muscle graft technique. **a** Free muscle graft harvest. **b** Muscle graft is simply placed over the dural defect. **c, d** Plugging the muscle graft as a dumbbell-shape to seal the dural defect

after operation. Postoperative lumbar drainage was not used routinely.

The patients were closely monitored on days 1–7 during the period of their stay in the hospital and later on day 30. After this, they were visited every 2 months. Symptoms and signs contributing to CSF leakage (otorrhea, rhinorrhea, wound leakage, and flap bulging) or meningitis (fever, headache, and stiffness of neck) were taken into consideration. Success was defined as lack of these signs and symptoms and an aerated middle ear during physical examination. The mean follow up value was 44 months (ranging from 3 to 85 months).

Results

In our study, the autologous single layer muscle graft closure was utilized in 36 consecutive patients undergoing different middle cranial and skull base surgery for various primary causes (Table 1).

There were twenty female patients and sixteen male patients. The mean age of the patients was 48 years (ranging from 20 to 60). The type of primary surgical

intervention and location of the defects are listed in Table 1. The mean size of the defects (in greater diameter) was 5 mm (ranging from 2 to 10 mm). In the operative field, an autologous muscle from a different source (SCM muscle or temporalis muscle), in a dumbbell fashion sealed the leakage in all cases successfully.

During the 1 week of hospitalization, in case of any evidence of CSF leakage, conservative management, including strict bed rest, 30° head-up positioning, avoidance of straining and nose blowing, and administration of acetazolamid, antiemetics, and stool softeners was enforced for 1 week. CSF diversion via lumbar drainage was indicated as a secondary step for cases that were refractory to primary conservative treatment for more than 1 week.

Thirty-one of the 36 patients (86%) appeared to have been cured by this technique and showed no evidence of further leakage during the remaining period of hospitalization as well as the follow up period. Five patients (13.8%) showed some evidence of continued post-operative leakage. CSF leakage in three out of five of these patients (8.3%) was subsequently resolved after a 1-week trial of conservative management without lumbar puncture.

Table 1 The frequency of primary pathology, type of surgery and location of the dural defect

Primary pathology	Site of defect	Surgical approach	Frequency
Congenital deafness	Footplate (a case of patent cochlear aqueduct)	Middle ear exploration	1
Glomus jugularis	Entrance of the 9th cranial nerve to the posterior fossa	Fisch Type A	3
Glomus jugularis	Posterior fossa dura	Fisch Type A	9
Glomus jugularis	Posterior fossa dura and the jugular foramen area	Fisch Type A	1
Endolymphatic sac tumor	Erosion of the posterior sac wall dura	Labyrinthectomy	1
Rhabdomyosarcoma	End of IAC	Lateral temporal bone resection	1
COM ^a	Tegmen tympani (three cases) and tegmen mastoideum (one case)	Simple mastoidectomy	4
Acquired cholesteatoma	Tegmen tympani	Open cavity mastoidectomy	3
Congenital cholesteatoma	Lateral IAC fundus	Open cavity mastoidectomy	2
Cholesteatoma and temporal bone fracture ^b	Tegmen tympani	Mastoidectomy	2
MEO ^c	Medial dura of the jugular bulb	Petrosectomy	1
Giant cell tumor	Medial dura of the jugular bulb	Lateral temporal bone resection	1
BCC	Middle fossa dura	Lateral temporal bone resection	1
Temporal bone Fx	Middle fossa dura	Mastoidectomy	3
Osteosarcoma	IAC	Lateral temporal bone resection	1
Neurinoma of the 9th and 10th cranial nerve	Entrance of the cranial nerves to the posterior fossa	Fisch Type A	2

^a Patients with COM were referred due to suspicion of CSF leakage caused by pervious surgery

^b These two cases were referred for post-traumatic facial paralysis. Cholesteatoma and brain hernia were diagnosed during exploratory surgery

^c Malignant External Otitis

The remaining two patients (5.5%) had both undergone glomusjugularis surgery. One patient had persistent CSF leakage for 10 days without any response to conservative management and lumbar puncture. Therefore, the site of the operation was re-explored after taking a high resolution CT scan. A second 3 mm defect was found in the posterior fossa region while the previous defect about 8 mm in the jugular foramen area appeared to have been sealed. The new defect was successfully repaired with muscle graft like the first one. The second patient with a primary size defect of 6 mm experienced CSF leakage for 1 week despite conservative management. However, after two lumbar punctures, the leakage was resolved. Post-operative meningitis or other related complications were not detected.

Following an average of 44 months of close follow up (ranging from 3 to 85 months), there was no evidence of encephalocele or CSF leakage recurrence in any patient. No patient developed meningitis in the postoperative period.

Discussion

CSF leakage occurs relatively frequently after skull base surgery. The rate of CSF leakage ranges between 3.3 and 20% depending on the surgical approach employed [9]. The most significant complication of CSF leakage is meningitis [4]. Without intervention, the risk of developing meningitis is estimated to be 10% annually and 40% in the long term [10]. Surgical intervention remains the panacea for managing iatrogenic CSF leakages [11].

Numerous techniques are available for dural reconstruction including watertight and interrupted dural suturing, dural closure with autologous or allogenic materials. Autologous materials, such as temporalis fascia, temporalis muscle, fascia lata, cortical bone, cartilage and fat are widely available. Bone plate mixed with fibrin glue has been reported to be an effective graft. A range of synthetic materials is also commercially available [1]. Multilayer repair with autologous or allogenic materials may provide optimum results [4]; however, there is no consensus in the literature and a standard closure method is yet to be entrenched.

Marchioni et al. [5] have proposed the use of different materials depending on the size of the defect. Single layer technique with the use of a Duragen graft (Integra, Plainsboro, NJ, USA) or temporal fascia graft for most cases and addition of a piece of cortical mastoid graft as a second layer in extremely large defects proved to be adequate and effective.

Savva et al. [12] have reported that the principal factor in successful surgical management is the multilayer

technique. In their study, various graft materials were used to seal the dural defect. In most cases, a free muscle graft with fascia lata was employed. According to other studies [13], small pieces of muscle graft can be used to reinforce any small dural defects to ensure a watertight closure.

According to a study conducted by Gonen et al. [14], posterior pedicle's strip of the temporal muscle can be used as the main sealing tissue in most cases and rigid fixation with additional bone graft may be necessary only in selected cases in which the ossicles are exposed or if the defect is large (>1 cm in diameter).

In the current study, we successfully used a single layer free muscle graft technique to seal intraoperative CSF leakage, which had occurred during different skull base surgeries focused on the temporal bone. Our success rate was about 94% in the immediate postoperative period (including the three patients who responded to the one-week trial of conservative management but no lumbar puncture). Although previous studies align with multilayer approach, as opposed to single layer repair as an effective method in controlling CSF leakages, however optimal multilayer graft placement is challenging given the narrow surgical corridor especially when combined with dynamic (non-fixed) temporal lobe retraction [15, 16]. In addition, even multilayer techniques that incorporate solid and/or semisolid materials have not always achieved a watertight sealing [17].

In our study, we used temporalis muscle as an autologous free graft. Autologous materials are optimal dural graft substrate that remain inert and do not precipitate immunological or inflammatory reactions. They are non-toxic, rapidly integrated into native tissues, flexible, strong, easily suturable, and inexpensive [18]. Thus, there is no concern regarding tissue reactions or infection from foreign materials such as artificial dura.

Park et al. [19] have presented a watertight dural closure technique with the addition of muscle pieces in a “plugging” fashion. Similar to our series, the cross-section of the muscle pieces used was dumbbell shaped. However, contrary to our study, in their study dura mater was first closed with interrupted stitches, and then the muscle pieces inserted into the space between the stitches were sutured to the duramater. Tissue sealant was also used for fixation of the muscle patch. Suturing and tissue sealant may have contributed to the sealing effect.

Although simply sewing or patching over CSF leakages is possible, the long-term results are poor [12]. The procedure for suturing is time consuming, even for experienced surgeons [16]; and even watertight suturing of dura mater may result in CSF leakage, possibly because of the piercing of the needle through the dura mater [19]. Conventional stitching is difficult in the skull base region. Tissue sealants increase the costs of surgical treatment and

are not universally available [16]. We used no tissue sealant or dura suturing and achieved a good surgical result.

Sweeney et al. [15] have recently presented a “pull-through” method for middle fossa floor reconstruction. A composite autologous graft made up of layering fascia, bone and/or cartilage and dural substitute was positioned through the defect and guided by traction on the suture tail that was made to pass through all layers. In other words, the suture is pulled through the defect to help advance and center the graft.

In comparison, we only used a single layer free autologous muscle graft. Theoretical advantages include decreased operative time (because graft harvesting is achieved throughout a simple technique and assembled *ex situ*), a reduced learning curve for CSF leakage repair, and improved confidence in graft placement. This approach can provide an adequate seal that can withstand CSF pressure during the healing period. Without using any artificial grafts, abdominal fat graft and lumbar CSF diversion, this method is considerably more suitable and successful for intraoperative CSF leakages.

The high success rate of the described closure method relies on the special technique of placing the muscle intra and extradurally in a dumbbell-shaped manner. In our series, the dura defect was in close proximity to the bone margins, and the muscle piece sealed the defect as effectively as a “champagne cork”. The intradural part of the graft was supported against the cranial side of the skull base by the ICP. In the process of using a dumbbell shaped muscle graft, the part of the muscle piece inside the dura makes any outward flow of CSF practically impossible [19].

In our proposed method, CSF pressure on the intradural portion of the muscle resulted in a more effective sealing. Intraoperative or postoperative lumbar drainage was not used because CSF pressure reinforced the placement of the muscle graft. The gravitational pressures reinforced the dumbbell shaped graft placement with lower risk of graft migration.

Based on the innovative technique employed in this study, no other similar studies can be compared to such a method. Our series is the first to focus on primary intraoperative repair of iatrogenic CSF otorrhea using “dumbbell technique” single layer free autologous muscle graft.

In retrospect, there are several limitations of our study. First and foremost, the small to moderate size of the dural defects in our series (mean diameter of 5 mm) probably affected the surgical outcomes. We can argue and justify that our technique of single layer muscle graft is an appropriate management for small to moderate dural defects.

In addition, our series constitute a heterogeneous group of patients with uneven distribution in their primary etiology that necessitated surgical intervention. Ultimately, it

would have been ideal to have a randomized controlled trial in order to compare our technique to other reconstruction techniques.

It is under consideration that the follow up period for this study be extended. It should be noted however, that to this date, December 2015, none of the patients returned due to relapse or a recurrence of CSF leakage. Rao et al. reported a case from their patient series in which a recurrence of CSF otorrhea developed 8 years after transmastoid repair with only fascia and fibrin glue. This patient, however, experienced spontaneous CSF leakage, the recurrence of which may be triggered by persistent baseline pathology causing progressive erosion of the thin tegment [20].

Conclusion

In selecting an intraoperative approach to CSF leakage of the temporal bone, we believe that a single layer free autologous muscle graft, using the dumbbell technique through a small to moderate dura defect, is an effective, easily applied, and safe method to seal iatrogenic leakage during temporal bone surgery. This approach compares favorably with other techniques including multilayer grafting with autologous or allogenic materials. To date, there have been no postoperative CSF leakages or episodes of meningitis in any of the patients selected for this study.

Acknowledgements We are indebted to the wonderful personnel of the operating room of the Amir-Alam Hospital for their invaluable help.

Compliance with Ethical Standards

Conflict of interest Nasrin Yazdani, Mohammad Taghi Khorsandi Ashtiani, Hamed Tashakorinia, Mahtab Rabbani Anari and Narges Mikaniki declare that they have no conflict of interest.

Ethical Standard All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

References

1. Raine C (2005) Diagnosis and management of otologic cerebrospinal fluid leak. *Otolaryngol Clin N Am*. 38(4):583–595
2. Moza K, McMenomey SO, Delashaw JB Jr (2005) Indications for cerebrospinal fluid drainage and avoidance of complications. *Otolaryngol Clin N Am* 38(4):577–582
3. Bedrosian JC, Anand VK, Schwartz TH (2014) The endoscopic endonasal approach to repair of iatrogenic and noniatrogenic cerebrospinal fluid leaks and encephaloceles of the anterior cranial fossa. *World Neurosurg*. 82(6 Suppl):S86–S94. doi:10.1016/j.wneu.2014.07.018

4. Kim L, Wisely CE, Dodson EE (2014) Transmastoid approach to spontaneous temporal bone cerebrospinal fluid leaks: hearing improvement and success of repair. *Otolaryngol Head Neck Surg* 150(3):472–478. doi:[10.1177/0194599813518173](https://doi.org/10.1177/0194599813518173)
5. Marchioni D, Bonali M, Alicandri-Ciufelli M, Rubini A, Pavesi G, Presutti L (2014) Combined approach for tegmen defects repair in patients with cerebrospinal fluid otorrhea or herniations: our experience. *J Neurol Surg B Skull Base* 75(4):279–287. doi:[10.1055/s-0034-1371524](https://doi.org/10.1055/s-0034-1371524)
6. Kuczkowski J, Niemczyk K, Stankiewicz C, Pilarska E, Szurowska E, Plichta L (2014) Lateral petrosectomy with obliteration cavity for spontaneous cerebrospinal otorrhea in children. *Am J Otolaryngol*. 35(5):651–654. doi:[10.1016/j.amjoto.2014.06.010](https://doi.org/10.1016/j.amjoto.2014.06.010)
7. Gonen L, Monterio E, Klironomos G, Alghonaim Y, Vescan A, Zadeh G, Gentili F (2015) Endoscopic endonasal repair of spontaneous and traumatic cerebrospinal fluid rhinorrhea: a review and local experience. *Neurosurg Clin N Am* 26(3):333–348. doi:[10.1016/j.nec.2015.03.003](https://doi.org/10.1016/j.nec.2015.03.003)
8. Jeevan DS, Ormond DR, Kim AH, Meiteles LZ, Stidham KR, Linstrom C, Murali R (2015) Cerebrospinal fluid leaks and encephaloceles of temporal bone origin: nuances to diagnosis and management. *World Neurosurg* 83(4):560–566. doi:[10.1016/j.wneu.2014.12.011](https://doi.org/10.1016/j.wneu.2014.12.011)
9. Blioskas S, Magras I, Polyzoidis S, Kouskouras K, Psillas G, Dova S, Markou K (2014) Repair of temporal bone encephalocele following canal wall down mastoidectomy. *Case Rep Otolaryngol* 2014:271824. doi:[10.1155/2014/271824](https://doi.org/10.1155/2014/271824)
10. Hayashi N, Mitsuya K, Gorai K, Inoue K, Ito I, Nakagawa M, Nakasu Y (2015) A novel graft material for preventing cerebrospinal fluid leakage in skull base reconstruction: technical note of perifascial areolar tissue. *J Neurol Surg B Skull Base* 76(1):7–11. doi:[10.1055/s-0034-1386655](https://doi.org/10.1055/s-0034-1386655)
11. Gunaratne DA, Singh NP (2015) Endoscopic pedicled nasoseptal flap repair of spontaneous sphenoid sinus cerebrospinal fluid leaks. *BMJ Case Rep*. doi:[10.1136/bcr-2014-209157](https://doi.org/10.1136/bcr-2014-209157)
12. Savva A, Taylor MJ, Beatty CW (2003) Management of cerebrospinal fluid leaks involving the temporal bone: report on 92 patients. *Laryngoscope* 113(1):50–56
13. Azad T, Mendelson ZS, Wong A, Jyung RW, Liu JK (2015) Fat graft-assisted internal auditory canal closure after retrosigmoid transmeatal resection of acoustic neuroma: technique for prevention of cerebrospinal fluid leakage. *J Clin Neurosci*. doi:[10.1016/j.jocn.2015.08.016](https://doi.org/10.1016/j.jocn.2015.08.016)
14. Gonen L, Handzel O, Shimony N, Fliss DM, Margalit N (2015) Surgical management of spontaneous cerebrospinal fluid leakage through temporal bone defects—case series and review of the literature. *Neurosurg Rev*. doi:[10.1007/s10143-015-0665-8](https://doi.org/10.1007/s10143-015-0665-8)
15. Sweeney AD, Carlson ML, Haynes DS, Thompson RC, Chambliss LB, Wanna GB, Rivas A (2015) novel method for autograft placement during tegmen repair: the suture “pull-through” technique. *Laryngoscope* 125(2):323–325. doi:[10.1002/lary.24879](https://doi.org/10.1002/lary.24879)
16. Freyschlag CF, Goerke SA, Obernauer J, Kerschbaumer J, Thomé C, Seiz M (2015) A sandwich technique for prevention of cerebrospinal fluid rhinorrhea and reconstruction of the sellar floor after microsurgical transsphenoidal pituitary surgery. *J Neurol Surg A Cent Eur Neurosurg* 77:229–232
17. Cavallo LM, Solari D, Somma T, Savic D, Cappabianca P (2014) The awake endoscope-guided sealant technique with fibrin glue in the treatment of postoperative cerebrospinal fluid leak after extended transsphenoidal surgery: technical note. *World Neurosurg* 82(3–4):e479–e485. doi:[10.1016/j.wneu.2013.01.017](https://doi.org/10.1016/j.wneu.2013.01.017)
18. Giovanni S, Della Pepa GM, La Rocca G, Lofrese G, Albanese A, Maria G, Marchese E (2014) Galea-pericranium dural closure: can we safely avoid sealants? *Clin Neurol Neurosurg* 123:50–54. doi:[10.1016/j.clineuro.2014.05.005](https://doi.org/10.1016/j.clineuro.2014.05.005)
19. Park JS, Kong DS, Lee JA, Park K (2007) Intraoperative management to prevent cerebrospinal fluid leakage after microvascular decompression: dural closure with a “plugging muscle” method. *Neurosurg Rev* 30(2):139–142 (**discussion 142**)
20. Rao AK, Merenda DM, Wetmore SJ (2005) Diagnosis and management of spontaneous cerebrospinal fluid otorrhea. *Otol Neurotol* 26(6):1171–1175