INTRODUCTION

In posterior fossa surgery, such as microvascular decompression (MVD), cerebrospinal fluid (CSF) leakage is crucial problem. When there is damage to the anatomical barrier between subarachnoid spaces and the tympanic cavity, CSF rhinorrhea or otorrhea can occur from abnormal communication. While the temporo-occipital bone is drilled out during surgery, the mastoid air cells can be opened and CSF can leak through this pathway. Most cases of ear fullness or conductive hearing loss are from irrigation fluid. These symptoms resolve as fluid reabsorbs within a few days after surgery. However if there are persistent symptoms, CSF leakage due to incomplete closure of dura and opened air cells must be con-
sidered. Various symptoms can occur such as headache, nausea, ear fullness, and CSF rhinorrhea/otorrhea problems [1-3]. Furthermore, CSF leakage can cause complications such as delayed wound healing, wound infections, and meningitis. Early diagnosis and treatment of CSF leakage is very important. Lumbar drain (LD) insertion and CSF diversion through the catheter is the first step of recent treatment modality for CSF leakage problem [2,4,5]. Although we significantly reduced CSF leakage problem by the triple-layer closing technique (TLCT), there were still a few patients of CSF leak. In this article we share our management process for CSF leakage from diagnosis to treatment and provide an analysis.

**MATERIALS AND METHODS**

From August 2018 to April 2022, 749 patients who underwent MVD surgery were retrospectively reviewed. All surgical procedures were performed by single surgeon. In the surgical process, the temporo-occipital bone was drilled out. If the mastoid air cells were opened in this process, it was immediately sealed with bone wax. After finishing decompression, bone wax was applied again to secure, and the dura was sutured using the TLCT. TLCT is a wound closure technique performed in our clinic that includes the following steps: 1. putting a collagen matrix dural substitute (Duragen®; Integra Lifescience, Princeton, NJ, USA) on dura sutures and ties based on check valve principle, 2. covering with a fibrin sealant patch (Tachosil®; Corza Health, Del Mar, CA, USA) and fibrin sealant (Tisseel®; Baxter, Deerfield, IL, USA) that is spray over the area, and 3. bone cement is fixed to the occipital bone with screw and plate and perform dural tack-up suture to the plate to prevent CSF leakage and other complications such as epidural hemorrhage (Fig. 1).

Despite the meticulous wound reconstruction described above, some patients had CSF leakage symptoms such as CSF rhinorrhea, otorrhea. When a patient was suspected of CSF rhinorrhea, a glucose oxidase test was performed first. If the rhinorrhea contains glucose, the specificity of the test for CSF can be improved by excluding other factors that increase the glucose concentration of a nasal discharge. If the nasal discharge is not blood stained, the blood glucose measured at the same time should be less than 6

Fig. 1. The triple-layer closing technique used to close the dura in a watertight manner. (A) First, using thick silk material, the opened dura is sutured at three points. Two dural tack-up sutures for epidural hemorrhage prevention are made at the cranial and lateral sides of the opened wound. (B) Next, using thin silk material, the remnant dural portion is sutured and a collagen matrix (Duragen®) is tied upon it intermittently in a watertight fashion. (C) The previous steps are followed by covering it with double-layered fibrin sealant patch (Tachosil®) and spraying fibrin glue over it. (D) A bone cement flap is fixed with plates and screws, and the previous dural tack-up sutures are tied to the plates.
mmol/L (about 108 mg/dL). If there are no other symptoms of upper respiratory tract infection, such as sneezing, cough, sore throat, sputum, or purulent nasal discharge, then the likelihood that the discharge contains CSF is increased [6]. Temporal bone computed tomography (TBCT) was then performed for a patient with suspected CSF leakage. Fluid pooling in mastoid air cells and eustachian tube, which is the pathway to the nasal cavity was evaluated by TBCT. When there is prominent fluid pooling in mastoid air cells, we consulted otolaryngologist for middle ear exam. Ear drum findings were confirmed with otoscope, and hearing tests including pure tone audiometry and speech audiometry were performed because of their ear fullness and hearing difficulty symptoms. It was also important to distinguish conductive hearing loss with sensorineural hearing loss. Ear drum puncture for sampling effusion was also considered to analyze whether the fluid was CSF, but the procedure did not perform in our cases because of infection concerns. Since none of the above findings could specifically confirm presence of CSF leakage, the possibility of CSF leakage was considered by aggregating above results and characteristics of patient’s clinical symptoms (e.g., onset, frequency, duration and amount of rhinorrhea).

After aggregating the above findings, if the possibility of CSF leakage was high or certain, a subarachnoid LD catheter was inserted. In patients whose rhinorrhea symptoms appeared at a relatively short time (1–2 days) after surgery, it was difficult to distinguish true CSF leakage with intraoperative irrigation saline or postoperative exudate at early stage of surgery. In these cases, the benefit versus risk of LD was contemplated and whether or not there was true CSF leakage should be determined as quickly as possible. On the other hand, if the symptoms appeared at a relatively long time (5–6 days) after surgery, we regarded that it had high possibility of true CSF leakage. So, LD insertion was performed without hesitation in those cases.

If there were any suspicious symptoms of CSF leakage, absolute bed rest (ABR) was performed immediately. In cases whose symptoms was suspected of CSF leakage, but ambiguous whether it was true CSF leakage, ABR was maintained and closely observed for about a day without LD insertion. Nevertheless, if the symptoms persisted, it was regarded that there was high possibility of CSF leakage and immediate LD insertion was performed. An inserted LD catheter was maintained for 5–6 days. The catheter drained CSF continuously at a constant rate throughout the day. The initial amount of drainage was decided empirically according to the severity of rhinorrhea symptoms (volume or frequency of rhinorrhea symptoms). If the amount of rhinorrhea was relatively small and the frequency of the symptom was low, the initial amount of drainage was about 8 mL/hr (60 mL per 8 hours). And if the amount of rhinorrhea was relatively massive and frequency of the symptom was high, it was considered as high flow CSF leakage. In those cases, CSF was drained at about 10 mL/hr to 12 mL/hr rate (80–100 mL per 8 hours). The reason why the amount of drainage was divided every 8 hours was that it was easy to divide the day into three parts to count and adjust the drain amount. The amount of drainage was adjusted if there were side effect symptoms such as low intracranial pressure headache or dizziness. But if there were no side effects symptoms, the amount of drainage was maintained. During the LD inserted period, neurological change was closely observed for prevention of severe problem associated with CSF overdrainage.

Besides LD insertion, conservative treatment such as ABR, head elevation about 30 degrees, and avoidance of Valsalva maneuvers was accompanied. Before the LD was removed, it was clamped for 12 hours and observed if the symptoms recurred. And if the symptoms did not reappear, LD was removed. After close observation for 1–3 days from LD removal, the patients were discharged and followed up in the outpatient clinic.

We used vancomycin and ceftriaxone as prophylactic antibiotics while the LD was inserted to prevent infection associated with the LD and CSF leakage.

Through the above protocol shown in Fig. 2, we considered what findings and symptom characters would further suggest true CSF leakage. We considered LD indications and management (e.g., time to insertion and removal, safe drainage, and associated complications) in patients who presented postoperative CSF leakage problem. While performing conservative management including LD, it was examined whether postoperative CSF leakage problem could be solved without wound repair surgery.

Ethical statements

This study was exempted by the Institutional Review Board of Konkuk University Medical Center (No. KUMC 2022-09-039). The requirement for the patient’s written consent was waived as it was a retrospective study.

Case illustration

Case 1

A 39-year-old female underwent MVD surgery for right side hemifacial spasm (HFS). Surgical findings showed compression by the anterior inferior cerebellar artery and decompression was successfully achieved with teflon felt. The mastoid air cells were widely opened during drilling for a craniectomy and we sealed the pathway with bone wax. The patient complained of nasal drip on the second day after surgery. A glucose oxidase test showed level

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of 164 mg/dL, while blood glucose was 89 mg/dL. TBCT showed fluid effusion in mastoid air cells (Fig. 3) and fluid effusion was also seen through otoscope (Fig. 4). Despite of conservative treatment such as ABR, rhinorrhea continued to the next day. And she complained of right side hearing difficulty, audiometry was also performed. It showed right side conduction type hearing loss (Fig. 4). We concluded it had the more possibility of CSF leakage, so decided to insert a LD and drained 180 mL of CSF throughout a day (60 mL per 8 hours) at a constant rate. The rhinorrhea symptom disappeared immediately. On the fourth day after LD insertion, follow-up TBCT showed a decreased amount of fluid effusion in the mastoid air cells and middle ear. LD was clamped at midnight, there were no rhinorrhea symptom relapse for 12 hours, so LD was removed. She was discharged without relapse symptoms or other complications.

**Case 2**
A 63-year-old male patient underwent MVD surgery for left HFS. During surgery, mastoid air cells opened, so it was sealed with bone wax. He abruptly presented a large amount of watery nasal and post-nasal drip at 5 days after surgery. The glucose level of the rhinorrhea was 185 mg/dL, while blood glucose was 87 mg/dL. The symptoms highly suggested high flow CSF leakage, and the relatively delayed onset of the symptoms also supported this because intraoperative irrigation fluid usually resolves within early stage after surgery. TBCT showed fluid effusion in mastoid air cells and the middle ear (Fig. 5). In the middle ear findings, serious fluid effusion was confirmed and left side conductive hearing loss was diagnosed through audiometry. We inserted LD immediately. About 240 mL was drained throughout a day (80 mL per 8 hours) at a constant rate. His rhinorrhea symptom disappeared after the LD insertion. On the fifth day from the LD insertion, a follow up TBCT showed decreased mastoid air cell effusion. At midnight, the LD was clamped, and there was no relapse of CSF rhinorrhea over 12 hours. The LD was removed, and he was discharged without relapsed symptoms or other complications.

**Case 3**
A 30-year-old female patient underwent MVD surgery for left HFS. She had nasal drip on the next day after surgery. The glucose level of the rhinorrhea was 181 mg/dL, while the blood glucose level was 99 mg/dL. The TBCT showed opened mastoid air cells
with fluid effusion (Fig. 6). The otoscope showed fluid effusion in the middle ear and left side conductive hearing loss was diagnosed. However, since it was only the first day after surgery, it was difficult to distinguish whether it was real CSF or just postoperative fluid collection from irrigation saline or postoperative exudate. However intermittent rhinorrhea symptom continued to the next day even after ABR. Thus, we concluded there was the more possibility of CSF leakage. The LD was inserted and about 180 mL was drained throughout the day (60 mL per 8 hours) at a constant rate. Her rhinorrhea symptom disappeared after the LD insertion. On the fifth day after insertion, the LD was clamped and there was no relapse of CSF leakage. In a follow-up TBCT, decreased fluid of mastoid effusion was found. It was removed and she was discharged without any complications.

RESULTS

Among 749 patient cohort, there were 11 cases (1.4%) of CSF leakage and the symptom was CSF rhinorrhea in every patient. Five patients (45.5%) had the symptom on first day, two patients (18.2%) on the second day, one patient (9.1%) on the third day, and three patients (27.3%) had the symptom on the fifth day after surgery. All patient’s mastoid air cells were opened during surgery. The interval from the CSF rhinorrhea symptom to LD insertion was immediately after symptom in three patients, the day after symptom in one patient, and 2 days after symptom in seven patients. The LD was placed for 5.4 days on average. Their hospital stay was 13.3 days on average. The patient’s hospital stay was extended to 5.3 days compared to the routine stay for MVD operation (8 days) of patient without any postoperative complication in our clinic. After LD insertion, intermittent CSF rhinorrhea disappeared in all patients. As LD complications, only intermittent light headache or dizziness was observed in three patients (27.3%). In these patients, the amount of drainage was adjusted, and then the complications improved. There were no other complications associated with the LD including infection problems. All patients complained of conductive hearing difficulty, and the symptom was improved over time as the middle ear effusion was resolved, which was confirmed with follow-up audiometry. All patients had no recurrent symptoms suggesting CSF leakage, thus there was no need for wound repair surgery (Table 1).

DISCUSSION

The incidence of CSF leakage following a suboccipital craniotomy for multiple etiologies has been reported to range from 1.5% to 14.5% [7]. In our clinic, MVD operation wounds have been closed with the TLCT since August 2018, and to date, only 11 of 749 cases (1.4%) had symptoms associated with CSF leakage. By closing the operation wound with the TLCT, the CSF leakage ratio could be markedly reduced after MVD surgery. Besides use of the TLCT, tight thin bone wax sealing repeatedly at the opened...
Fig. 4. (A) The patient in Case 1 was diagnosed with right conductive hearing loss (HL) through pure tone audiometry (PTA). The patient's hearing difficulty was not sensorineural-type HL due to cranial nerve VIII damage during surgery. (B) Middle ear findings through the otoscope in Case 1, showing serous fluid effusion suspected to be cerebrospinal fluid leakage. AC: air conduction, BC: bone conduction, SII: Speech Intelligibility Index, dB EM: dB effective masking.
mastoid air cells was also important to plug CSF leakage pathway during surgery. Nevertheless, there was CSF rhinorrhea in 11 patients, and we managed this problem using the same diagnostic flow and treatment regimen.

A glucose oxidase test was performed first because it is fast, inexpensive, and widely practicable. However, CSF leakage may not be confirmed by this result alone. It has poor diagnostic sensitivity and specificity because glucose can be detected in normal nasal or lacrimal secretion, the airway of a patient who has diabetic mellitus, during stress hyperglycemia, and nasal epithelial inflammation due to a viral cold [6]. Other diagnostic tests can be considered including the beta-2 transferrin test or the beta-trace pro-
Table 1. Clinical course of 11 patients who presented with symptoms suggesting cerebrospinal fluid leakage  

<table>
<thead>
<tr>
<th>No.</th>
<th>Age/sex</th>
<th>Dx.</th>
<th>Mastoid air cell open</th>
<th>Time to symptom from surgery (d)</th>
<th>LD insertion date from surgery (d)</th>
<th>Duration of LD (d)</th>
<th>Hospital stay (d)</th>
<th>Recurrent symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62/M</td>
<td>HFS Lt.</td>
<td>+</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>57/F</td>
<td>HFS Rt.</td>
<td>+</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>16</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>38/F</td>
<td>HFS Rt.</td>
<td>+</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>62/F</td>
<td>HFS Rt.</td>
<td>+</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>17</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>65/M</td>
<td>HFS Lt.</td>
<td>+</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>11</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>62/F</td>
<td>HFS Lt.</td>
<td>+</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>58/F</td>
<td>HFS Rt.</td>
<td>+</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>11</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>56/F</td>
<td>HFS Rt.</td>
<td>+</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>39/F</td>
<td>HFS Rt.</td>
<td>+</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>13</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>63/M</td>
<td>HFS Lt.</td>
<td>+</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>30/F</td>
<td>HFS Lt.</td>
<td>+</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>13</td>
<td>-</td>
</tr>
</tbody>
</table>

All symptoms were cerebrospinal fluid rhinorrhea. Five patients (45.5%) had the symptom on the first day after microvascular decompression surgery, two patients (18.2%) had the symptom on the second day, one patient (9.1%) had the symptom on the third day, and three patients (27.3%) had the symptom on the fifth day. The lumbar drain (LD) was placed for 5.4 days on average. The hospital stays of the patients were 13.3 days on average. None of the patients had recurrence of symptoms suggesting leakage. Dx.: diagnosis, M: male, F: female, HFS: hemifacial spasm, Lt.: left, Rt.: right.

tein test. In the case of beta-2 transferrin, which detects proteins specifically present in the CSF, several detection methods exist. The most common technique used in a clinical laboratory is immunofixation electrophoresis. This study results in excellent sensitivity (84%) and specificity (100%) with high positive (100%) and negative (95%) predictive values [8]. In the case of beta-trace protein, which is the most abundant CSF protein, it can be detected with a nephelometric assay that based on antigen–antibody complexes reactions. Results are typically available within 20 minutes and require relatively small (200 μL) sample volumes. However, cut-off values for beta-trace protein vary widely (0.35–6 mg/L) [8]. Risch et al. [9] used receiver operating characteristic curve analysis in patients with suspected CSF leakage. They confirmed that a cut-off of 1.11 mg/L beta-trace protein effectively identified patients with CSF leakage with excellent sensitivity (93%) and specificity (100%). Although the beta-trace protein test is a good method to diagnosis CSF leakage, it is still designated for research use only [9]. We could not employ these two tests because of their time-consuming, expensive characteristics and the limitation of our institute. But if it could be performed, it would helpful to distinguish whether the fluid was real CSF before an invasive procedure.

The LD insertion was first introduced by Voursh in 1960 [10]. It is a closed system using a subarachnoid spinal catheter for diverting CSF flow. The indications for LD in a general neurosurgery department are as follows: diagnosis and management of hydrocephalus, post-traumatic or postoperative CSF leakage, to reduce brain retraction before a cranial procedure, and prevent CSF fistula formation [11]. Despite the controversy about placement of LD in patients with CSF leakage, a number of studies have reported its benefit in comparison with only conservative management without a LD [2,5,12]. Various authors have reported that LD showed a successful treatment rate of 85% to 94% in reducing and resolving CSF leakage [10].

Subarachnoid LD insertion is a quite invasive procedure in itself, and it can cause some problems such as low-pressure headache, lumbosacral radiculopathy, CSF pooling adjacent to the lumbosacral space, and serious complication such as meningitis, pneumocephalus, and subdural hematoma [11,13,14]. Several reports have cited tension pneumocephalus as a severe complication resulting in transtentorial herniation. Graf et al. [15] reported three cases of neurologic deterioration that were caused by the sudden occurrence of a massive pneumocephalus because of an abrupt large amount of drainage via the LD. The sudden overdrainage with head elevation creates a pressure gradient between the atmospheric pressure and the intracranial pressure, thus air can flow into the space by the siphon effect. Because of this serious problem, CSF must be drained continuously at a constant rate. In case of meningitis, it is known to be significantly associated with the duration of LD placement and minimal manipulation [11,16]. Liang et al. [17] reported that keeping the LD for more than four days was the most important risk factor for infectious problems. For these reasons, the risks and benefits of LD should be considered carefully and implement it only when CSF leakage is certain. If LD insertion is performed, appropriate management should follow. We did not do unnecessary manipulation such as CSF sampling, and maintained LD for 5 to 6 days. None of our patients had LD-associated overdrainage and infection problems.
We aggregated the above test findings with the patient’s symptom course and decided whether it had more possibility of CSF leakage. For instance, if patient’s rhinorrhea symptom continued for several days even with ABR, this would suggest CSF leakage more because it is generally non-sensical that irrigation saline or postoperative exudate would flow out for several days. If there was possibility of CSF leakage more, we inserted the LD as quickly as possible to foster initial wound healing and prevent further progression to infectious problem. The intermittent CSF rhinorrhea of our patients disappeared immediately after LD insertion. If the CSF leakage symptoms disappeared after CSF diversion via the LD, it was considered evidence that there was true CSF leakage. We considered LD removal within 5 or 6 days after insertion. This duration was sufficient to treat CSF leakage after retromastoid suboccipital craniectomy in our clinic. Before LD removal, it was helpful to clamp it and observe whether CSF rhinorrhea symptoms relapsed. If the symptom did not recur, we removed the LD.

Except for CSF diversion via LD, conservative treatments for CSF leakage include bed rest, head elevation about 30 degrees, and usage of acetazolamide drug. Cough, sneezing, and constipation should be cautious for avoidance of the Valsalva maneuver. We did not use acetazolamide drug but it may be helpful for lowering intracranial pressure by reduction of CSF production.

We used prophylactic antibiotics to prevent meningitis associated with the LD catheter and CSF leakage problem itself. But, usage of prophylactic antibiotics is controversial. Some authors have claimed that they absolutely reduce the rate of meningitis. Other authors, however, argue that they can alter normal nasopharyngeal microflora causing gram-negative infection followed by ascending infections such as meningitis [18-20].

Patients with CSF rhinorrhea who were operated in our clinic did not need operative wound repair surgery. However, if symptoms persist despite the above conservative treatments including LD, surgical treatment should be considered earlier.

**CONCLUSION**

Although we try hard to prevent CSF leakage in open microsurgery, there are inevitable cases of leaks and they are more frequent in posterior fossa surgeries. We cannot prevent the leakage perfectly but should limit the complications to prevent progression to other severe problems such as meningitis. Closing technique such as TLCT is useful, but also early diagnosis of CSF leakage and management with LD are important.

**Limitation**

In case of CSF rhinorrhea, to distinguish true CSF leakage from postoperative normal exudate, we performed all practicable tests in general clinic, but no tests could specifically confirm CSF leakage. We aggregated the above test findings with patient’s clinical symptom course, and estimated the possibility of CSF leakage and LD indication. But, it should be studied more about practicable and confirmative test method to determine whether it is true CSF leakage. Also, the duration of LD maintenance and amount of CSF drainage were empirically determined, and CSF leakage problem was well treated without any severe complications associated with LD. However, a more large-scale case study would be needed to determine appropriate duration of LD and amount of CSF drainage.

**CONFLICTS OF INTEREST**

No potential conflict of interest relevant to this article was reported.

**REFERENCES**