A Novel Graft Material for Preventing Cerebrospinal Fluid Leakage in Skull Base Reconstruction: Technical Note of Perifascial Areolar Tissue

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Abstract

Objectives Perifascial areolar tissue (PAT), a layer of loose connective tissue on the deep fascias with a rich vascular plexus, serves as a vital cover over defects with scarce vascularity. We report the usefulness of PAT as a nonvascularized alternative to flaps for reconstruction of dural defects in skull base surgery and transsphenoidal surgery while evaluating its effect on control of cerebrospinal fluid (CSF) leakage.

Design A retrospective chart analysis was performed on patients who had undergone repair of a dural defect with PAT during skull base surgery or transsphenoidal surgery between December 2004 and October 2011.

Results Twenty-one patients were included: 11 patients had received surgical treatment and/or irradiation. Fourteen of the 21 patients had pre- and/or intraoperative CSF leakage. Only one patient (4.8%) had postoperative CSF leakage requiring additional surgical repair. Ten patients underwent postoperative irradiation from 1 to 15 months after transplant of the PAT. None of the patients had postoperative CSF leakage after irradiation.

Conclusion We successfully repaired dural defects using PAT in skull base surgery and transsphenoidal surgery, even in patients with a history of multiple operations and radiotherapy. PAT may serve as a valuable tool for skull base reconstruction.

Keywords

- ▶ cerebrospinal fluid leakage
- ▶ perifascial areolar tissue
- ▶ skull base
- ▶ transsphenoidal surgery

Introduction

Postoperative cerebrospinal fluid (CSF) leakage results in life-threatening intracranial complications including meningitis, cerebral abscess, and pneumocephalus.¹ Repair of CSF leakage in the skull base is especially difficult in conditions of hypovascularity after radiation or of complex shapes or cavitations of the bone structure. Although vascularized pedicle flaps are well-established methods used to prevent CSF leakage in skull base reconstruction, they are demanding and time-consuming techniques.^{2–5}

The subcutaneous fat is anatomically classified into two adipofascial layers.⁶ Perifascial areolar tissue (PAT) is a layer

of loose connective tissue on the deep fascia, located under the deep adipofascial layer and directly on the deep fascia, and it has an abundant vascular plexus (▶ **Fig. 1**).⁷ Our coauthors previously reported that PAT could serve as a vital cover over a defect with scarce circulation.⁷ The tissue is sufficiently flexible to fix many types of defects, such as a plane or spaces with complex shapes, and it can be transferred as a nonvascularized graft. This novel material was used for the treatment of skin ulcers and fistulas with poor blood supply associated with tendon and bone exposure, soft tissue defects after head and neck cancer resection, and dead space after tumor resection in skull base surgery and transsphenoidal surgery, resulting in good healing with a low

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Fig. 1 Schematic drawing of perifascial areolar tissue (PAT).

complication rate.⁷ In the present study, we used a PAT graft as a nonvascularized alternative to flaps for reconstruction of dural defects after skull base surgery and transsphenoidal surgery. We evaluated pre- and postoperative CSF leakage and discussed the usefulness of PAT grafting, especially in patients with repeat operations, radiotherapy, and/or with planned postoperative irradiation.

Patients and Methods

A retrospective chart analysis was performed on patients who had undergone a repair of a dural defect at the skull base with PAT between December 2004 and October 2011 at Shizuoka Cancer Center Hospital. Approval for this study was obtained from the institutional research ethics board. PAT was used for the repair of dural defects in the skull base of 21 patients: 9 transsphenoidal, 8 anterior skull base, 2 suboccipital, 1 endonasal endoscopic, and 1 pterional approach, performed by the senior author (Y.N.). ▶**Table 1** summarizes the background patient data. Fourteen of 21 patients were included in the case series previously reported by the coauthor for plastic surgeons.⁷

Surgical Procedure

For a PAT graft, the donor site was usually in the inguinal region or femoral anterolateral area. The PAT was easily raised with a scalpel because of its loose attachment to the deep fascia (▶**Fig. 2**). The prepared grafts were 20 to 100 mm long depending on the volume of the area that was to receive the graft.

For transsphenoidal surgery, a small ball of PAT was usually covered with a hemostatic agent of an oxidized cellulose polymer and put into the cavity of the sellar region. Another sheet of PAT was spread over the sellar floor and fixed with fibrin glue (▶**Fig. 3**).

For skull base surgery, a patch of combined femur fascia and PAT was usually prepared and sutured to the dura to cover the defect. For repair of the frontal skull base, the graft was reinforced by a galea periosteum flap with a basal vascularized pedicle sealing the opened frontal sinuses.

Results

A total of 21 patients (13 men, 8 women) were included, with ages ranging from 31 to 70 years (mean: 50 years) (▶**Table 1**). Eight patients had received prior surgical treatment including

five patients who had undergone open surgery and three patients who had undergone transsphenoidal surgery. Two patients had previously received proton beam therapy. One patient with a tentorial meningioma (case 8) had undergone two previous operations and stereotactic radiosurgery. The follow-up period ranged from 17 to 95 months (mean: 43.8 months).

Fourteen of the 21 patients presented with pre- and/or intraoperative CSF leakage. Two of the 14 patients had postoperative CSF leakage. One of these two patients had undergone total removal of a malignant meningioma in the frontal skull base with enucleation of the left eye 9 months prior to the occurrence of CSF leakage (case 20). The large dural defect had been repaired by a patch of fascia, 70 × 80 mm, taken from the femoral region. The frontal skull base was reconstructed with free vascularized composite skin and muscle flap from the thigh. This patient had undergone a ventriculoperitoneal shunt operation and a revised repair of the CSF leakage with a PAT grafted into the ethmoid sinus at 4 months after the first operation for the CSF leakage using PAT. In the other patient (case 21), who had undergone three previous transsphenoidal operations, the postoperative CSF leakage was observed at postoperative day 2 and stopped after lumbar CSF drainage for 6 days. Seven patients presented without pre- and/or intraoperative CSF leakage, and none experienced postoperative CSF leakage. The incidence of postoperative CSF leakage requiring surgical repair was 4.8% (1 of 21 patients).

In 10 patients, postoperative irradiation was performed in the period between 1 to 15 months (mean: 4.8 months) after the repair with PAT: 8 received proton beam therapy and 2 patients were treated with X-ray irradiation. In the follow-up period for these 10 patients, which ranged from 28 to 89 months (mean: 48.9 months), no CSF leakage occurred.

Discussion

Postoperative CSF leakage is a problematic complication of neurosurgical procedures. It occurs relatively frequently after skull base surgery because complete watertight closure of the basal dura mater is not always possible.⁸ Depending on the surgical approach, the rate of CSF leakage reported in the literature ranges between 3.3% and 20%.^{9–14} Musculofascial or vascularized pericranial flaps are of great importance for sealing the dead space left by the removal of lesions.^{15–17} Vascularized pericranial flaps are used for repair after anterior or transbasal approaches and craniofacial resection.^{2,3} Packing the dead space with autologous fat grafts, muscle, fascia lata, or fibrin glue is also an important technical adjunct that decreases the likelihood of CSF leakage and enhances healing of the postoperative dural defect.

The introduction of the vascularized nasoseptal flap has reduced the incidence of CSF leakage in patients with anterior skull base defects after the endoscopic endonasal transsphenoidal approach.^{4,5} Several techniques have been developed because a conventional nasoseptal flap has several complications: a long operative time and olfactory disorders.^{18,19}

Table 1 Summary of data in patients treated with perifascial areolar tissue

Case no.	Sex/Age	Pathology	Procedure	Prior surgery or RT	Pre/Intraoperative CSF leakage	Postoperative CSF leakage	Postoperative irradiation	Period between operation and RT, mo	Follow up (month)
1	M/32	Pituitary adenoma	Transsphenoidal	–	No	No	No		45
2	M/35	Pituitary adenoma	Transsphenoidal	–	No	No	Proton	15	36
3	F/51	Paraganglioma	Transsphenoidal	–	No	No	Proton	1	37
4	M/40	Pituitary adenoma	Transsphenoidal	–	No	No	No		31
5	M/58	Chordoma	Transsphenoidal	–	No	No	Proton	2	28
6	M/38	Rhabdomyosarcoma	Anterior skull base	–	No	No	No		22
7	M/69	Meningioma	Pterional	–	No	No	No		18
8	F/70	Meningioma	Suboccipital	Two operations (suboccipital), SRS	Yes	No	Proton	1	33
9	M/32	Pituitary adenoma	Transsphenoidal	Operation (TSS)	Yes	No	No		95
10	M/55	Neuroblastoma	Anterior skull base	–	Yes	No	Proton	1	89
11	F/41	Neuroblastoma	Anterior skull base	Proton	Yes	No	No		79
12	M/61	Nasal carcinoma	Anterior skull base	–	Yes	No	X-ray	8	80
13	F/68	Chondrosarcoma	Suboccipital	Operation (subtemporal)	Yes	No	Proton	13	49
14	F/31	Pituitary adenoma	Transsphenoidal	Operation (craniotomy)	Yes	No	No		44
15	M/48	Pituitary adenoma	Transsphenoidal	Operation (TSS)	Yes	No	Proton	4	53
16	M/40	Neuroblastoma	Anterior skull base	–	Yes	No	Proton	2	40
17	M/41	Neuroblastoma	Anterior skull base	Operation (skull base)	Yes	No	X-ray	1	44
18	M/41	Neuroblastoma	Anterior skull base	proton	Yes	No	No		30
19	F/69	Neuroblastoma	Anterior skull base	–	Yes	No	No		19
20	F/65	Meningioma	Endonasal endoscopic	Operation (skull base)	Yes	Yes	No		17
21	F/62	Pituitary adenoma	Transsphenoidal	Three operations (TSS)	Yes	Yes	No		30

Abbreviations: CSF, cerebrospinal fluid; RT, radiation therapy; SRS, stereotactic radiosurgery; TSS, transsphenoidal surgery.

Note: Cases 1–4, 8, 9, 12–18, and 21 were included the case series previously reported by the coauthor.¹⁶

Fig. 2 A graft of perifascial areolar tissue (PAT). (A) A layer of loose connective tissue was elevated from the surface of the femoral fascia. (b) Macrographic and (C) histologic appearance of the PAT (hematoxylin and eosin) showing loose connective tissue with a rich vascular plexus.

Ideally, a substitute to the vascularized flaps would be flexible, easy to handle, and have long-term survival. In addition, the substitute procedure would be safe, simple, and applicable for skull base or transsphenoidal operations. Comparisons of

Fig. 3 Postoperative T1-weighted magnetic resonance imaging of a patient with a pituitary adenoma (case 15). Arrow indicates the perifascial areolar tissue (PAT) that was put into the cavity of the sellar region; the asterisk indicates how the PAT was distributed in the sphenoid sinus to seal up the sellar floor.

characteristics of several materials used for skull base repair are listed in ►Table 2. In the present study, PAT was utilized for repair of dural deficits after skull base surgery. The PAT was harvested from the inguinal region or femoral area by a plastic surgeon without disturbing surgical procedures by neurosurgeons, leading to a shorter surgical time. Although additional incision at the donor site was needed, no complications related to the procedure of preparing the PAT occurred in our series: infection, prolonged pain, or deformity at the donor site. PAT is a new material that has a rich vascular plexus, and it is sufficiently flexible to fix many types of defects, such as a plane or spaces with complex shapes, and can be transferred as a nonvascularized graft.⁷ Koizumi et al reported that the total survival rate of the PAT grafts was 91% in 32 patients.⁷ PAT has a great advantage in patients who have undergone previous treatments such as multiple operations or radiotherapy that make them vulnerable to postoperative CSF leakage.¹⁴ It is noteworthy that half of the patients included in our PAT series had previously undergone surgical or radiologic treatment, and the procedure proved successful in preventing CSF leaks, with the exception of a large dural defect in one patient. For anterior skull base tumors, postoperative radiation is often planned, which is potentially accompanied by the risk of flap necrosis and secondary CSF leakage.^{20–22} In the present report, 10 patients underwent postoperative irradiation in the period between 1 and 15 months (mean: 4.8 months) after repair with PAT. No patients presented with postoperative CSF leakage in the follow-up period, which ranged from 28 to 89 months (mean: 48.9 months).

Table 2 Comparison of characteristics of materials used for skull base repair

	Pedicated mucosal flap	Fascia lata/ Muscle piece	Fat	Artificial material	PAT
Vascularity	++	–	–	–	+
Flexibility	+	+	+	–	++
Long-term survival	++	–	–	–	+
Safe and simple procedure for preparation	–	+	+	++	+
Harmless to donor site	–	–	–	+	–
Good visibility on postoperative MRI	+	–	++	–	+

Abbreviations: MRI, magnetic resonance imaging; PAT, perifascial areolar tissue.

One limitation of the PAT graft is that the strength of a sheet of PAT is not suitable for a dural substitute. It should be prepared in combination with fascia for a large dural defect receiving continuous CSF pressure. The incidence of postoperative CSF leakage requiring surgical repair (4.8%) in our study is comparable with that achieved with the techniques described in the existing literature.

Although our report included a small number of patients, this short communication brings new data of importance for patients who underwent dural repair after skull base surgery.

Conclusion

We successfully repaired dural defects and prevented CSF leakage in skull base surgery and transsphenoidal surgery using PAT, even in patients who had previous multiple operations and radiotherapy. With its enduring advantages for hypovascularity, flexibility in fixing defect of complex shapes, and a short, easy, and safe surgical procedure, PAT may become one of the valuable and available tools for skull base reconstruction.

Conflicts of Interest

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this article.

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