Accepted Manuscript

Submission Date: 2024-08-11
Accepted Date: 2024-11-04
Accepted Manuscript online: 2024-11-07

Journal of Neurological Surgery Part B: Skull Base

Dural closure method using dural suture and polyglycolic acid nonwoven fabric in the endoscopic endonasal approach

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DOI: 10.1055/a-2462-8835

Please cite this article as: Tanioka D, Natori I, Kobayashi Y et al. Dural closure method using dural suture and polyglycolic acid nonwoven fabric in the endoscopic endonasal approach. Journal of Neurological Surgery Part B: Skull Base 2024. doi: 10.1055/a-2462-8835

Conflict of Interest: The authors declare that they have no conflict of interest.

Trial registration: 2023-201-B, Japan Primary Registries Network (http://rctportal.niph.go.jp), Retrospective, Randomized

Abstract:

Introduction

The indications for surgery using the endoscopic endonasal approach (EEA) for tumors in the sella turcica and parasellar region are expanding. However, the risk of cerebrospinal fluid (CSF) leakage is also increasing. Therefore, to prevent postoperative CSF leakage, it is essential to use safe reconstruction methods for the sella turcica. A polyglycolic acid (PGA) nonwoven fabric is applied during dural reconstruction in neurosurgery. Nevertheless, its suitability for sella turcica reconstruction has not been validated.

Methods

This study enrolled patients who underwent lesion resection using EEA, followed by sella turcica reconstruction using the dural closure method and the simple and robust suture and PGA (S-PGA) method. The outcomes of the surgery were compared with those of fat-based reconstructive procedures performed prior to the introduction of the S-PGA method.

Results

In total, 325 patients underwent dural closure using the S-PGA method. The incidence rates of postoperative CSF leakage were 0.8% for the S-PGA method and 5.2% for the fat-filling method. This finding indicated significant improvement in the incidence rates of postoperative CSF leakage ($P < 0.01$). The S-PGA method did not affect radiogram interpretation for magnetic resonance imaging performed at 3 months after surgery due to the absence of intrasellar fat filling.

Conclusion

The S-PGA method in EEA is a simple and reliable technique for decreasing the risk of postoperative CSF leakage to the greatest extent possible. Hence, it can be an excellent option for skull base reconstruction.

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Abstract

Introduction The indications for surgery using the endoscopic endonasal approach (EEA) for tumors in the sella turcica and parasellar region are expanding. However, the risk of cerebrospinal fluid (CSF) leakage is also increasing. Therefore, to prevent postoperative CSF leakage, it is essential to use safe reconstruction methods for the sella turcica. A polyglycolic acid (PGA) nonwoven fabric is applied during dural reconstruction in neurosurgery. Nevertheless, its suitability for sella turcica reconstruction has not been validated.

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Conclusion The S-PGA method in EEA is a simple and reliable technique for decreasing the risk of postoperative CSF leakage to the greatest extent possible. Hence, it can be an excellent option for skull base reconstruction.

Keywords:
Polyglycolic acid nonwoven fabric, dural suture, endoscopic endonasal approach, cerebrospinal fluid leakage, reconstruction of skull base

Introduction

The endoscopic endonasal approach (EEA) for pituitary neuroendocrine tumors (PitNETs) was first introduced by Jho and Carrau et al.[1] Thereafter, it has been used to manage various lesions in the sella turcica and parasellar region.

EEA is a minimally invasive surgical technique for resecting sellar and parasellar lesions. It has several advantages. For example, it has a wide panoramic view and can facilitate enhanced visualization of relevant anatomical structures.[2] However, the risk of cerebrospinal fluid (CSF) leakage has increased with the expansion of surgical indications.[3] Postoperative CSF leakage is associated with major complications such as headache, incision infections, meningitis, pneumocephalus, and intracranial hypotension.[4] To prevent this condition, primary

reconstruction of the skull base is the best option.

Different methods can be used for skull base reconstruction.[5] With the development of multilayered repair protocols, the incidence of CSF leakage after extended sphenoidal surgery has decreased over the years.[6,7] Nevertheless, repair techniques have become more complex, and nasoseptal flaps have been associated with adverse effects.[8,9,10]

The current study aimed to examine the use of the suture and polyglycolic acid (S-PGA) method, which is a simple, novel sellar reconstruction method that uses dural sutures and a PGA nonwoven fabric (dura wave™, Gunze Ltd., Osaka, Japan) without damaging intranasal structures in EEA.

Methods

Study details

Patients who underwent sella turcica reconstruction using the S-PGA method after lesion resection using EEA at Showa University Hospital were enrolled in this study from January 2018 to March 2024. The intraoperative findings, surgical videos, and postoperative outcomes of the patients were reviewed retrospectively. At our institution, fat-filled sella turcica reconstruction procedures were performed from April 2012 to December 2017. Fibrin glue was applied after intradural and epidural fat filling. This method was performed by simply filling with a fat graft without using nasal septal mucosal flaps or various grafts. The postoperative outcomes of the fat-filling and S-PGA methods were compared. Intraoperative spinal fluid leaks were classified as grade 0–3 using the grading system proposed by Esposito et al.[11] The protocol for the sella turcica reconstruction was determined based on this grading system (Table 1). Informed consent for the surgery and presentation of this article was obtained from the patients. The Showa University Ethics Committee approved the current study (approval no. 2023-201-B).

Surgical technique

The patient was placed in the supine position with the upper body elevated at 20° under general anesthesia. The patient's head was then secured to a horseshoe headrest. Sellar and parasellar lesions were reached using the transseptal approach. Based on lesion size, the sellar and parasellar bones were removed. The dura mater was then incised in an H-shape or horizontally and straight across. To prevent the formation of a hematoma in the sella turcica postoperatively, cotton-type oxidized cellulose (SURGICELSNoW™ Absorbable Hemostat, Johnson & Johnson Co.) was filled. The dura mater was then sutured using a 5-0 nylon suture (ETHILON™, Johnson & Johnson Co., Ltd., Tokyo, Japan). Dural suturing was conducted using the sliding-lock-knot technique proposed by Sakamoto et al.[12] The dural suture does not need to be a perfect watertight suture, and gentle CSF leakage is acceptable. This method was used for Esposito grades 0–2 leaks. In Esposito grade 3 leaks, the dural defect is often extensive. If the dural defect is large, it is sutured together with the dura using the rectus abdominis fascia (Table 1). To ensure the largest possible contact area with the dura, the PGA nonwoven fabric, which was previously soaked in fibrinogen, a fibrin glue, was adhered over the sutured dura mater. Next, it was laid between the dura and the bone of the sella turcica at the bone margin (i.e., the epidural space). Finally, thrombin, a fibrin glue, was applied. The Valsalva maneuver was used to identify the absence of CSF leakage. Fat was not packed intradurally, and rigid materials such as the nasal septum and titanium plates were not used epidurally. A nasoseptal flap and intraoperative and postoperative lumbar drainage were also not utilized (Figs. 1a–1e and 2a–2c).

Statistical analysis

Continuous variables were reported as mean ± standard deviation and compared with the unpaired Student's *t*-test. Categorical variables were

compared with the chi-square test with the Yates' correction test or Fisher's exact test, as appropriate. A probability value of <0.05 indicated statistically significant difference, and all reported probability values were two-tailed. All calculations were performed using the js-STAR XR+ release 1.6.0 j (Programming by Satoshi Tanaka & Nappa, Japan).

Result

In total, 325 patients underwent dural closure using the S-PGA method after lesion resection. The patients comprised 144 men and 181 women, with a mean age at surgery of 53.3 (range: 15–88) years. The clinical diagnoses included PitNET (n = 248), Rathke's cleft cyst (n = 36), craniopharyngioma (n = 14), meningioma (n = 11), pituitary inflammation (n = 7), cancer metastasis (n = 7), and chordoma (n = 2). Intraoperative CSF leakage was classified into four grades based on the Esposito's CSF leak classification system.

Meanwhile, 268 patients underwent dural closure via fat filling. The patients comprised 112 men and 156 women, with a mean age at surgery of 52.6 (range: 10–93) years. The clinical diagnoses were PitNET (n = 190), Rathke's cleft cyst (n = 49), craniopharyngioma (n = 9), meningioma (n = 2), pituitary inflammation (n = 3), cancer metastasis (n = 8), and chordoma (n = 7) (Table 2). Table 3 shows the details of the intraoperative CSF leakage. The incidence rates of intraoperative CSF leakage (grades 1, 2, and 3) were 65.6% for the S-PGA method and 64.2% for the fat-filled method.

The incidence rates of postoperative CSF leakage were 0.8% for the S-PGA method and 5.2% for the fat-filling method, thereby indicating a significant improvement ($P < 0.01$). There was a significant difference in the incidence of postoperative CSF leakage, particularly grades 2 and 3 ($P < 0.05$) (Table 4). Patients who underwent reconstruction using the S-PGA method did not undergo lumbar drainage during or after surgery.

Two patients who underwent surgery using the S-PGA method had grade 3 postoperative CSF leakage. The two patients, both of whom had craniopharyngioma, underwent multiple previous EEAs, followed by CyberKnife irradiation. These patients underwent reconstruction with ample fat graft filling of the intrasellar and sphenoid sinus without the use of a nasal mucosal flap or bone graft.

Based on magnetic resonance imaging (MRI) performed 3 months after surgery, the effect of postoperative radiogram interpretation for MRI was hardly present because of the lack of fat filling in the S-PGA method (Figs. 1f–1g and 2d–2e).

Discussion

EEA facilitates a minimally invasive and maximally effective surgical resection of skull base tumors. It enables early optic nerve decompression while preventing excessive vascular manipulation. Further, it provides superior visual results compared with transcranial approaches.[13,14,15] With the development of these techniques, even larg pituitary lesions and various tumors in the skull base and sella turcica can be resected.[16,17] However, postoperative CSF leakage is still a common complication and can lead to serious conditions such as meningitis, pneumoencephalopathy, and the need for repeated surgery.[18,19,20] Waterproof repair of the skull base is the most important technique for preventing postoperative CSF leakage.

The requirements for skull base repair include the following: 1) certainty of closure of a CSF leak, 2) simplicity of the procedure, 3) less influence of postoperative radiogram interpretation for computed tomography (CT) scan and MRI, and 4) minimum autologous tissue collection.

The proposed S-PGA method has been proven to be more reliable in preventing postoperative CSF leakage than the use of fatty tissues in skull base reconstruction. The incidence rate of postoperative CSF leakage in

the S-PGA method was 0.8%. According to Khan et al., the incidence rate of postoperative CSF leakage in EEA is up to 20%. Thus far, the incidence rate of postoperative CSF leakage in the S-PGA method is the lowest.[21] Recently, multilayered reconstruction has been proposed for skull base reconstruction.[22,23,24] These methods are complicated and not the best because they overfill various materials into the sella turcica and the sphenoid sinus. Our method is simple and convenient. This is because it only involves suturing of the dura mater and laying down of the PGA nonwoven fabric and lumbar drainage is not required. This study simply compared the fat closure method with the S-PGA method. Notably, unclear bias such as the operator's learning curve might have affected the improvement in the rate of cerebrospinal fluid leakage, which is considered a limitation of this study.

Another advantage of the proposed method is that the collection of autologous tissue can be reduced to the greatest extent possible. In most patients in the current study, the extent of the dural defect was not significant, and there was no need to harvest the rectus abdominis fascia. A nasoseptal flap was not used. In recent years, the use of nasoseptal flaps has been introduced.[25] However, nasoseptal flap harvesting is associated with significant morbidities. For example, nasal crusting, loss of smell, and nasal discharge cited are relatively common issues encountered.[26,27,28] Further, the S-PGA method did not require rigid materials such as the nasal septum bone and titanium plates. Simply suturing the dura mater can almost always suppress the pulsation of the cerebrospinal fluid. Moreover, Terasaka et al. performed experiments on rabbits. Results showed that the combination of PGA nonwoven fabric and fibrin glue can withstand up to 109.9 ± 37.1 mmHg. In an experiment using beagle dogs, fibroblasts and collagen fibers were induced in the PGA nonwoven fabric and replaced by these.[29] Thus, robust reconstruction can be achieved without using rigid materials. In cases without intraoperative CSF leakage, dural closure using the S-PGA method is controversial. Identifying the

presence or absence of intraoperative CSF leakage is influenced by the surgeon's subjective judgment. Therefore, the risk of CSF leakage may not be recognized, and S-PGA reconstruction is necessary in all cases to ensure certainty.

The S-PGA method may seem difficult to perform because of the need to suture the dura mater. However, it is actually a simple procedure. In the study of Kim et al.[30], dural suturing was performed in transsphenoidal surgery. Results showed that needle handling was initially challenging. Nevertheless, it gradually became manageable. When our technique was first introduced, five sutures were placed within approximately 30 min. Nonetheless, after performing 20–30 surgeries, the dura can now be repaired in half the previously mentioned time. Further, the sliding-lock-knot technique proposed by Sakamoto et al. allows the knot to be created outside the nasal cavity, thereby making it easy to tie the knot.

In the S-PGA method, oxygenated cellulose is used after the lesion is removed. However, because it is not fat-filled, the effect of postoperative radiogram interpretation for CT scans and MRI was minimal. Some implanted materials, such as fat, could be observed on MRI for as long as 10 years after the surgery. Meanwhile, other materials, such as hemostatic materials, could be identified for only 1 month after surgery.[31] Another advantage of the S-PGA method is that it allows long-term follow-up.

In this study, two patients with postoperative CSF leakage were treated with radiation therapy. This indicated the importance of adequate blood flow to the normal adjacent dura mater. Therefore, patients receiving radiation therapy or those who have undergone repeated EEA should not be considered candidates for the S-PGA method.

Conclusion

This study described the S-PGA method, which involves dural suturing and closure using EEA and a PGA nonwoven fabric. It is a simple method that

can decrease the risk of postoperative spinal fluid leakage to the greatest extent possible. Thus, it can be an excellent option for skull base reconstruction.

Ethical Approval

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.

Conflict of Interest

None declared.

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Fig. 1 Endoscopic view of the closure procedure using the suture and polyglycolic acid nonwoven fabric method. a) After PitNET removal. b) Insertion of the cotton-type oxidized cellulose to prevent postoperative hematoma formation. c) Dura mater suturing with a 5-0 nylon thread. It does not need to be perfectly watertight. d) The polyglycolic acid nonwoven fabric over the dura mater. e) Adhere the polyglycolic acid

nonwoven fabric was laid to the dura mater, and fibrin glue was applied. The absence of CSF leakage was confirmed using the Valsalva maneuver. f) Preoperative gadolinium contrast-enhanced magnetic resonance imaging showing PitNET. g) Gadolinium contrast-enhanced magnetic resonance imaging at 3 months post-surgery. The inserted cotton-type oxidized cellulose was absorbed and clearly legible.

Fig. 2 Endoscopic view of the closure procedure using the suture and polyglycolic acid nonwoven fabric method when the dural defect was large. a) After Meningioma removal. b) Dura mater sutured using the rectus abdominis fascia. c) The polyglycolic acid nonwoven fabric was adhered to the dura mater, and fibrin glue was applied. The absence of CSF leakage was confirmed via the Valsalva maneuver. d) Preoperative gadolinium contrast-enhanced magnetic resonance imaging showing tuberculum sellae meningioma. e) Gadolinium contrast-enhanced magnetic resonance imaging at 3 months post-surgery. The tumor has been evidently removed.

Table. 1 Cerebrospinal fluid leak repair protocol (Rearranged from Esposito et al.[11])

Grade of leak	Description of leak	Current repair method
Grade 0	Absence of cerebrospinal fluid leak, confirmed by Valsalva maneuver	1) Cotton-type oxidized cellulose 2) Dural suture 3) PGA nonwoven fabric is placed on the dura mater 4) Applying fibrin glue to the surgical field
Grade 1	Small “weeping” leak, confirmed by Valsalva maneuver, without obvious or with only small diaphragmatic defect	
Grade 2	Moderate cerebrospinal fluid leak, with obvious diaphragmatic defect	
Grade 3	Large cerebrospinal fluid leak, typically created as part of extended transsphenoidal approach through the supradiaphragmatic or clival dura for tumor access	1) Cotton-type oxidized cellulose 2) Dural suture (If the defect is large, the rectus abdominis fascia is used.) 3) PGA nonwoven fabric is placed on the dura mater 4) Applying fibrin glue to the surgical field

PGA; Polyglycolic acid

Table. 2
Pathological diagnosis of the S-PGA method and fat reconstruction

Pathology	No. of patients	
	S-PGA method	Fat reconstruction
PitNET	248	190
Rathke's cleft cyst	36	49
Craniopharyngioma	14	9
Meningioma	11	2
Hypophysitis	7	3
Metastasis	7	8
Cordoma	2	7

S-PGA method; suture and polyglycolic acid nonwoven fabric method
PitNET; Pituitary neuroendocrine tumor

Table. 3
Intraoperative cerebrospinal fluid leak rate

CSF leak grade	S-PGA method (%)	Fat reconstruction (%)
Grade 0	85 (34.4%)	96 (35.8%)
Grade 1	68 (27.4%)	79 (29.5%)
Grade 2	40 (16.1%)	50 (18.7%)
Grade 3	55 (22.1%)	43 (16.0%)
Totals	248	268

S-PGA method; suture and polyglycolic acid nonwoven fabric method
CSF; cerebrospinal fluid

Table. 4
Repair failure rate in the S-PGA method and fat reconstruction

CSF leak grade	S-PGA method (%)	Fat reconstruction (%)	
Grade 0	0 (0.0%)	0 (0.0%)	> 0.05
Grade 1	0 (0.0%)	1 (1.3%)	> 0.05
Grade 2	0 (0.0%)	6 (12.0%)	< 0.05
Grade 3	2 (3.6%)	7 (16.3%)	< 0.05
Totals	2 (0.8%)	14 (5.2%)	< 0.01

(Fisher's exact test)

S-PGA method; suture and polyglycolic acid nonwoven fabric method
CSF; cerebrospinal fluid