



Pitfalls of skull base reconstruction in endoscopic endonasal approach

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Abstract

Various skull base reconstruction techniques have been developed in endoscopic endonasal approach (EEA) for skull base lesions to prevent postoperative cerebrospinal fluid (CSF) leakage. This study was performed to evaluate the efficacy and pitfalls of our method of skull base reconstruction after EEA. A total of 123 patients who underwent EEA (127 surgeries) between October 2014 and May 2017 were reviewed. Our algorithm for skull base reconstruction in EEA was categorized based on intraoperative CSF leakage graded as follows: grade 0 was excluded from this study; grade 1, dural suturing with abdominal fat graft or packing of gelatin sponge into the cavity; grade 2, method for grade 1 with addition of mucosal flap or nasoseptal flap (NSF); and grade 3, duraplasty in fascia patchwork closure with NSF. Bony reconstruction was not mandatory, and there was no postoperative bed rest or initial lumbar drainage (LD) insertion in any of the cases. Postoperative CSF leakage after EEA was mostly prevented (96.3%) by our algorithm without postoperative initial LD or bed rest. On the other hand, reconstruction surgery was required for postoperative CSF leakage in two cases—one with prior multitranssphenoidal surgery and radiotherapy and another patient with poor compliance due to communication difficulties. Both of the latter patients were obese. Greater care with regard to postoperative CSF leakage is required in patients with prior EEA with radiotherapy and obesity. In such high-risk patients, initial LD or bed rest may be required to prevent postoperative CSF leakage. It is also important to restrict activities that result in increased intracranial pressure.

Keywords Skull base reconstruction · Endoscopic endonasal surgery · CSF leakage · Pituitary

Introduction

Endoscopic endonasal approach (EEA) is a minimally invasive operation suitable for midline skull base tumors, such as pituitary adenoma, craniopharyngioma, and meningioma. With the development of surgical techniques and improvement of surgical instruments, indications for EEA have been expanded and the EEA has shown rapid advancement over the past several decades [5, 7, 8, 11, 15, 22]. However, surgical

difficulties and risks of EEA are increasing, and there are some practical limitations regarding this procedure. In particular, there are concerns regarding the greater risk of postoperative cerebrospinal fluid (CSF) leakage that may lead to meningitis and also tension pneumocephalus, rarely though [5, 8, 11–15, 20, 22]. Therefore, various skull base reconstruction techniques for prevention of postoperative CSF leakage are essential to improve the surgical results [5–7, 12, 13, 19, 23]. Here, we report our algorithm for skull base reconstruction during EEA without initial lumbar drainage (LD) management and discuss the associated outcomes and pitfalls.

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Materials and methods

Patient criteria

We performed a retrospective analysis of 123 patients (68 females and 59 males) with a mean age of 54.1 years (range 14–87 years) that underwent EEA (total 127 surgeries) at

Shinshu University Hospital and its affiliated hospitals between October 2014 and May 2017. Cases with spontaneous CSF leakage or no intraoperative CSF leakage were excluded from the study. All patients underwent surgery including skull base reconstruction by the first author (T.O.). The histological diagnoses included pituitary adenoma ($n = 95$), Rathke's cleft cyst ($n = 10$), craniopharyngioma ($n = 6$), meningioma ($n = 4$), chordoma ($n = 2$), metastatic tumor ($n = 1$), atypical teratoid/rhabdoid tumor ($n = 1$), chondrosarcoma ($n = 1$), cavernous hemangioma ($n = 1$), hypophysis ($n = 1$), and adenoid cystic carcinoma ($n = 1$).

Reconstruction technique

EEA was performed by a single neurosurgeon with a scope holder, which is defined as the two-hand technique [4]. A rigid scope 4 mm in diameter, 18 cm in length, with 0° and 30° angled lenses (Karl Storz & Co, Tuttlingen, Germany) was used. Neuronavigation system was routinely used for intraoperative confirmation of anatomical location. Endoscopic endonasal skull base reconstruction was routinely performed following resection of the lesions.

Various reconstruction methods were available in our technique as follows: (1) *dural suturing*, the dura was sutured with 6–0 nylon following packing with abdominal fat tissue or gelatin sponge to hold it in position and prevent graft migration (Fig. 1a); (2) *fascia patchwork closure* [14], the fascia was laid in the intracranial epiarachnoid space and patch-sutured around its entire circumference, yielding an inlay patch (Fig. 1b, Video 1); (3) *mucosal flap* [1], mucosa was harvested from the posterior wall of the sphenoid sinus and

was laid out on the skull base defect (Fig. 1c); (4) *NSF* [13, 19], intraoperative harvesting of the NSF from the septal mucoperiosteum and mucoperichondrium of the left side with preservation of the patency of the sphenopalatine artery: it was rotated to resurface the skull base defect at the end of the surgical procedure (Fig. 1d); and (5) *sphenoid sinus packing*, collagen sponge, fibrin glue, or an inflated sinus balloon catheter “controlled pressure” (Fuji System, Tokyo, Japan) were also used to fill the sphenoid sinus cavity.

Algorithm of skull base reconstruction (Table 1, Fig. 2)

Our algorithm of skull base reconstruction during EEA was categorized based on the intraoperative CSF leakage grading system (grade 0, absent; grade 1, small; grade 2, moderate; grade 3, large) as reported previously by Esposito et al. [8] (Fig. 2a–d): grade 0 or 1, abdominal fat graft or gelatin sponge packing into the removal cavity, which was anchored by dural suturing, and the skull base was covered with a polyglycolic acid (PGA) sheet. Grade 2, abdominal fat graft packing into the cavity, which was anchored by dural suturing, and the skull base was covered with a PGA sheet and covering with a mucosal flap from the posterior wall of the sphenoid sinus or NSF. Grade 3, duraplasty was performed with the fascia patchwork closure technique (Video 1). NSF was then laid on the skull base with sinus balloon compression (Table 1). Bony reconstruction was not mandatory. According to our basic policy which reduction of patient distress was idealized as much as possible for less invasive treatment, there was no postoperative bed rest or initial LD insertion (*defined as perioperative application of LD to prevent susceptible*

Fig. 1 Intraoperative photograph showing skull base reconstruction in endoscopic endonasal surgery. The fat graft was packed into the cavity with anchoring dural sutures (a). Watertight duraplasty was achieved using the fascia patchwork closure technique (b). The mucosal flap from the posterior wall of the sphenoid sinus covered the sellar turcia (c). A pedicled nasoseptal flap was rotated to resurface the skull base defect at the end of the surgical procedure (d)

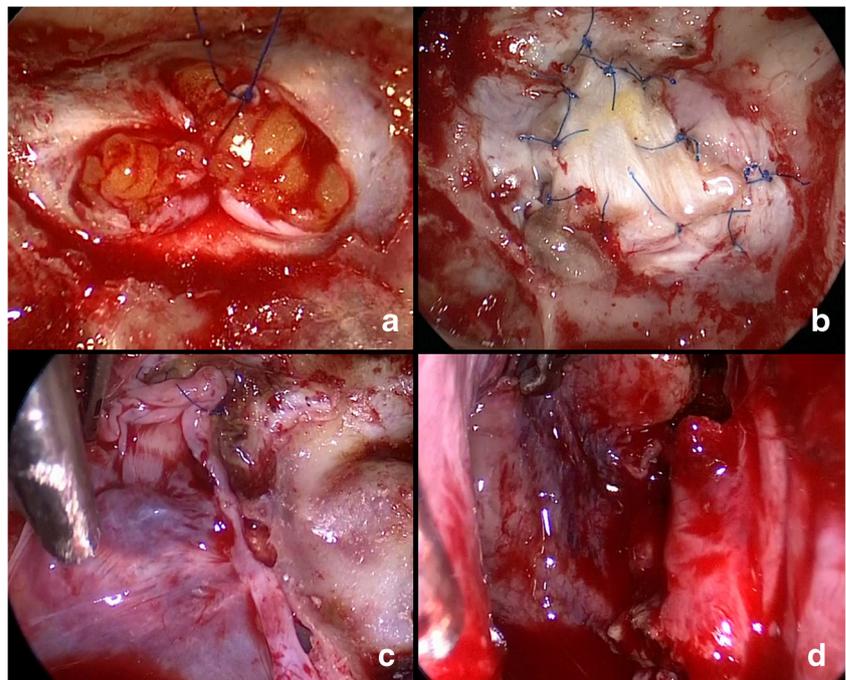
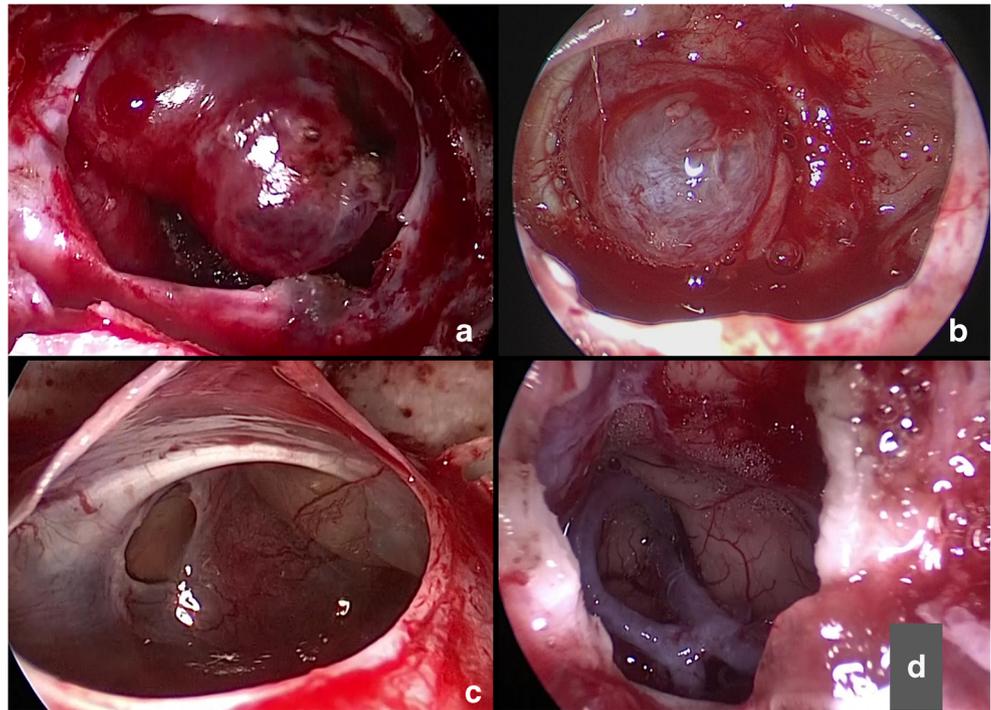


Fig. 2 Intraoperative photograph showing degree of CSF leakage. No leak was observed (a). Small leak was observed without obvious diaphragmatic defect (b). Moderate leak with small arachnoid defect was observed (c). High-flow CSF leak was observed with large diaphragmatic and dural defect (d)



postoperative CSF leakage) in any of the cases. The clinical outcomes were analyzed.

Results

Intraoperative CSF leak

Among a total of 127 surgeries, in 73 operations (57%), there were no evidence of CSF leakage (grade 0). Obviously, those cases showed no evidence postoperative CSF leak, thus excluded from this study. In the remaining 54 surgeries (43%), the rate of intraoperative CSF leakage was categorized as follows: grade 1, 44.5%; grade 2, 18.5%; and grade 3, 37% (Fig. 3).

Postoperative CSF leak

Among the included 54 surgeries, postoperative CSF leakage after EEA was mostly prevented (96.3%) by our algorithm without postoperative management using initial LD or bed

rest. On the other hand, two cases showed postoperative CSF leakage (overall CSF leak rate 3.7%) and required repeat reconstruction surgery; one was a recurrent case with radiotherapy and several surgeries, and the other was a foreigner coming from another country (non-Japanese) and so, there were problems with communication. Both patients had grade 3 intraoperative CSF leakage and were obese. Detailed data regarding these two cases are presented below.

Case 1: A 47-year-old obese man (body mass index (BMI) 32.7%) with a past history of endonasal surgery seven times, craniotomy once, and stereotactic radiosurgery twice for recurrent intractable craniopharyngioma presented with rapidly progressive visual impairment. Magnetic resonance imaging (MRI) revealed a recurrent mass at the suprasellar region with optic chiasma compression (Fig. 4a). EEA was performed via the transplanum sphenoidale route. High-flow intraoperative CSF leakage occurred during the procedure, and duraplasty was performed using the fascia patchwork closure technique [14]. In addition, a PGA sheet was applied

Table 1 Algorithm for skull base reconstruction during endoscopic endonasal surgery

CSF leak grade	Reconstruction techniques
1	Fat graft or sponge packing, dural suturing, PGA sheet
2	Fat graft packing, dural suturing, PGA sheet, MF, or NSF
3	Duroplasty with FPC, PGA sheet, NSF, SB

PGA polyglycolic acid, MF sinus mucosal flap, NSF nasoseptal flap, FPC fascia patchwork closure, SB sinus balloon compression

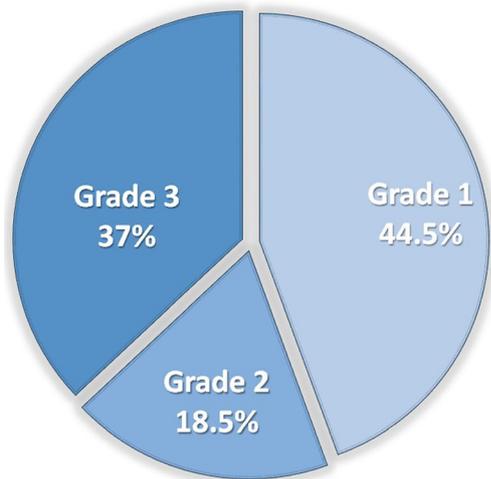
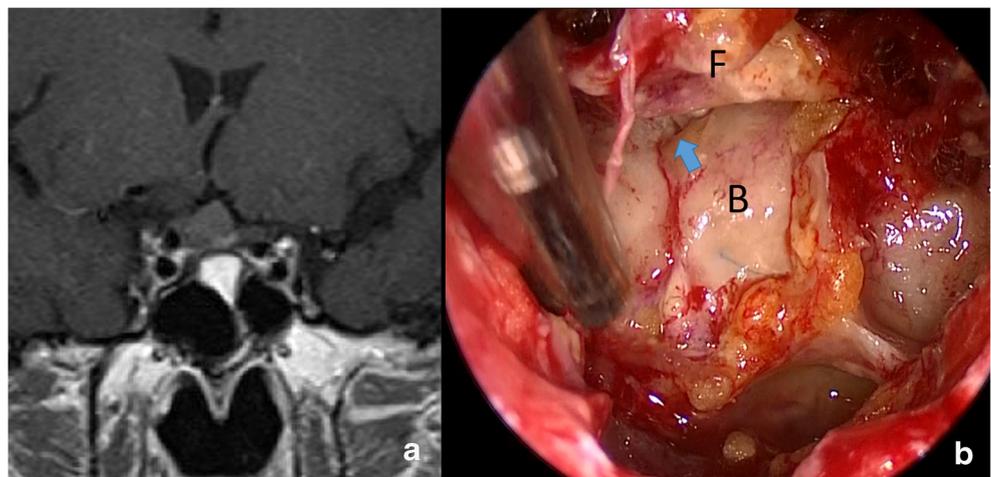


Fig. 3 The distribution of intraoperative CSF leak. Grade 1, 44.5%; grade 2, 18.5%; grade 3, 37%

over the area of bone defect, and fascia graft and abdominal fat tissue were laid on the skull base. Unfortunately, a pedicled NSF was not available because normal structures in the nostrils had been destroyed during the previous several surgeries. There was no postoperative spinal drainage and no bed rest. CSF leakage occurred on postoperative day 4, which could not be controlled with conservative therapy, and endoscopic endonasal repair of CSF leakage was performed. Re-exploration of the sella revealed that the bone, dura mater, and arachnoid membrane were atrophic and avascular, and there was no adhesion of inserted graft tissue (fat and fascia) to the surrounding structures (Fig. 4b). The skull base reconstruction procedure was the same, but postoperative bed rest and late LD (*defined as postoperative application of LD to treat evident CSF leak*) were applied for 1 week. CSF leakage then stopped with no occurrence of meningitis. Finally, the patient's visual symptoms recovered and pituitary function was unchanged.

Fig. 4 Preoperative MRI showing a suprasellar tumor with optic chiasm compression (a). Intraoperative photograph showing the skull base following peeling off the fascia graft. Minor CSF leakage was identified (arrow). F: fascia graft, B: bony reconstruction



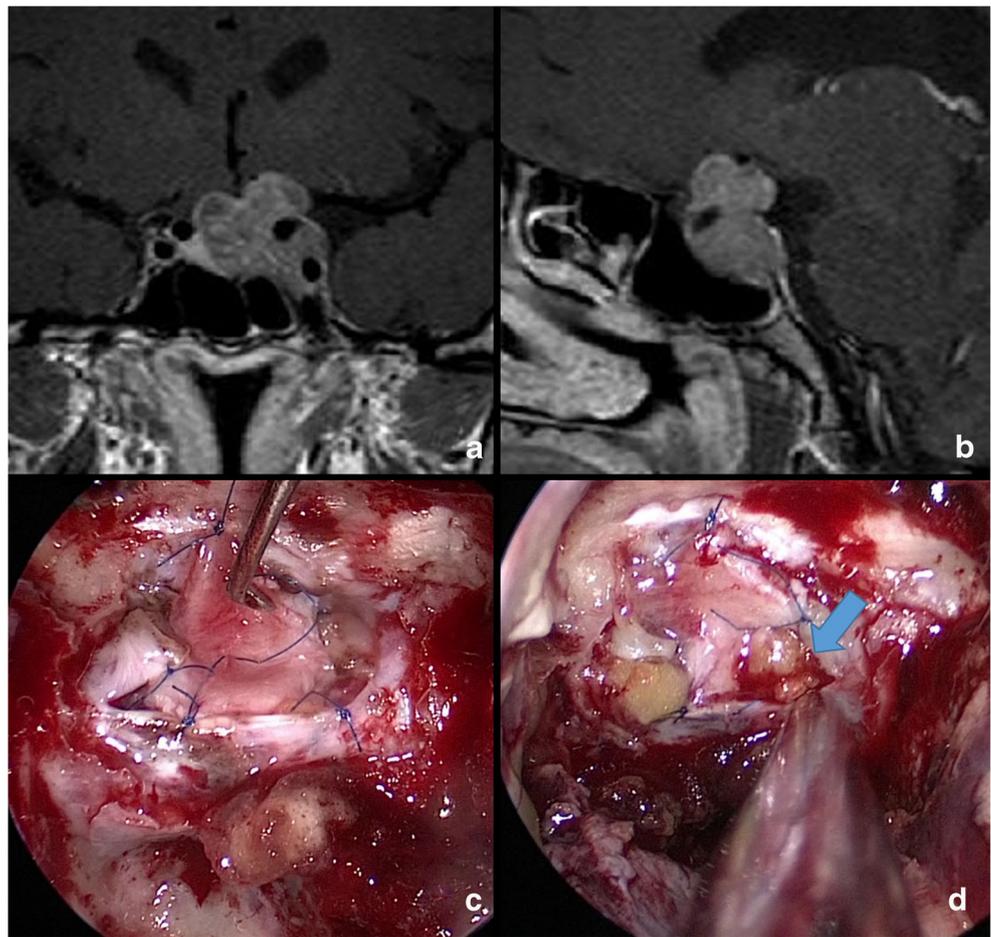
Case 2: A 49-year-old obese foreign woman (BMI 32.1%) presented with rapidly progressive visual impairment. MRI revealed a mass at the sellar and suprasellar region with optic chiasma compression (Fig. 5a, b). A diagnosis of invasive non-functioning pituitary adenoma was made, and EEA was performed. Intraoperatively, high-flow CSF leakage occurred, and duraplasty was performed with a fascia patchwork closure technique with a PGA sheet and NSF according to our algorithm (Fig. 5c). Initial LD was not applied. CSF leakage occurred on postoperative day 4, following straining despite restricted instructions. An endoscopic endonasal repair of CSF leakage was performed. Intraoperatively, NSF showed points of non-adherence. The skull base was exposed while preserving the NSF for re-use, and a small leakage site was identified (Fig. 5d). Three sutures were added, and overlay reconstruction was the same. Additionally, postoperative bed rest and late LD management were applied. The CSF leakage was cured with no signs of meningitis. Finally, visual impairment recovered and there were no postoperative hormonal disorder, including diabetes insipidus.

Discussion

Techniques of skull base reconstruction during EEA

The key aspects for successful reconstruction include meticulous multilayered reconstruction with inlay graft, overlay graft, bony reconstruction, and sinus packing [12, 13]. Vascularized NSF plays an effective role for prevention of postoperative CSF leakage [11–13, 19]. Although multilayer reconstruction (including inlay/onlay layers) may be effective,

Fig. 5 Preoperative MRI showing an invasive pituitary tumor with optic chiasm compression (**a, b**). Intraoperative photograph showing duraplasty with fascia patchwork closure technique (**c**). Intraoperative photograph in repeat surgery showing leakage point (arrow) following peeling off the adhered NSF (**d**)



this technique still has a number of issues that should be resolved. The materials for reconstruction remain controversial, and various materials have been used as inlay grafts, including fat, fascia, and gelatin sponge [5, 6, 10, 13, 18, 19]. The dura should be closed with restoration of its watertight nature, as in craniotomy; however, it is technically difficult to perform the same manipulation as used in microscopic craniotomy due to the deep and narrow surgical field in EEA. Some dural closure techniques have been reported for such situations [14, 23]. Fascia patchwork closure is as effective as partial multilayer closure for the prevention of CSF leakage [14]. The establishment and adoption of this technique may result in the further development of EEA [14]. In the present study, this technique was applied in cases of grade 3 intraoperative CSF leakage. For sellar defects, as in pituitary macroadenomas, a piece of autologous abdominal fat tissue is occasionally inserted into the sellar defect, and the dura is sutured to hold it in position to prevent graft migration. This technique was used in the case of grade 0–2 intraoperative CSF leakage in the present study. In our experience, meticulous dural closure is the most effective method for prevention of postoperative CSF leakage. We believe that is better for the patient to achieve tight dural closure with suturing. Initial LD reduces the CSF leak rates; however,

some concerns regarding its indications, the duration, and the postoperative meningitis are still presented. Postoperative management, including LD insertion, has been controversial.

Our algorithm involving multilayer reconstruction using NSF combined with fascia graft dural suturing is a more reliable method for the prevention of postoperative CSF leakage after EEA in cases of high-flow intraoperative CSF leakage, but it is not necessary in cases of low-flow CSF leakage [12]. This strategy is based on our idea that meticulous dural closure can modify the intraoperative CSF flow rate by decreasing the high-flow to low-flow CSF leakage, and then applying the NSF which completes the skull base reconstruction and prevents the postoperative CSF leak. However, none of these methods is perfect, and a number of different methods are used by different neurosurgeons or institutions.

Elevated BMI and risk of postoperative CSF leakage

Brian et al. reported that elevated BMI is an independent predictor of postoperative CSF leakage following EEA [3]. Koutourousiou et al. also reported that overweight/obese individuals have higher rates of postoperative CSF leakage [16]. In the present study, obesity may have been involved in the

failure of reconstruction after EEA in both cases. Greater care is, therefore, required for repair in patients with obesity.

Prior transsphenoidal surgery (TSS) and/or radiotherapy and risk of postoperative CSF leakage

Nishioka et al. reported that the risk of postoperative CSF rhinorrhea is significantly increased in cases with prior TSS and/or radiotherapy [21]. In contrast, cases with previous TSS and radiotherapy tend to show incomplete repair after intraoperative leakage. The tissue materials used in skull base reconstruction in TSS may be difficult to engraft in such cases. This is considered to be because radiotherapy to the sellar region can result in atrophy and diminished vascularization of the sellar structures, including bone, dura, and arachnoid. Prior radiation therapy may produce secondary changes, including thinning of the bone at the skull base and therefore may predispose the patient to postoperative CSF leakage [17]. Indeed, this was demonstrated by intraoperative findings in case 1. In addition, postoperative changes in the form of scarring, adhesions, unusual vascularity, and distortions of normal anatomy add to the hazards of repeat surgery [17]. Furthermore, NSF is sometimes not available due to previous surgery, as in case 1.

Patient education and risk of postoperative CSF leakage

Restriction of postoperative activity is routinely explained to the patient both before and after surgery. It is important for the patients themselves to take care for prevention of postoperative CSF leakage. With this reorganization, initial LD and bed rest are not routinely required. However, postoperative CSF leakage occurred due to straining in case 2, because she did not have sufficient command of Japanese language and did not fully understand the instructions. With regard to intraoperative findings, NSF showed satisfactory adhesion, but partially peeled off with a sudden increase in intracranial pressure. This suggested that communication among medical staffs and the patient was insufficient. We will examine importance of patient education in a subsequent study.

Limitations

Keeping into consideration that the occurrence of CSF leakage might depend on the underlying pathology, 77% of our study population were pituitary adenomas; accordingly, most of our CSF leak (76.9%) was related to pituitary adenoma surgeries. Besides, we included few cases with extremely large defects of the diaphragm and arachnoid membrane (4.6% craniopharyngiomas and 2.4% meningiomas), such as intraoperative CSF leakage grade 3 (Fig. 6), which would be associated with more challenging skull base reconstruction.

GRADE 3 CSF LEAK

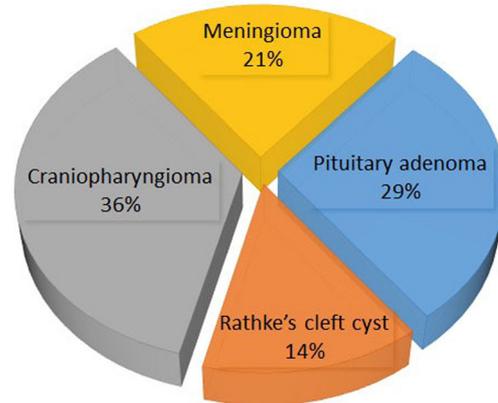


Fig. 6 The distribution of grade 3 CSF leak in relation to the underlying pathology

The method of skull base reconstruction for prevention of postoperative CSF leakage in EEA was assessed, but postoperative olfaction or subjective stress level of the patient due to postoperative bed rest was not investigated. Postoperative bed rest with LD placement may be not so serious for patients than we consider. Elevation of NSF might also result in olfactory disturbance which worries patients [2, 9]. Further assessment using NSF and the accumulation of clinical data are needed to modify the algorithm of skull base reconstruction in EEA.

Conclusions

For expansion of surgical indications using EEA for skull base lesions, a modified algorithm including indication of LD and bed rest should be constructed to achieve both prevention of CSF leakage and less invasiveness for the nasal cavities, especially in overweight patients, foreign nationals, and patients with prior TSS and radiotherapy. Endoscopic endonasal suturing technique for skull base reconstruction following EEA can be also considered as an algorithm to prevent postoperative CSF leakage.

Compliance with ethical standards

Conflict of interest The authors 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 research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent The patient/next of kin/guardian has consented to the submission of this original article for submission to the journal.

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