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Multi-layer reconstruction of skull base after endoscopic transnasal surgery for invasive pituitary adenomas

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ABSTRACT

Objective. To explore the efficacy of multi-layer skull base reconstruction after endoscopic transnasal surgery for invasive pituitary adenomas (IPAs).

Clinical rationale for the study. Skull base reconstruction for IPAs.

Material and methods. This retrospective analysis involved 160 patients with IPAs who underwent operations from October 2018 to October 2020. All patients were diagnosed with IPAs by pituitary enhanced magnetic resonance imaging, and all tumours were confirmed to be Knosp grades 3a, 3b, or 4. The experimental group and the control group comprised 80 patients in each, and we used different methods to reconstruct the skull base in each group. The comparison indicators included cerebrospinal fluid leakage, sellar floor bone flap (or middle turbinate) shifting, delayed healing of the skull base reconstructed tissue, nasal discomfort, and epistaxis. We used the chi-square test, and $p < 0.05$ was considered statistically significant.

Results. In the experimental group, cerebrospinal fluid leakage occurred intraoperatively in 73 patients, two of whom had cerebrospinal fluid leakage postoperatively. Brain CT 12 months postoperatively showed no sellar floor bone flap (or middle turbinate) shifting. Endoscopic transnasal checks performed seven days after surgery showed that the skull base reconstructed tissue had healed in 74 patients and had failed to heal in six. However, endoscopic transnasal checks showed that all six of these patients' pedicled nasoseptal flaps had healed well by 14 days after surgery. Other sequelae comprised nasal discomfort in four patients, and epistaxis in four. In the control group, cerebrospinal fluid leakage occurred intraoperatively in 71 patients, 14 of whom had cerebrospinal fluid leakage postoperatively. Brain CT 12 months postoperatively showed floor bone flap (or middle turbinate) shifting in 12 patients. Endoscopic transnasal checks performed seven days after surgery showed that the skull base reconstructed tissue had healed in 65 patients. In 12 patients, pedicled nasoseptal flaps had healed well by 14 days after surgery, while the remaining three patients required reoperation. Other sequelae comprised nasal discomfort in five patients, and epistaxis in six.

Conclusions. This new method of multi-layer skull base reconstruction could play an important role in endoscopic transnasal IPA surgery.

Key words: invasive pituitary adenoma, Knosp classification, multiple layers of materials, skull base reconstruction

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Introduction

Pituitary adenomas originate from the adenohypophysis, and comprise 10% of intracranial tumours, with gliomas and meningiomas being more common. Pituitary adenomas are characteristically benign, but some of them are invasive. The concept of invasive pituitary adenomas (IPAs) was first proposed by Jefferson [1] in 1940. IPAs can destroy the sellar floor and adjacent dura mater, invade the cavernous sinus, and even invade the frontal and temporal lobes. In 1993, Knosp et al. [2] proposed a classification of pituitary adenomas that is now commonly used clinically. In this classification, there are five grades based on the relationship between the pituitary adenoma and internal carotid artery on coronal magnetic resonance imaging (MRI). Grades 3a, 3b, and 4 are IPAs.

The most common surgical procedure currently used to treat IPAs is an endoscopic endonasal approach [3]. However, the invasion makes the surgical approach more complex and less likely to achieve complete (curative) resection. The more extensive procedure required to achieve complete resection of IPAs and the associated resolution of endocrine dysfunction usually result in a higher incidence of intraoperative cerebrospinal fluid leakage than occurs after excision of non-IPAs. How best to reduce the incidence of cerebrospinal fluid leakage, and other postoperative complications, thus warrants further research.

Clinical rationale for the study

This study was performed in order to explore the efficacy of skull base reconstruction for IPAs.

Material and methods

The inclusion criteria for this study were: first-time surgical treatment of an IPA; a Knosp grade 3a, 3b, or 4 IPA; no other complications such as heart disease or hepatic disease; and no history of nasal injury or surgery.

The exclusion criteria were: a history of surgery for a pituitary adenoma; a Knosp grade 1 or 2 IPA; the presence of other complications such as heart failure or cancer; and a history of nasal injury or surgery.

Information

The cohort in this retrospective study comprised 160 patients. In the experimental group, 80 patients (34 males and 46 females) ranged in age from 38 to 75 years, with a mean of 56.3 ± 10.0 years. Twenty-two of the 80 patients had growth hormone-secreting pituitary adenomas, 20 of the tumours were prolactin-secreting, 16 were adrenocorticotropic hormone-secreting, five were poly-secreting functional, and 17 were non-functional. There were 30 pituitary macroadenomas and 50 giant pituitary adenomas as defined by the pituitary adenoma volume. According to the Knosp classification (Tab. 1), 21 patients had a Knosp grade 3a tumour, 29 had a Knosp grade 3b, and 30 had a Knosp grade 4 (Fig. 1A–F). The postoperative length of stay ranged from 8 to 15 days, with a mean of 10.8 ± 1.9 days. The time required to reconstruct the skull base ranged from 40 to 60 minutes, with a mean of 51.4 ± 5.6 minutes.

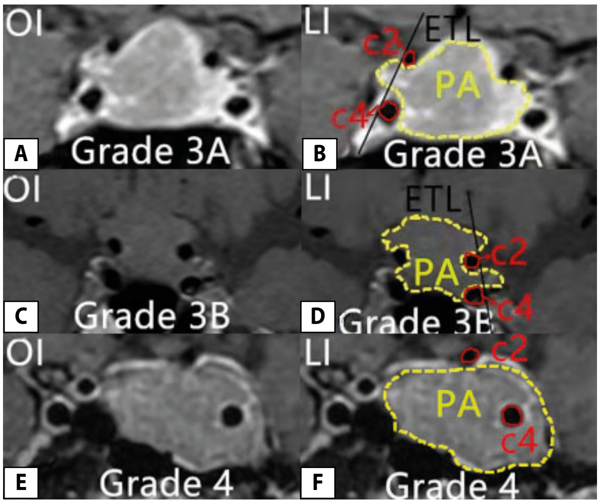

Figure 1. Pituitary adenoma of Knosp grade 3 and 4. C2 — c2 of internal carotid artery; C4 — c4 of internal carotid artery; ETL — external tangential line; LI — labelled image; OI — original image; PA — pituitary adenoma

Table 1. Knosp classification

Grade 0	Grade 1	Grade 2	Grade 3		Grade 4
			Grade 3A	Grade 3B	
Cavernous sinus is of normal shape, with enhancement of the venous plexus, and the tumour doesn't exceed the internal tangential line of c2–c4 vascular diameter.	When the tumour exceeds the cut off line of c2–c4 vascular diameter, but doesn't exceed the central line of c2–c4 vascular diameter, the venous plexus in the medial cavernous sinus disappears.	When the tumour exceeds the central line of c2–c4 vascular diameter, but doesn't exceed the external tangential line of c2–c4 vascular diameter, the upper or lower venous plexus of the cavernous sinus may disappear	When the tumour exceeds the external tangential line of c2–c4 vascular diameter, extending laterally into the upper cavernous sinus	When the tumour exceeds the external tangential line of c2–c4 vascular diameter, extending laterally into the lower cavernous sinus	The internal carotid artery in the cavernous sinus segment is completely encapsulated, resulting in internal diameter stenosis, disappearance of venous plexus in each part, and spherical outward expansion and protrusion of the superior wall and outer wall of the cavernous sinus

In the control group, 80 patients (37 males and 43 females) ranged in age from 40 to 74 years, with a mean of 56.4 ± 10.0 years. Nineteen of the 80 patients had growth hormone-secreting pituitary adenomas, 24 of the tumours were prolactin-secreting, 15 were adrenocorticotropic hormone-secreting, seven were poly-secreting functional, and 15 were non-functional. There were 32 pituitary macroadenomas and 48 giant pituitary adenomas as defined by the pituitary adenoma volume. According to the Knosp classification, 20 patients had a Knosp grade 3a tumour, 32 had a Knosp grade 3b, and 28 had a Knosp grade 4 (Fig. 1A–F). The postoperative length of stay ranged from 8 to 20 days, with a mean of 11.0 ± 2.6 days. The time required to reconstruct the skull base ranged from 35 to 55 minutes, with a mean of 50.0 ± 4.9 minutes. There was no significant difference in the above data between the two groups ($p > 0.05$) (Tab. 2). We reviewed the patients' medical records after obtaining clinical ethics committee approval.

Surgical procedure

Experimental group

Preoperative preparation

The patients fasted for 6–8 hours before the surgery.

Operative position

We performed all surgeries under general anaesthesia with the patient in a horizontal supine position. After adjusting the patient's head position so that their nostrils were oriented toward the surgeon, we used an iodine solution to disinfect the area around the nostrils three times, after which we injected iodine solution into both nasal cavities. At the same time, we marked a 4 × 3 cm oval skin flap between the patient's right knee and hip joint and disinfected it within 15 cm three times with iodine solution. We then draped the sterile area with sterile surgical towels (Fig. 2A–D).

Construction of sellar floor bone flap

Provided that the sellar floor bone had not been invaded by the pituitary adenoma, the scope of the sellar floor bone flap was determined by the findings on preoperative paranasal sinus computed tomography (CT) and pituitary MRI. First,

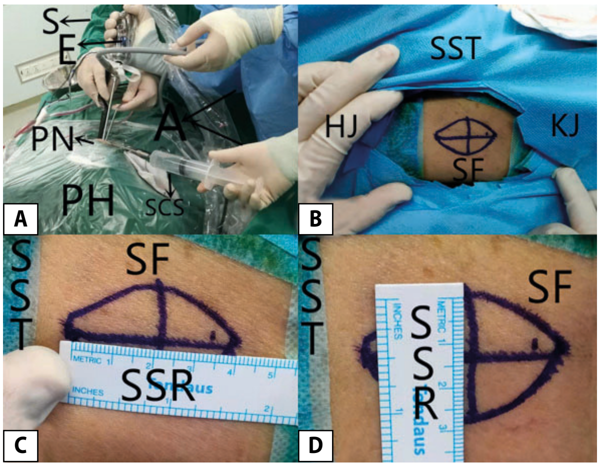

Figure 2. Operative position and skin flap. S — surgeon; E — endoscopy; A — assistant; PN — patient's nostrils; PH — patient's head; SCS — sodium chloride solution; HJ — hip joint; KJ — knee joint; SF — skin flap; SST — sterile surgical towels; SSR — sterile surgical ruler

Table 2. Patients' basic information

Information		Experimental group	Control group	P-value
Gender	M	34	37	
	F	46	43	0.750
Age		56.3 ± 10.0	56.4 ± 10.0	0.874
Hormone	GH	22	19	
	PRL	20	24	
	ACTH	16	15	
	PSF	5	7	
	NF	17	15	0.898
Pituitary adenoma volume	PMAA	30	32	
	GPA	50	48	0.871
Knosp grade	3a	21	20	
	3b	29	32	
	4	30	28	0.919
Postoperative length of stay		10.8 ± 1.9	11.0 ± 2.6	0.867
Time of reconstruction		51.4 ±5 .6	50.0 ± 4.9	0.632

M — male; F — female; GH — growth hormone; PRL — prolactin; ACTH — adrenocorticotropic hormone; PSF — poly-secretory functional; NF — non-functional; ; PMAA — pituitary macroadenomas; GPA — giant pituitary adenomas

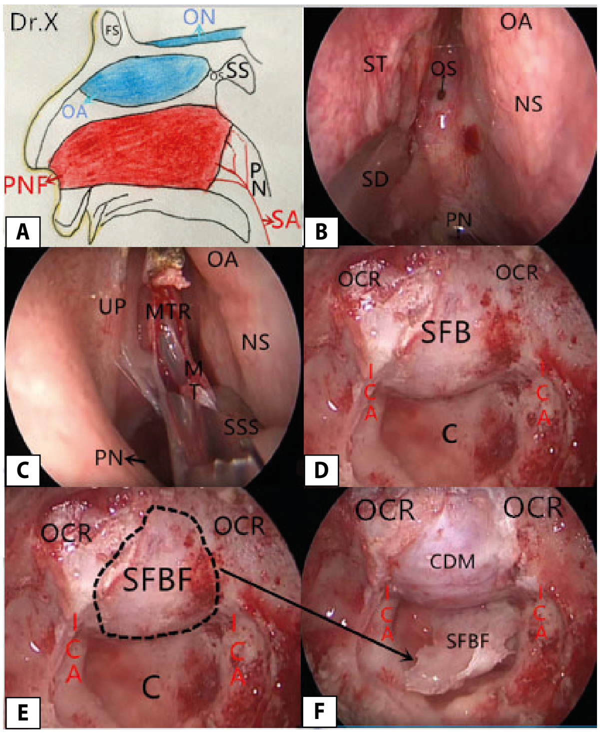

Figure 3. Making sellar floor bone flap. FS — frontal sinus; OA — olfactory area; OS — opening of sphenoid sinus; ON — olfactory nerve; PN — posterior naris; PNF — pedicled nasoseptal flap; SA — sphenopalatine artery; SS — sphenoid sinus; Dr. X — drawn by Dr. Xing; NS — nasal septum; ST — superior turbinate; SD — surgical detacher; UP — uncinate process; MTR — middle turbinate root; MT — middle turbinate; SSS — surgical scissors; OCR — optic carotid recess; SFB — sellar floor bone; C — clivus; ICA — internal carotid artery; SFBF — sellar floor bone flap; CDM — cerebral dura mater

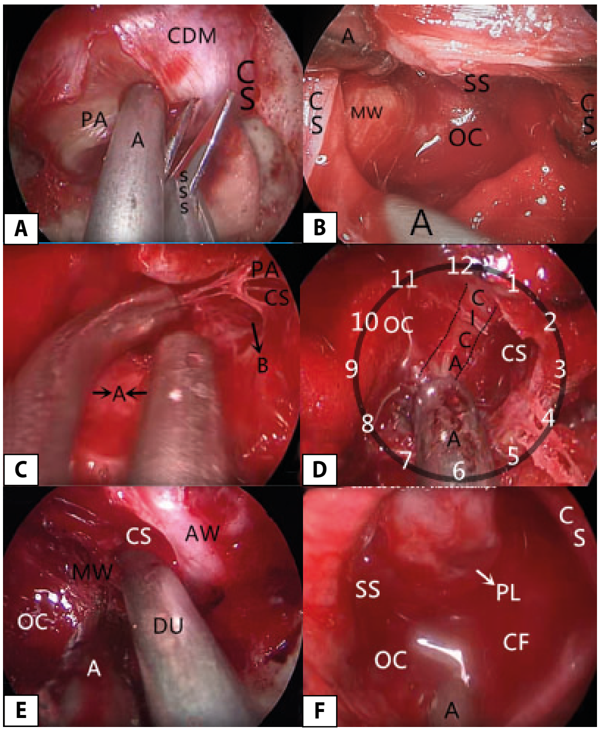

Figure 4. Resection of invasive pituitary adenoma. PA — pituitary adenoma. A — aspirator; CDM — cerebral dura mater; SSS — surgical scissors; CS — cavernous sinus; OC — operative cavity; SS — saddle septum; MW — medial wall of cavernous sinus; B — breaches of cavernous sinus; CICA — cavernous internal carotid artery; DU — Doppler ultrasound; AW — anterior wall of cavernous sinus; CF — cerebrospinal fluid; PL — point of leakage

we thinned the tissues around the sellar floor bone flap and pierced the inferior aspect of the sellar floor bone. Next, we used a Kerrison bone rongeur to remove the thinned bone and completely detach the sellar floor bone flap while protecting the entire base of the epidural saddle. Finally, we placed the sellar floor bone flap in the clivus recess until needed. On the other hand, if the pituitary adenoma had invaded the sellar floor bone and dura mater, we used a Kerrison bone rongeur to directly construct a bony window. We then used the middle turbinate to replace the sellar floor bone flap during reconstruction of the skull base (Fig. 3A–F).

Resection of IPA

In patients in whom the pituitary adenoma had invaded the dura mater, we inserted micro-scissors directly inferior to the saddle to cut that dura. While closely monitoring the pituitary adenoma capsule, we used a curette and aspirator to aspirate the pituitary adenoma and capsule in all directions, paying particular attention to the breaches in the medial walls of both cavernous sinuses (Fig. 4A–B). Given that the tumours were Knosp grades 3 or 4, one or both cavernous sinus medial walls had always been invaded (Fig. 4C). To prevent recurrence of the pituitary adenoma and achieve resolution of endocrine dysfunction, we attempted to resect the invaded medial wall(s) of the cavernous sinus simultaneously. The procedures used to resect the medial wall of the cavernous sinus were as follows.

First, we used a stripper to peel off the medial wall of the cavernous sinus in a 4-to-5-o'clock orientation (Fig. 4D) of the surgical field to fully separate the medial wall of the cavernous sinus to be resected. Second, we severed numerous dural ligaments, including the caroticoclinoid ligament, inferior parasellar ligament, and suprasellar ligament [4], by further opening the free orifice. Finally, we achieved complete separation of the medial wall of the cavernous sinus and resected it. At this stage, we used aspirators to completely clear all tumour from the cavernous sinus. We paid special attention to protecting the cavernous internal carotid artery and its branches during resection of the IPA from the cavernous sinus. Doppler ultrasound, electrophysiological monitoring, and surgery navigation were used, thus minimising rupture and bleeding of these arteries (Fig. 4E). Notably, the dural wall is thin, especially at the junction between the medial wall of the

Table 3. Grades of cerebrospinal fluid leakage

Grade 0	Grade 1	Grade 2	Grade 3
Absence of cerebrospinal fluid leak, confirmed by Valsalva manoeuvre	Small weeping leak, confirmed by Valsalva manoeuvre, without obvious, or with only small, diaphragmatic defect	Moderate cerebrospinal fluid leak, with obvious diaphragmatic defect	Large cerebrospinal fluid leak, typically created as part of extended trans-sphenoidal approach through the supra diaphragmatic or clival dura for tumour access

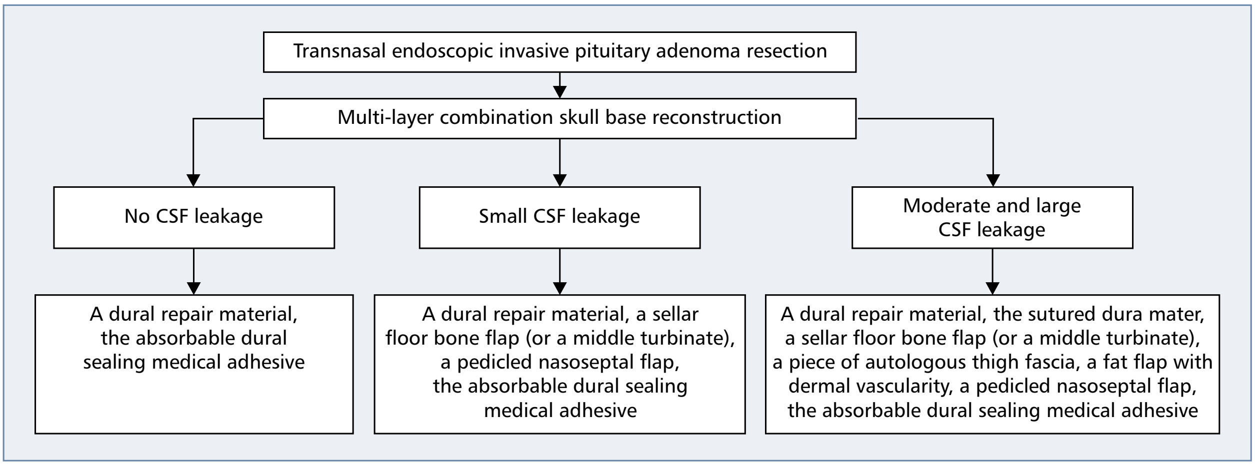

Figure 5. Reconstruction of skull base

cavernous sinus and saddle septum. Therefore, cerebrospinal fluid leakage can easily occur when performing this procedure. At this time, the Valsalva manoeuvre [5] was performed by the anaesthetist to increase the intracranial pressure to approximately 30 mmHg for identification of cerebrospinal fluid leakage (Fig. 4F). If a leak was identified, it was graded (Tab. 3). We used fluid gelatin and haemostatic gauze to stop the bleeding after resection of the IPA and then prepared for skull base reconstruction.

Reconstruction of skull base

According to the grade of cerebrospinal fluid leakage, different strategies were used to reconstruct the skull base (Fig. 5). For grade 0 cerebrospinal fluid leakage, we inserted dural repair material (Durafix; Beijing YHBIOMAX Biologic Technologies, Beijing, China) into the operative cavity inferior to the dura at the base of the saddle, and we then used an absorbable dural sealing medical adhesive (Jinan Success Biologic Technologies, China) to cover the dural repair material. For grade 1 cerebrospinal fluid leakage, a dural repair material was inserted into the tumour cavity to cover the source of the leakage, and the sellar floor bone flap was fixed by haemostatic gauze. The pedicled nasoseptal flap with the absorbable dural sealing medical adhesive was placed outside the sellar floor bone flap. For grades 2 and 3 cerebrospinal fluid leakage, we used a dural repair material, the sutured dura mater, a sellar floor bone flap (or the middle turbinate), a piece of autologous thigh fascia [6], a fat flap with dermal vascularity, a pedicled nasoseptal flap, and the absorbable dural sealing medical adhesive to reconstruct the skull base.

The specifics of our reconstruction procedure were as follows. (I) We inserted the dural repair material into the operative cavity inferior to the dura at the base of the saddle to cover any point of leakage. This dural repair material acts as a saddle septum, comprising the first layer of leak containment (Fig. 6A). (II) We usually created a double-cross slip knot [7] with the intranasal suture outside the nasal cavity to suture the dura mater. Because the dura mater was incomplete as a result of invasion or destruction by the pituitary adenoma, and shrinkage after incision, and the suturing of the dura mater mainly served as a support for the dural repair material, we did not attempt to achieve complete and tight suturing of the dura mater (Fig. 6B–C). (III) As the third layer for reconstruction of the skull base, we placed the sellar floor bone flap or the middle turbinate exterior to the dura mater. Notably, we trimmed the middle turbinate outside the nasal cavity to fit and completely cover the sellar floor defect (Fig. 6D). (IV) Next, we collected a piece of autologous thigh fascia and a fat flap with dermal vascularity from the lateral right thigh of the patient and laid it exterior to the sellar floor bone flap [8]. In accordance with the preoperative marking, we cut a 4 × 3 cm oval skin flap with a subcutaneous adipose layer between the patient's right knee and hip joint. We cut off the epidermal layer with tissue scissors, preserving the dermis layer with its subcutaneous adipose layer as a complete flap for further use. We then further explored the subcutaneous adipose layer until

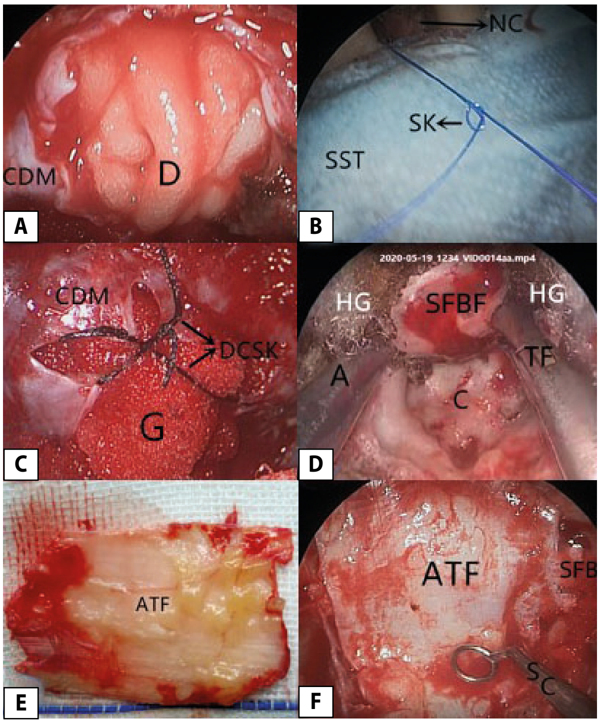

Figure 6. Multi-layer reconstruction of skull base (first four levels). D — dural repair material (Durafix); CDM — — cerebral dura mater; SST — sterile surgical towels; SK — slip knot; NC — nasal cavity; G — gelfoam; DCSK — double-cross slip knot; HG — haemostatic gauze; A — aspirator; C — clivus; SFBF — — sellar floor bone flap; TF — tissue forceps; ATF — autologous thigh fascia; SFB — sellar floor bone; SC — surgical curette

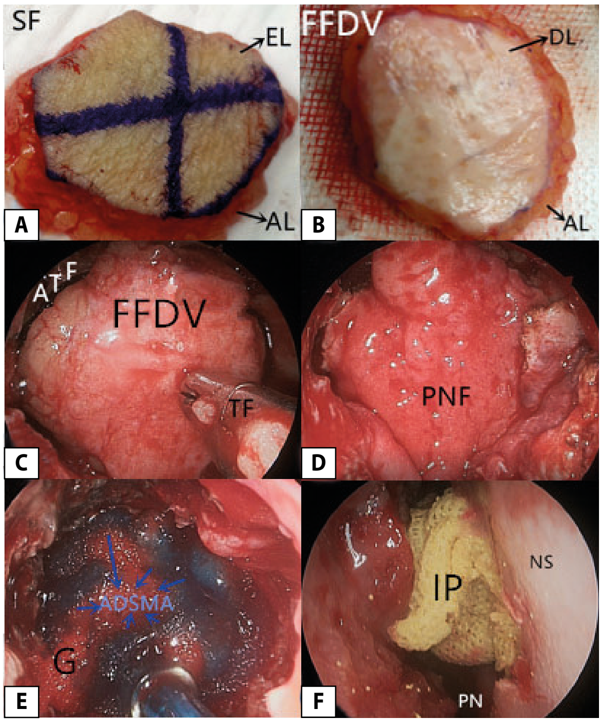

Figure 7. Multi-layer reconstruction of skull base (remaining three levels). SF — skin flap; EL — epidermal layer; AL — adipose layer; FFDV — fat flap with dermal vascularity; DL — dermis layer; ATF — autologous thigh fascia; TF — tissue forceps; PNF — pedicled nasoseptal flap; G — gelfoam; ADSMA — absorbable dural sealing medical adhesive; IP — iodoform sponges; PN — posterior naris; NS — nasal septum

we reached the muscle fascia, after which we sheared off the same size piece of fascia (4 × 3 cm), followed by suturing the incision after carefully ensuring haemostasis. We first laid the autologous thigh fascia exterior to the sellar floor bone and tried to thoroughly attach the fascia to the sellar floor bone in all directions (Fig. 6E–F). We then laid the fat flap with dermal vascularity exterior to the fascia.

Using a fat flap with dermal vascularity is an innovation developed by our department for skull base reconstruction material; this development was originally inspired by skin replantation techniques used in burn patients [9]. These flaps are waterproof, thick, and rich in blood vessels, enabling them to play a valuable role in preventing cerebrospinal fluid leakage and ensuring the success of skull base reconstruction (Fig. 7A–C). (V) The importance of a pedicled nasoseptal flap as the sixth layer for skull base reconstruction is obvious. A suitable pedicled nasoseptal flap was constructed as follows. We made an incision at the level of the opening of the right sphenoid sinus to avoid the olfactory area near the sphenoid sinus recess and the superior turbinate. Dissection then proceeded anteriorly to immediately posterior to the junction of the nasal mucosa and normal skin. Next, we dissected caudad to the inferior aspect of the nasal cavity to reach the inferior nasal passage, after which we proceeded posteriorly until the base of the nasoseptal mucosa and vascular pedicles larger than 1cm in width were visible. We then separated the pedicled nasoseptal flap from the nasal septum and placed it in the posterior nares (Fig. 7D). (VI) We used an absorbable dural sealing medical adhesive to fill the gaps around the skull base reconstructed tissue, especially in the upper quadrant of the surgical field (Fig. 7E). Regardless of which grade of cerebrospinal fluid leakage, we used two pieces of iodoform sponge to support these reconstructed materials (Fig. 7F).

Further treatment

We flushed an appropriate amount of sodium chloride solution into both nasal cavities, then removed any bone fragments before ending the operation.

Control group

The surgical procedures in the control group were the same as those in the experimental group except that the sutured dura mater was not used. A piece of autologous thigh fascia and a fat flap with dermal vascularity were used in skull base reconstruction for moderate and large intraoperative cerebrospinal fluid leakage.

Postoperative care

In this patient cohort, we did not routinely use antibiotics. Brain CT was performed six hours, seven days, one month, six months and 12 months postoperatively, and pituitary-enhanced MRI was performed 24 hours postoperatively. According to the results of the postoperative pituitary hormone status review, we prescribed methylprednisolone or levothyroxine sodium tablets as appropriate. The pituitary hormone status was followed up every three days for one month after normal levels had been achieved. Postoperatively, all patients were asked to avoid coughing, sneezing, and the Valsalva manouevre. We administered stool softener to assist defecation. We removed the iodoform sponges seven days postoperatively after performing an endoscopy to confirm the absence of persistent leakage. We did not routinely place lumbar catheter drains.

Therapeutic evaluation

Cerebrospinal fluid leakage intraoperatively

We recorded the patients who developed cerebrospinal fluid leakage intraoperatively.

Cerebrospinal fluid leakage postoperatively

On the first postoperative day, we examined the patients for cerebrospinal fluid leakage from their nasal cavities. On the seventh postoperative day, we performed an endoscopic transnasal check to identify any cerebrospinal fluid leakage before removing the iodoform sponges. Further endoscopic transnasal checks for cerebrospinal fluid leakage were performed 14 and 28 days after surgery.

Sellar floor bone flap (or middle turbinate) shifting

We performed brain CT 6 hours, 7 days, 1 month, 6 months and 12 months postoperatively to diagnose sellar floor bone flap (or middle turbinate) shifting.

Healing of skull base reconstructed tissue

We performed endoscopic transnasal checks 7, 14, and 28 days after surgery to determine whether the skull base reconstructed tissue had healed and to identify necrosis, lack of healing, pale oedema, or any other problems with the flap.

Nasal discomfort

As soon as the patients had recovered from general anaesthesia, we asked about their nasal sensations and followed this up in all patients for 12 months, recording the number of patients who experienced nasal discomfort.

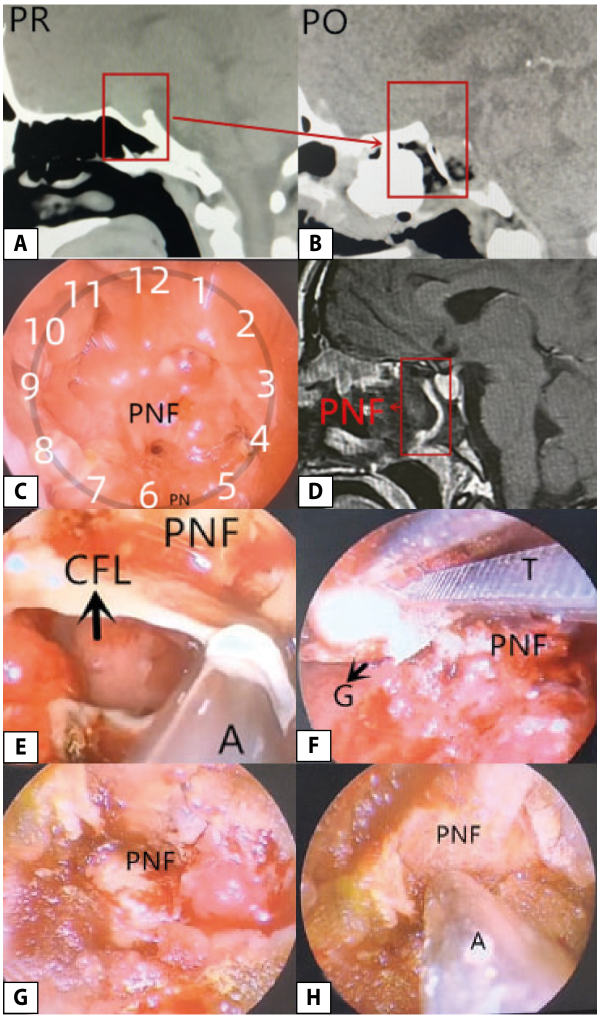

Figure 8. Postoperative CT and endoscopic transnasal check. PR — preoperative computed tomography image; PO — postoperative computed tomography image; PNF — pedicled nasoseptal flap; PN — posterior naris; CFL — cerebrospinal fluid leakage; A — aspirator; G — gelfoam; T — tweezers

Epistaxis

We recorded any episodes of epistaxis from the end of the surgery to the day of discharge from hospital.

Results

We followed all patients for one year; none were lost to follow-up. In the experimental group, intraoperative cerebrospinal fluid leakage occurred in 73 patients (91.3%), two of whom (2.5%) had cerebrospinal fluid leakage postoperatively despite the multiple layers used for skull base reconstruction. The leakage was stopped by the use of gelfoam, iodoform sponges, lumbar catheter drainage, and bed rest. No sellar floor bone flap (or middle turbinate) shifting occurred in any patients, as determined by brain CT six hours, seven days, one month, six months and twelve months postoperatively (Fig. 8A–B). Endoscopic transnasal checks performed seven days after the surgery showed that the skull base reconstructed tissue had healed in 74 patients (92.5%) and failed to heal in six. Two of these six patients had cerebrospinal fluid leakage in the 11 o'clock orientation (Fig. 8C) of the surgical field, and were treated with gelfoam, iodoform sponges, lumbar catheter drainage, and bed rest. The pedicled nasoseptal flap of the remaining four of these patients failed to heal in the 1 o'clock orientation (Fig. 8C) of the surgical field without cerebrospinal fluid leakage, and they were treated with gelfoam, iodoform sponges, and bed rest. All three of these patients' pedicled nasoseptal flaps had healed well by the 14^{th} postoperative day as determined by endoscopic transnasal checks. The skull base reconstructed tissue was clearly seen on the postoperative pituitary enhancement MRI, indicating survival of the skull base reconstructed tissue (Fig. 8C–H).

None of the 80 patients reported preoperative nasal discomfort. Immediately after recovering from general anaesthesia, and one year postoperatively, four patients (5.0%) reported nasal discomfort that did not affect their normal life or sleep. Although we evaluated every patient's nasal cavity before the end of the surgery and found no bleeding, four patients (5.0%) had epistaxis on the seventh postoperative day after removal of the iodoform sponges. We managed this successfully by immediately inserting inflatable haemostatic devices, after which the epistaxis resolved. In the control group, cerebrospinal fluid leakage occurred intraoperatively in 71 patients (88.8%), 14 of whom (17.5%) had cerebrospinal fluid leakage postoperatively. Brain CT one year postoperatively showed sellar floor bone flap (or middle turbinate) shifting in 12 patients (15.0%). Endoscopic transnasal checks performed seven days after surgery showed that the skull base reconstructed tissue had healed in 65 patients (81.3%) and had failed to heal in 15. In 12 of these 15 patients, the pedicled nasoseptal flaps had healed well by 14 days after surgery, whereas the remaining three patients required reoperation. Other sequelae comprised nasal discomfort in five patients (6.3%) and epistaxis in six (7.5%). We compared these two groups by the chi-square test, and the results showed a significant difference in postoperative cerebrospinal fluid leakage, sellar floor bone flap (or middle turbinate) shifting, and healing of the skull base reconstructed tissue between the two groups ($p < 0.05$). However, there was no significant difference in terms of intraoperative cerebrospinal fluid leakage, nasal discomfort, or epistaxis between the two groups ($p > 0.05$) (Tab. 4).

Table 4. Comparison of sequelae between experimental and control groups

Items	Experimental group	Control group	P-value
ICSFL	91.3%	88.8%	0.793
PCSFL	2.5%	17.5%	0.001
SFBFS	0	15.0%	0.002
SBRTH	92.5%	81.3%	0.029
ND	5.0%	6.3%	0.732
Ep	5.0%	7.5%	0.746

ICSFL — intraoperative cerebrospinal fluid leakage; PCSFL — postoperative cerebrospinal fluid leakage; SFBFS — sellar floor bone flap (or middle turbinate) shifting; SBRTH — skull base reconstructed tissue healed; ND — nasal discomfort; Ep — epistaxis

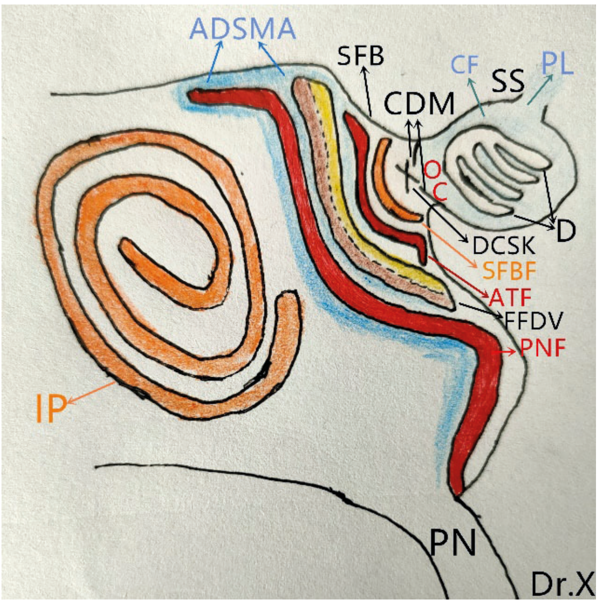

Figure 9. Illustration of multi-layer reconstruction of skull base. PL — point of leakage; SS — saddle septum; CF — cerebrospinal fluid; CDM — cerebral dura mater; SFB — sellar floor bone; OC — operative cavity; PN — posterior naris; D — dural repair material (Durafix); DCSK — double-cross slip knot; SFBF — sellar floor bone flap; ATF — autologous thigh fascia; FFDV — fat flap with dermal vascularity; PNF — pedicled nasoseptal flap; ADSMA — absorbable dural sealing medical adhesive; IP — iodoform sponges; Dr. X — drawn by Dr. Xing

Discussion

On the basis of our experience, we believe that multi-layer reconstruction of the skull base has the following advantages.

(I) Suturing the dura at the base of the saddle and the sellar floor bone flap are forms of anatomical reduction and help to preserve the integrity of the skull base.

(II) With the exception of the first layer of Durafix, the rest of the repair layers are autologous tissues, and therefore confer minimal risk of postoperative rejection and infection.

(III) In multi-layer reconstruction of the skull base, each layer makes a separate and unique contribution. Every layer contributes separately to preventing cerebrospinal fluid leakage. Multi-layer reconstruction of the skull base does not consist of a simple 'super positioning' of multiple layers, because with these layers 1 + 1 is greater than 2 (Fig. 9).

Previously published studies have revealed a c.7% incidence of postoperative cerebrospinal fluid leakage in patients with various types of pituitary adenomas in whom Hadad–Bassagasteguy [10] mucosal flaps were used for reconstruction. However, there is no independent data regarding the incidence of cerebrospinal fluid leakage after surgery for IPAs. In our previously published article, the incidence of intraoperative cerebrospinal fluid leakage during surgeries for all kinds of pituitary adenomas (including IPAs and non-IPAs) was 43.3%, while the incidence of postoperative cerebrospinal fluid leakage was 3.3% [8].

In our current experimental group of 80 patients with IPAs, the incidence of intraoperative cerebrospinal fluid leakage was 91.3%, while the incidence of postoperative cerebrospinal fluid leakage after multi-layer reconstruction of the skull base was 2.5%. In the control group, the incidence of intraoperative cerebrospinal fluid leakage was similar to the experimental group at 88.8%; however, the incidence of postoperative cerebrospinal fluid leakage was much higher than that in the experimental group, at 17.5%. These findings indicate the role of multi-layer reconstruction of the skull base in preventing cerebrospinal fluid leakage. Multi-layer reconstruction of the skull base ensures anatomical reduction and is clearly effective in preventing sellar floor bone flap (or middle turbinate) shifting. In the experimental group, after a 1-year follow-up, the reconstructed skull bases were still stable and no sellar floor bone flap (or middle turbinate) shifting had occurred. In the control group, however, the incidence of sellar floor bone flap (or middle turbinate) shifting was 15%, with a significant difference between the two groups. Survival of the skull base reconstructed tissue is particularly critical. In the experimental group, the tissue had healed well in 92.5% of the patients by seven days after surgery as assessed by endoscopic nasal examination. According to nasal endoscopy checks 14 days after surgery, the remaining six patients achieved complete healing with gelfoam, iodoform sponges, lumbar catheter drainage (two patients), and bed rest. At seven days after surgery in the control group, the incidence of healing of the skull base reconstructed tissue was only 81.3%, and three patients even required reoperation. The incidences of nasal discomfort and epistaxis were low in both groups, and there was no significant difference. This indicates that the multi-layer reconstruction of the skull base did not cause additional damage to the patients. To further reduce patients' suffering, we need to take even greater care to minimise damage to normal tissues in the future.

In conclusion, the advantages of our multi-layer reconstruction of the skull base after transnasal endoscopic resection of IPAs include a decreased incidence of cerebrospinal fluid leakage, with no increase in the incidence of other complications.

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