Surgical Repair of Spontaneous Cerebrospinal Fluid (CSF) Leaks: A Systematic Review

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**Objectives:** To review the safety and efficacy of surgical management for spontaneous cerebrospinal fluid (CSF) leaks of the anterior and lateral skull base.

**Data Sources:** A systematic review of English articles using MEDLINE.

**Review Methods:** Search terms included spontaneous, CSF, cerebrospinal fluid, endoscopic, middle fossa, transmastoid, leak, rhinorrhea. Independent extraction of articles by 3 authors.

**Results:** Patients with spontaneous CSF leaks are often obese (average BMI of 38 kg/m²) and female (72%). Many patients also have obstructive sleep apnea (~45%) and many have elevated intracranial pressure when measured by lumbar puncture. In addition to thinning of the skull base, radiographic studies also demonstrate cortical bone thinning. Endoscopic surgical repair of anterior skull base leaks and middle cranial fossa (MCF) approach for repair of lateral skull base leaks are safe and effective with an average short-term failure rate of 9% and 6.5%, respectively. Long-term failure rates are low. One randomized trial failed to show improved success of anterior leak repairs with the use of a lumbar drain (LD) (95% with vs. 92% without; P = 0.2). In a large retrospective cohort of MCF lateral skull base repairs, perioperative LD use was not necessary in >94% of patients.

**Conclusions:** Spontaneous CSF leaks are associated with female gender, obesity, increased intracranial hypertension, and obstructive sleep apnea. Endoscopic repair of anterior skull base leaks and MCF or transmastoid approaches for lateral skull base leaks have a high success rate of repair. In most cases, intraoperative placement of lumbar drain did not appear to result in improved success rates for either anterior or lateral skull base leaks.

**Key Words:** Cerebrospinal fluid leak, CSF leak, spontaneous, endoscopic repair, MCF repair, anterior skull base, lateral skull base, obstructive sleep apnea, review.

**Level of Evidence:** 2a, Systematic Review.

**INTRODUCTION**

Spontaneous cerebrospinal fluid (sCSF) leaks occur in the absence of trauma, surgery, or another inciting event. Typically, in both the anterior and lateral skull base, these leaks occur in areas where the skull base and dura are breached in an area over a pneumatized space; anteriorly along the cribriform plate or over the paranasal sinuses (Fig. 1) and laterally in the area of the temporal bone (Fig. 2). Herniation of brain through the skull base defects, termed an encephalocele, can also occur (Fig. 2C).

The clinical presentation of sCSF leak should be recognized. Lateral sCSF leaks manifest with a clear middle ear effusion and aural fullness. Often patients will undergo myringotomy and tube placement resulting in continuous clear tube otorrhea that is pulsatile on otologic examination. Anterior sCSF leaks often present with clear rhinorrhea and headaches. Communication with the intracranial space increases the risk of meningitis and other cerebral complications. Intracranial complications may be the first presenting symptom of a sCSF leak. The average rate of preoperative meningitis in patients with a lateral skull base sCSF leaks is around 20%, with a reported range of 6% to 58%. Others patients can present with pneumocephalus.

The diagnosis of sCSF leak involves the combination of clinical history, a skull base defect on high resolution computed tomography (CT) and associated clear pulsatile otorrhea or clear rhinorrhea. Confirmatory testing of the fluid with β-2 transferrin can be performed although it is often not necessary if imaging findings and clinical history are consistent.

Unlike traumatic or iatrogenic leaks, sCSF leaks are highly associated with obesity and idiopathic intracranial hypertension (IIH). The obesity epidemic in the US started in the 1980s and after a 1–2 decade delay, there has been a corresponding rise in the number of patients...
Spontaneous CSF leaks do not typically self-resolve, and require surgical repair. For anterior skull base sCSF leaks, open repairs have largely been replaced by minimally invasive endoscopic repairs over the past 30 years, after Wigand reported the first endoscopic repair in the 1980s. Controversy still exists between open craniotomy (MCF), transmastoid or combined approach for repair of lateral skull base sCSF leaks.

The safety and efficacy of surgical treatment of sCSF leaks has not been systematically evaluated. The use of intra-operative fluorescein and peri-operative CSF diversion are controversial, but both will be discussed. This new systematic review hopes to elucidate the optimal approach and perioperative care for repair of skull base spontaneous CSF leaks.

MATERIALS AND METHODS

Study Method

Using a search methodology in accordance with PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), a systematic review of the literature was performed for sCSF leaks of the anterior and lateral skull base.

The following PICOS (Participants, Interventions, Comparisons, Outcomes, and Study design) criteria were utilized. The patient population included patients with sCSF leaks of both the anterior and lateral skull base. The intervention included those who underwent surgical repair of spontaneous CSF leaks. The comparison was between various approaches with and without lumbar drains in addition to performing a comparison of the anterior and lateral skull base cohorts. The outcomes included post-op CSF leak (i.e., success of repair) with various approaches for anterior skull base repair (i.e., endoscopic with and without septal flap) and lateral skull base repair (i.e., MCF vs. transmastoid vs. combined). In addition, we compared the postoperative CSF leak rates between anterior and lateral skull base cohorts. A secondary outcome evaluated was operative complications. The setting included one randomized controlled trial and all other studies were retrospective cohort studies.

Search Method

A search of all articles from January 1, 2000 until June 30, 2016 reporting outcomes after repair of sCSF leaks was performed using the Pubmed, Medline, and Cochrane Review Databases. This start date was chosen due to the previous meta-analysis of anterior sCSF leaks in 2000. To our knowledge, there has not been a systematic review of lateral sCSF leaks. Using a keyword search strategy, studies were identified and verified independently by two
authors (BCL, MMB) for the anterior skull base CSF leaks and by one author (RFN) for the lateral skull base CSF leaks.

The detailed keywords used for the anterior skull base search were as follows: Spontaneous, Cerebrospinal Fluid Leak, CSF Leak, Rhinorrhea, Endoscopic, Endonasal. The detailed keywords used for the lateral skull base search were as follows: Spontaneous, Cerebrospinal Fluid Leak, CSF Leak, Temporal, Otorrhea.

Sufficient number of patients (≥5), English language and ability to extract data were used as inclusion criteria. Data points extracted from each study included number of patients, patient demographics, leak location, types of repair (including layers, flap, and rigid repairs), surgical approach, rates of postoperative leak, average follow up duration, and adjunct use of CSF diversion, packing, fluorescein, or acetazolamide.

In studies where the relevant data points were not explicitly calculated and reported, but individual data points were presented, calculations were made in order to extrapolate the relevant data points. In cases where data could not be extracted, specifically gender breakdown or number of lumbar drains used, this was documented.

RESULTS

The literature search (Fig. 3) began by broadly searching for any references of CSF or cerebrospinal fluid, ultimately coning down to identify citations relevant to endoscopic or endonasal management of spontaneous skull base CSF leaks. Articles not in English, or where fewer than 5 patients with spontaneous leaks were incorporated into analysis were immediately excluded. Once relevant citations had been identified and reviewed, articles in which relevant information could not be extracted or was not reported within the article were also excluded.

Literature searches identified 45 anterior and 21 lateral articles suitable for full text review. After review, 14 anterior and 6 lateral articles were excluded due to insufficient detail regarding spontaneous leaks or insufficient data for meaningful analysis. Thus, our search yielding 31 anterior and 15 lateral sCSF leak articles for analysis, which included a cumulative total of 646 anterior and 394 lateral sCSF leak patients across all studies (Tables I and II).

All studies utilized retrospective review, however, one article was described as a prospective review due to prospective data collection. All studies had at least five patients with spontaneous CSF leaks. The average study cohort was 20.8 patients (range 5–77) for anterior sCSF leaks and 26.2 patients (range 9–60) for lateral sCSF leaks. Follow-up was variable and ranged from 1 to 124 months. A breakdown of analyzed studies can be seen in Tables I and II.

Demographics

The patient population with sCSF leaks are often obese females of middle age. In our review 77% of anterior sCSF leaks and 65% of lateral sCSF leaks occurred females (Tables I and II). Studies have demonstrated that patients with sCSF leaks have an elevated body mass index (average approximately 35-38 kg/m²). The
| Study Name, Year | Study Type | Patients (#) (Gender) | Approach | Recon Layers | LD (#) Duration | Follow up (avg) | Post-op CSF leak (%) | Fluorescein |
|-----------------|------------|-----------------------|----------|--------------|-----------------|----------------|----------------------|------------|
| Lopatin et al,36 2003 | Retro | 21 (15F/6M) | Endonasal | 3 layers | Yes (21/21) 5-8 d | 9–42 mo | 4.8% N.R. | |
| Tosun et al,37 2003 | Retro | 7 (CND) | Endonasal | 3 layers | Yes (CND) 1-5 d | 36 mo | 14% N.R. | |
| Schlosser et al,12 2003 | Retro | 16 (13F/3M) | Endonasal | 1 or 2 layers | Yes (16/16) 2-3 d | 14.1 mo | 0% Yes | |
| Zuckerman et al,38 2005 | Retro | 11 (8F/3M) | Endonasal | 2 layers or 3 layers | Yes (11/11) CND | 15 mo | 18.2% Yes | |
| Silva et al,39 2006 | Retro | 6 (5F/1M) | Endonasal | 3 layers or 4 layers | No | 27.4 mo | 0% Yes | |
| Basu et al,40 2006 | Retro | 8 (CND) | Endonasal | 2 layers | N.R. 25 mo | 12.5% No | |
| Woodworth et al,13 2008 | Retro | 56 (43F/13M) | Endonasal + Caldwell Luc | 2 layers or 3 layers | Yes (56/56) 2-3 d | 34 mo | 5% Yes | |
| Purkey et al,14 2009 | Retro | 7 (5F/2M) | Endonasal + Trephine | 2 layers | Yes (7/7) 2-3 d | 27.8 mo | 0% Yes | |
| Singh et al,41 2009 | Retro | 7 (5F/2M) | Endonasal | 3 layers | No | N.R. | 0% No | |
| Banks et al,42 2009 | Retro | 77 (57F/20M) | Endonasal | multiple | Yes (CND) CND | 21 mo | 9% Yes | |
| Alameda et al,43 2009 | Retro | 10 (CND) | Endonasal | 2 layers or 3 layers | Yes (10/10) 4-5 d | 23 mo | 6% Yes | |
| Forer et al,16 2010 | Retro | 7 (5F/2M) | Endonasal | 5 layers | No | 33.7 mo | 14% No | |
| Seth et al,44 2010 | Retro | 39 (33F/6M) | Endonasal | 3 layers | Yes (38/39) CND | 23 mo | 12.8% Yes | |
| Giannetti et al,45 2011 | Retro | 26 (24F/2M) | Endonasal | unk | Yes (CND) CND | 70 mo | 38% Yes | |
| Caballero et al,46 2012 | Retro | 40 (CND) | Endonasal | unk | Yes (30/40) CND | 13 mo | 20% Yes | |
| Kirtane et al,47 2012 | Retro | 13 (7F/6M) | Endonasal | 3 layers | No | 6–40 mo | 0% No | |
| Albu et al,21 2013 | Retro | 36 (CND) | Endonasal | 2 layers | Yes (17/36) 3 d | 48 mo | 16% Yes | |
| Deenadayal et al,48 2013 | Retro | 7 (5F/2M) | Endonasal | 2 layers | Yes (7/7) 2 d | 5–40 mo (15) | 0% No | |
| Study Name, Year | Study Type | Patients (#) | Approach | Recon Layers | LD (#) | Duration | Follow up (avg) | Post-op CSF leak (%) | Fluorescein |
|------------------|------------|--------------|----------|--------------|--------|----------|----------------|---------------------|------------|
| Virk et al,49 2013 | Retro      | 36 (27F/9M)  | Endonasal | 3 layers     | Yes (22/36) | 21 mo    | 11%           | Yes                 |            |
| Chaaban et al,8 2014 | Prosp     | 46 (34F/12M) | Endonasal | 3 layers     | Yes (38/46) | 22 mo    | 7.1%          | Yes                 |            |
| Elmorsy et al,50 2014 | Retro   | 31 (22F/9M)  | Endonasal | 4 layers     | No       | 32.4 mo  | 12.9%         | Yes                 |            |
| Fyrmpas et al,51 2014 | Retro   | 11 (8F/3M)   | Endonasal | 3 layers     | Yes (11/11) | 37.1 mo  | 9.1%          | No                  |            |
| Sannareddy et al,52 2014 | Retro  | 11 (9F/2M)   | Endonasal | 2–3 layers   | Yes (7/11) | 15 mo.   | 18.2%         | No                  |            |
| Lieberman et al,53 2015 | Retro  | 44 (35F/9M)  | Endonasal | 3 layers     | Yes (1/44) | 9.2 mo   | 0%            | Yes                 |            |
| Emanuelli et al,54 2015 | Retro  | 10 (8F/1M)   | Endonasal | 3 layers     | No       | 6–24 mo  | 0%            | Yes                 |            |
| Martínez-Capoccioni et al,55 2015 | Retro | 25 (20F/5M)  | Endonasal | 3 layers or 2 layers | Yes (25/25) | 1–72 mo  | 4%            | No                  |            |
| Pagella et al,56 2016 | Retro   | 6 (8F/0M)    | Endonasal | 2 layers or NSF | No       | 34–124 mo (80.8)  | 16.7%      | Yes                 |            |
| Ziade et al,23 2016 | Retro   | 10 (8F/2M)   | Endonasal | 2 layers     | No       | 6–38 mo  | 0%            | Yes                 |            |
| Nix et al,57 2016 | Retro     | 7 (CND)      | Endonasal | 2–4 Layers   | No       | N.R.     | 0%            | N.R                 |            |
| Sarkar et al,17 2016 | Retro   | 5 (3F/2M)    | Endonasal | 1 layer      | Yes (5/5) | 11.4 mo  | 0%            | N.R                 |            |
| Kljajic et al,58 2016 | Retro   | 10 (7F/3M)   | Endonasal | 3 layers     | Yes (10/10) | 5 d      | 0%            | Yes                 |            |

**Total** 646 (414F/124M) (77%F/23%M) 0-38% Avg = 9% 19 Studies

Avg = average; CND; could not determine; F = Female; LD = lumbar drain; M = Male; N.R. = not reported; Prosp = prospective; Retro = retrospective study.
Diagnosis and Location

Clear rhinorrhea or unilateral clear middle ear effusion/otorrhoea were reported throughout most studies as the presenting symptoms, with the minority of studies mentioning meningitis or other intracranial complications as a precipitating symptom.

The most common diagnostic test is a high resolution CT scan of the skull base (anterior or lateral) to evaluate for a skull base defect. It is essential to obtain fine cut images with <1mm slice thickness. Multi-planar reformats can also be helpful. MRI studies are also used when differentiation of a skull base mass is required preoperatively. When there is collectable CSF rhinorrhea, a β-2 transferrin assay is performed to confirm that the drainage is CSF and not due to allergic or vasomotor rhinitis.

The most common locations for anterior sCSF leak were the cribiform plate and lateral sphenoid sinus. However, one study noted the posterior table of the frontal sinus as the most common site of sCSF leak. Importantly, up to 31% of sCSF leaks have multiple defects in the anterior skull base. Lateral sCSF leaks occur over the tegmen mastoideum or the tegmen tympani most commonly. Up to 45% of patients have multiple tegmen defects.

Surgical Approach and Repair Technique

Surgical repair of anterior sCSF leaks is almost exclusively through endoscopic endonasal approach (Table I). In all but 2 studies, treatment was approached in a purely endonasal fashion. One study noted use of a Caldwell Luc approach to access the far lateral aspects of the sphenoid sinus. Purkey et al. utilized trephination to access a far lateral supraorbital ethmoid leak. These approaches were ultimately used to facilitate endoscopic treatment. Additional use of the transethmoid, transantral, or transpterygoid approach may be needed to access the leak site for repair.

Approaches to the lateral temporal bone sCSF leaks include middle cranial fossa (MCF), transmastoid (TM), or combined approach. The MCF or combined approach is the most common approach used (Table II). The advantages of MCF approach include the ability to see the entire skull base floor in the event of multiple defects, placement of large multilayer grafts and avoidance of removal of ossicles for repair of tegmen tympani defects. Subtotal petrosectomy with ear canal closure has also been performed in poor hearing ears with large meningocoele. HASTE imaging be performed at 18 months after repair to evaluate for residual epidermoid/cholesteatoma.

In the anterior skull base, multi-layer repairs are most commonly reported, with one study reporting 5 layers used for repair of lateral sphenoid leaks, and one study mentioned the use of single layer repairs. It is essential to note that in practice the number of layers utilized for anterior repairs is heavily dependent on the size of the skull base defect. Small defects (<5 mm) are typically closed using free grafting. Typically, leaks in the cribriform region were repaired using 2–3 layers. Fibrin glue or tissue sealant use was variable and most studies reported the use of dissolvable packing. Less than half of studies reported utilizing nonabsorbable packing. Removal of the nonabsorbable packing ranged from 2–13 days post operatively. Pedicled posterior naso-septal flaps can be utilized for cribriform and ethmoid defects, but typically smaller rotational or “trap door” flaps are used for spontaneous leaks. Bone grafting is useful in many locations along the anterior skull base, however along the cribriform this is technically very difficult and rarely used due to lack of circumferential bony edges for graft placement.

Multilayer closure also applies to lateral temporal bone sCSF leaks. Typical repair materials include autologous temporalis fascia, split calvarial bone grafts, cellulosic graft (Synthecel Dura Repair, DepuySynthes) and collagen graft (DuraGen, Integra). Additional reported materials used include vascularized flaps (temporal parietal flap) and bone cement. Hydroxyapatite cement (HAC) has been used to repair the skull base, and HAC is a calcium-phosphate cement that sets to hydroxyapatite (HA), the major component of human skeletal bone. This is advantageous because it can harden in a wet environment and it will osseointegrate into bone. The potential disadvantage is the risk of infection which has been reported up to 5% of cases.

It should be noted that there is a strong association between tegmen dehiscence and superior semicircular canal dehiscence (SSCD) and up to 15.2% of patients with sCSF leaks will also have SSCD. While SSCD repair may not be required during sCSF leak repair, pre-operative patient counseling about the risk of hearing loss and need for repair should be discussed.

Lumbar Drain and Fluorescein

The use of a lumbar drain in the treatment of sCSF leaks is controversial. The proposed advantages of placement of a lumbar drain intraoperatively are measurement of the CSF opening pressure (although the pressure measurement during an active leak may underrepresent the true intracranial pressure), administration of localizing agents such as fluorescein, and decompression of the temporal lobe during middle fossa craniotomy. Postoperative use of a lumbar drain may be used to decrease CSF pressure to facilitate arachnoid formation at the surgical site.

Lumbar drain use

Many anterior skull base sCSF leak repair studies (21 of 31 studies) described the use of a lumbar drain (Table I). A distinct advantage of lumbar drain placement is the use of interoperative fluorescein to localize the site of the leak endoscopically. Drains were typically used post-operatively for 2–5 days. In contrast, most
lateral skull base repairs are done without the use of a lumbar drain (Table II). In addition, with direct visualization of the entire skull base floor through a middle fossa approach negates the need for fluorescein.

Ascribing drain use to success or failure is largely impossible due to limited data regarding individual patient lumbar drain use in each study. One randomized study of anterior skull base repairs has demonstrated that the use of LD for anterior skull base repairs does not significantly decrease the recurrence rate of CSF leak post-operatively. A large retrospective review of MCF repair of lateral skull base repairs demonstrated that LD are not required for successful repair.

The risk of a lumbar drain has been reported to be as high as 12.3% and the complications include persistent lumbar leakage after removal, over drainage, and retained catheters. In addition, there is increased financial cost with placement and increased length of

### TABLE II.
Spontaneous CSF Leaks (Lateral Skull Base Repairs).

| Study Name, Year | Study Type | Patients (#) (Gender) | Approach (% of total) | LD (#) | Follow up (avg) | Post-op CSF leak (%) |
|------------------|------------|-----------------------|-----------------------|--------|----------------|---------------------|
| Gacek et al, 1999 | Retro      | 21 (14F/7M)           | MCF (89%) TM (11%)    | N.R.   | N.R.           | 0                   |
| Brown et al, 2004 | Retro      | 9 (3F/6M)             | MCF (88%) TM (22%)    | N.R.   | 14.8 mo        | 2 (22%)             |
| Leonetti et al, 2005 | Retro | 48 (28F/20M)        | MCF (100%)            | No     | 57 mo          | 2 (3.9%)            |
| Gubbels et al, 2007 | Retro | 15 (10F/5M)          | MCF (100%) Yes (14/15) | 13 mo  | 1 (7%)         |
| Kutz et al, 2008 | Retro      | 17 (12F/5M)           | MCF (76%) Combined (12%) TM (12%) | No     | 11 mo          | 1 (5.9%)            |
| LeVay et al, 2008 | Retro      | 14 (3F/11M)           | TM (100%)            | No     | 24-140 mo      | 0                   |
| Kari et al, 2011 | Retro      | 33 (CND)              | TM (75%) MCF (9%) Combined (9%) Subtotal (5%) Yes (33/33) | 54 mo  | 1 (3%)         |
| Oliaei et al, 2012 | Retro | 15 (12F/3M)          | TM (61%) MCF (23%) Combined (11%) | No     | 12.7 mo        | 1 (5.5%)            |
| Kenning et al, 2012 | Retro | 23 (12F/11M)         | Combined (100%)       | Yes (23/23) | 10.4 mo     | 1 (4%)              |
| Stucken et al, 2012 | Retro | 11 (8F/3M)           | Combined (64%) MCF (36%) | Yes (4/20) | 27.2 mo      | 1 (5%)              |
| Son et al, 2014 | Retro      | 33 (CND)              | Combined (53%)        | Yes (33/33) | 17.5 mo     | 2 (6%)              |
| Kim et al, 2014 | Retro      | 15 (9F/6M)            | TM (100%)            | No     | 9 mo           | 1 (7%)              |
| Vivas et al, 2014 | Retro      | 32 (22F/10M)          | MCF (84%) TM (16%)    | Yes (32/32) | 23 mo       | 3 (9.4%)            |
| Stevens et al, 2016 | Retro | 48 (38F/10M)         | TM (73%) MCF (15%) Combined (12%) | N.R.   | 23.1 mo       | 7 (14.5%)           |
| Nelson et al, 2016 | Retro | 60 (41/19)           | MCF (100%)            | No     | 19.5 mo        | 3 (6.5%)            |

**TOTAL 394 (212/116) 0–22%**

Avg = 6.6%

Avg = Average; Combined = MCF + TM; F = Female; M = Male; MCF = Middle Cranial Fossa; LD = lumbar drain; mo = months; Retro = retrospective study; TM = Transmastoid.
hospital stay. Thus, judicious use of lumber drains is recommended.

**Fluorescein use**

It should be noted that intrathecal fluorescein is an off-label use of the medication. Fluorescein was used in patients in 19 studies of anterior sCSF leak repairs (Table I). In a single study, fluorescein was used topically to help identify a leak. Typically, 10 mg of the substance is utilized, diluting 0.1 mL of 10% fluorescein in 10 mL of CSF or sterile preservative free saline and injected into the intrathecal space via a catheter or puncture over 10 minutes. Reported side effects include seizures, and with doses of 700 mg (70 times the recommended dose) death. No seizures or deaths due to fluorescein were noted in any of the analyzed studies. In our review, fluorescein was found to be used more frequently in the United States.

**Success Rates**

The overall success rate for surgical repair of anterior and lateral sCSF leaks is high (Tables I and II). For anterior sCSF leaks, the average overall failure rate was 9%, with 12 studies noting 0% failure rates (Table I). It should be noted that these were primary failure rates. Several studies reported taking patients back to the operating room for second and third repairs. These secondary and tertiary repairs were not analyzed. Most surgeons used the endoscopic approach with multi-layer closure and a septal flap.

For lateral sCSF leaks, the average overall failure rate was 6.6% (Table II). The average follow-up was typically more than 12 months. Both transmastoid and middle fossa approaches appeared to have low failure rates. There is not sufficient data to determine which approach has a higher success rate.

**Treatment Adjuncts**

Spontaneous CSF leaks are consistently associated with obesity. Studies have demonstrated elevated ICP in patients with sCSF leaks of the anterior and lateral skull base. However, diurnal variation of ICP occurs normally and not all patients with sCSF leaks have elevated ICP when measured. Options for decreasing elevated ICP after surgical repair can include acetazolamide or ventriculoperitoneal (VP) shunt. Long-term recurrence of CSF leaks is believed to result from lack of management of ICP. This management was advocated more in the anterior skull base sCSF leak literature compared to the lateral skull base literature.

**DISCUSSION**

Evaluating and treating patients with sCSF leaks has typically been challenging due to the underappreciated association with IIH and limited data catered specifically to this type of leak. In reviewing the literature several trends became apparent.

The etiology of sCSF leaks is not completely understood, but there is a clear association of sCSF leaks with obesity (~80% of patients), elevated ICP (~40% of patients) and OSA (~43% of patients). Data from the National Health and Nutrition Examination Survey (NHANES) have demonstrated high rates of obesity in the United States beginning in the early 1980s. It is currently estimated that 35.2% of males and 40.5% of females are obese. Recent NHANES data demonstrate a stabilization of the obesity rate in the United States for men since 2005, but a continued rise in the obesity rate for women. Correlating with the rise in obesity rates, there has been a more than doubling of the number of lateral skull base sCSF leak repairs from 2002 to 2012. Thus, sCSF leaks will likely continue to be prevalent for skull base surgeons.

Weight loss should be encouraged but currently there is no data showing that weight loss or bariatric surgery can alter ICP or the incidence of sCSF leaks.

IIH as determined by lumbar puncture is seen in ~40% of patients with sCSF leaks. It is also important to note that when opening pressure is obtained in the operating room using general anesthetic, the measured pressure is often lower than that experienced by the patient when awake. Measurement of ICP with lumbar puncture at 4–6 weeks after repair should be considered. Elevated ICP can be management medically with acetazolamide, a carbonic anhydrase inhibitor that decreases CSF production. Some patients with significantly elevated ICP should be considered for VP shunting by a neurosurgeon. However, there are risks of these management strategies. While acetazolamide is a relatively low-risk medication, it does come with the risk of electrolyte and metabolic derangements. Delayed measurement of CSF opening pressure is invasive. VP shunt risks include surgical site infections, meningitis, low-pressure headaches, shunt revisions, shunt failure leading to repeat CSF leaks and death.

Because of elevated ICP, some authors advocate patients to be evaluated by an ophthalmologist to evaluate for papilledema. Interestingly, one prospective study demonstrated that papilledema was absent in patients with sCSF leaks. There is also a strong association with obstructive sleep apnea (OSA) in patients with sCSF leaks. As many as 43% of patients with sCSF presented with the diagnosis of OSA and the incidence of OSA may be higher if all patients with sCSF leaks were prospectively tested for OSA. This association is important because it is know that ICP spike during apneic events suggesting that episodic rises in ICP may also contribute to skull base erosion over time (Fig. 4). Thus, it is recommended that all patients with sCSF leaks undergo a polysomnogram to assess for OSA. After surgical repair of lateral skull base sCSF leaks, it appears safe to resume CPAP treatment of OSA. It is unknown if CPAP treatment of OSA can delay or prevent the occurrence of sCSF leaks.

Diagnosis of sCSF leaks follows a relatively straightforward paradigm, with initial testing of nasal secretions for β-2 transferrin and high resolution imaging able to detect the vast majority of skull base defects.
Spontaneous CSF leaks are associated with female gender, obesity, increased intracranial pressure, and obstructive sleep apnea. Diagnosis can often be achieved with testing by β-2 transferrin and high-resolution imaging. Endoscopic repair of anterior skull base leaks and MCF or transmastoid approaches for lateral skull base leaks have a high success rate of repair. In most cases, intraoperative placement of lumbar drain did not appear to result in improved success rates for either anterior or lateral skull base leaks.

CONCLUSION

Spontaneous CSF leaks are associated with female gender, obesity, increased intracranial pressure, and obstructive sleep apnea. Diagnosis can often be achieved with testing by β-2 transferrin and high-resolution imaging. Endoscopic repair of anterior skull base leaks and MCF or transmastoid approaches for lateral skull base leaks have a high success rate of repair. In most cases, intraoperative placement of lumbar drain did not appear to result in improved success rates for either anterior or lateral skull base leaks.

BIBLIOGRAPHY

1. Son HJ, Karkas A, Buchanan P, et al. Spontaneous cerebrospinal fluid effusion of the temporal bone: repair, audiological outcomes, and obesity. Laryngoscope 2014;124:1204–1208.
2. Markou K, Goudakos J, Franco-Vidal V, et al. Spontaneous osteodural defects of the temporal bone: diagnosis and management of 12 cases. Am J Otolaryngol 2011;32:135–140.
3. Wannemaecker TJ, Hubbell RD, Nelson RF. Tension pneumocephalus related to spontaneous skull base dehiscence in a patient on BiPAP. Otol Neurotol 2016;37:e522–e524.
4. Nelson RF, Gantz BJ, Hansen MR. The rising incidence of spontaneous cerebrospinal fluid leaks in the United States and the association with obesity and obstructive sleep apnea. Otol Neurotol 2015;36:476–480.
5. Wigand ME. Transnasal ethmoidectomy under endoscopic control. Rhinology 1981;10:7–15.
6. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. PLoS medicine 2009;6:e1000100.
7. Hegazy HM, Carrau RL, Snyderman CH, et al. Transsphenoidal endoscopic repair of cerebrospinal fluid rhinorrhea: a meta-analysis. Laryngoscope 2006;116:1166–1172.
8. Chaaban MR, Illing E, Riley KO, et al. Transsphenoidal endoscopic repair of cerebrospinal fluid rhinorrhea: a five-year prospective evaluation. Laryngoscope 2014;124:70–75.
9. LeVay AJ, Kveton JF. Relationship between obesity, obstructive sleep apnea, and spontaneous cerebrospinal fluid otorrhea. Laryngoscope 2008;118:275–278.
10. Nelson RF, Roche JP, Gantz BJ, et al. Middle Cranial Fossa (MCF) approach without the use of lumbar drain for the management of spontaneous cerebrospinal fluid (CSF) leaks. Otol Neurotol 2016;37:1625–1629.
11. Kutz JW, Jr, Hussain IA, Isaacson B, et al. Management of spontaneous cerebrospinal fluid otorrhea. Laryngoscope 2008;118:2195–2199.
12. Schlosser RJ, Bolger WE. Spontaneous nasal cerebrospinal fluid leaks and empty sella syndrome: a clinical association. Am J Rhinol 2001;15:91–96.
13. Woodworth BA, Prince A, Chiu AG, et al. Spontaneous CSF leaks: a paradigm for definitive repair and management of intracranial hypertension. Otolaryngol Head Neck Surg 2008;138:715–720.
14. Purkey MT, Woodworth BA, Hahn S, et al. Endoscopic repair of suprornital ethmoid cerebrospinal fluid leaks. ORL 2009;71:83–88.
40. Basu D, Haughey BH, Hartman JM. Determinants of success in endoscopic cerebrospinal fluid leak repair. Otalaryngol Head Neck Surg 2006:135:769–773.

41. Singh R, Hazarika P, Nayak DR, et al. Endoscopic repair of cerebrospinal fluid rhinorrhea - Manipal experience. Indian J Otolaryngol Head Neck Surg 2009:61:14–18.

42. Banks CA, Palmer JN, Chiu AG, et al. Endoscopic closure of CSF rhinorrhea: 193 cases over 21 years. Otalaryngol Head Neck Surg 2009:140:826–833.

43. Alamada YA, Busquets JM, Portela JC. Anterior skull base cerebrospinal fluid fistulas in Puerto Rico: treatment and outcome. Boletin de la Asociacion Medica de Puerto Rico 2009:101:29–33.

44. Seth R, Rajasekaran K, 3rd, Luong A, et al. Spontaneous CSF leaks: factors predictive of additional interventions. Laryngoscope 2010:120:2141–2146.

45. Giannetti AV, de Morais Silva Santiago AP, Becker HM, et al. Comparative study between primary spontaneous cerebrospinal fluid fistula and late traumatic fistula. Otalaryngol Head Neck Surg 2011:144:463–468.

46. Caballero N, Bhaulla V, Stankiewicz JA, et al. Effect of lumbar drain placement on recurrence of cerebrospinal rhinorrhea after endoscopic repair. Int Forum Allergy Rhinol 2012:2:222–226.

47. Kirtane MV, Lali A, Chavan K, et al. Endoscopic repair of lateral sphenoid recess cerebrospinal fluid leaks. Indian J Otolaryngol Head Neck Surg 2012:64:188–192.

48. Deenadayal DS, Vidysagar D, Navyen Kumar M, et al. Spontaneous CSF rhinorrhea our experience. Indian J Otolaryngol Head Neck Surg 2013:65:271–275.

49. Vign ES, Elniyeh B, Saleh HA. Endoscopic management of cerebrospinal fluid rhinorrhoea: the charring cross experience. J Neurol Surg Part B Skull Base 2013:74:61–67.

50. Elmorey SM, Khafagy YM. Endoscopic management of spontaneous CSF rhinorrhea with septal graft and middle turbinante rotational flap technique: a review of 31 cases. Bar Nose Throat J 2014:53:E14–E19.

51. Fyrmag K, Konstantindis I, Selviardi P, et al. Management of spontaneous cerebrospinal fluid leaks of the sphenoid sinus: our experience. J Laryngol Otol 2014;128:797–802.

52. Sannareddy RR, Ramababu K, Kumar RK, et al. Endoscopic management of CSF rhinorrhea. Neurology India 2014:62:532–539.

53. Lieberman SM, Chen S, Jethanamset D, et al. Spontaneous CSF rhinorrhea: prevalence of multiple simultaneous skull base defects. Am J Rhi- nology 2015:29:77–81.

54. Emanuelli E, Milanese L, Rossetto M, et al. The endoscopic endonasal approach to spontaneous cerebrospinal fluid rhinorrhea in the elderly. Clin Neurosurg 2015:132:1–25.

55. Martinez-Capoccioni G, Serramito-Garcia R, Huertas-Pardo B, et al. Spontaneous cerebrospinal fluid leaks in the anterior skull base: a surgical challenge. J Laryngol Otol 2015:129:358–364.

56. Pagella F, Busateri A, Matti E, et al. Endoscopic management of spontaneous crival cerebrospinal fluid leaks: case series and literature review. World Neurosurg 2016:86:470–477.

57. Nix P, Tafuri A, Phillips N. Retrospective analysis of anterior skull base CSF leaks and endoscopic repairs at Leeds. Br J Neurosurg 2016:30:422–428.

58. Klajic V, Vulekovic P, Vlaski L, et al. Endoscopic repair of cerebrospinal fluid rhinorrhea. Braz J Otorhinolaryngol 2016.

59. Gacek RR, Gacek MR, Tart R. Adult spontaneous cerebrospinal fluid otor- rhoea: diagnosis and management. Am J Otolaryngol 1999:20:770–776.

60. Brown NE, Grundfast KM, Jabre A, et al. Diagnosis and management of spontaneous cerebrospinal fluid-middle ear effusion and rhinorrhea. Laryngoscope 2004:114:800–805.

61. Gubbes SP, Selden NR, Delashaw JB, et al. Spontaneous middle fossa encephalocele and cerebrospinal fluid leakage: diagnosis and manage- ment. Otol Neurotol 2007:28:1131–1139.

62. Kari E, Mattox DE. Transcranial management of temporal bone ence- phaloceles and CSF leaks: review of 56 consecutive patients. Acta Oto- laryngol 2011:131:391–394.

63. Oligny S, Mahboubi H, Djallian IR. Transmastoid approach to temporal bone cerebrospinal fluid leaks. Am J Otolaryngol 2012:33:556–561.

64. Stucken EZ, Selenskih SB, Brown KD. The role of obesity in spontaneous tem- poral bone encephaloceles and CSF leak. Otolar Neurotol 2012:35:1412–1417.

65. Kim L, Wisely CE, Dodson EE. Transmastoid approach to spontaneous temporal bone cerebrospinal fluid leaks: hearing improvement and suc- cess of repair. Otolar Neurotol Head Neck Surg 2014:150:472–478.

66. Stevens SM, Rink HG, McIlwain WR, et al. Association between lateral skull base thickness and surgical outcomes in spontaneous CSF otor- rhoea. Otolar Neurotol Head Neck Surg 2016:154:707–714.