Fibrin-coated collagen fleece versus absorbable dural sealant for sellar closure after transsphenoidal pituitary surgery: a comparative study

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Various surgical methods to prevent postoperative cerebrospinal fluid (CSF) leaks during transsphenoidal surgery have been reported. However, comparative studies are scarce. We aimed to compare the efficacy of a fibrin-coated collagen fleece (TachoSil) versus a dural sealant (DuraSeal) to prevent postoperative CSF leakage. We perform a retrospective study comparing two methods of sellar closure during endoscopic endonasal transsphenoidal surgery (EETS) for pituitary adenoma resection: TachoSil patching versus DuraSeal packing. Data concerning diagnosis, reconstruction technique, and surgical outcomes were analyzed. The primary endpoint was postoperative CSF leak rate. We reviewed 198 consecutive patients who underwent 219 EETS for pituitary adenoma from February 2007 and July 2018. Intraoperative CSF leak occurred in 47 cases (21.5%). A total of 33 postoperative CSF leaks were observed (15.1%). A reduction of postoperative CSF leaks in the TachoSil application group compared to the conventional technique using Duraseal was observed (7.7% and 18.2%, respectively; p = 0.062; Pearson exact test) although non-statistically significant. Two patients required lumbar drainage, and no revision repair was necessary to treat postoperative CSF rhinorrhea in Tachosil group. Fibrin-coated collagen fleece patching may be a valuable method to prevent postoperative cerebrospinal fluid (CSF) leaks during EETS for pituitary adenoma resection.

Pituitary adenomas represent approximately 15% of all intracranial neoplasms. Endonasal endoscopic transsphenoidal surgery (EETS) has become the preferred method for treating these tumors. While the procedure is considered safe and effective, cerebrospinal fluid (CSF) leak remains a significant complication after EETS. Numerous techniques of sellar reconstruction to prevent this complication have been described. Many involve using autologous tissue grafts, including muscle, septal cartilage/bone, fat, or free mucosal flap. Autologous grafts can lead to additional incisions, increased operative time, risk of additional complications, and patient discomfort. To avoid these limitations, cadaveric acellular dermis or cadaveric fascia lata can be used. Various adhesive substances that locally reinforce sellar repair can also be used, either alone or in combination, including fibrin sealants or collagen-based compounds. Finally, vascularized flaps have gained increasing popularity. However, the nasoseptal flap (NSF) is not exempt from complications and can lead to nasal discomfort, excessive crusting, anosmia, and the necessity for multiple debridements. The ideal alternative to...
these techniques would be an option effective at preventing CSF leak, technically simple to handle, inexpensive, and minimizing morbidity.

TachoSil (Takeda Pharma, Wien, Austria) consists of a sheet of collagen, which is coated on one side with human fibrinogen, human thrombin, and riboflavin. The preparation is ready to use and can be applied directly to the target tissue. Recent studies have demonstrated that TachoSil can be useful during EETS, obviating the need for autologous tissue grafts, postoperative lumbar drainage, and NSF reconstruction.

In this study, we compare the safety and efficacy of a fibrin-coated collagen fleece (TachoSil) patch with fibrin glue versus a dural sealant (DuraSeal, Covidien, Dublin, Ireland) to prevent postoperative CSF leakage.

Methods

Patient population. The Erasmus-ULB ethics committee approved this study (P2018/408) and waived patient consent due to the retrospective study design. Eligible patients were identified from a prospectively maintained institutional pituitary tumor database. All procedures were performed by senior authors (SH and ODW) with extensive experience in pituitary surgery (i.e. with more than 400 transsphenoidal surgeries performed between 1993 and 2007). Eligible patients underwent EETS for pituitary adenoma between February 2007 and July 2018. The primary outcome was postoperative CSF leak rate following sellar repair. Secondary outcomes included the lumbar drain use and reoperation for repeat surgical closure. For each patient, a thorough chart review was conducted, and information obtained included: patient age, gender, tumor size, modified Hardy’s classification for sellar invasion and suprasellar extension, previous surgery, histopathologic diagnosis, intraoperative CSF leakage, repair method, postoperative complications, management of postoperative CSF leak and the length of stay.

Surgical technique. Under general anesthesia, the patient was placed in a supine position. The approach was performed via one nostril. A 30° rigid endoscope was introduced into the nasal cavity and the middle turbinate was lateralized by gentle pressure with an elevator. The rostrum was partially resected. An anterior sphenoidotomy was performed, and the sphenoid septum was removed. Medtronic electromagnetic neuronavigation system was used to tailor precisely the exposure to the tumor size. After complete tumor removal, the sellar cavity was then explored for evidence of a CSF fistula or tumor remnant. Two different methods were successively used to reconstruct the sella. Accordingly, the patients were divided into cohorts based on the closure technique. In cohort 1 (from 2007 to 2015), we packed the sphenoid sinus with a dural sealant (DuraSeal) alone. In cohort 2 (from 2015 to 2018), we covered the anterior wall of the sella by a single layer of the TachoSil patch and then packed the sphenoid sinus with a fibrin sealant (Tisseel; Baxter Medical, Deerfield, IL, USA).

Intraoperative CSF leak and repair methods. Intraoperative CSF leaks were classified in operative protocols as “low” flow CSF leaks which are small “weeping” leaks flowing even without Valsalva maneuver and “high” flow CSF leaks which are moderate or large CSF leaks with or without obvious diaphragmatic defect. In the instance of an intraoperative CSF leak, the postoperative cavity dead space was usually filled with a small piece of absorbable gelatin foam (Gelfoam; Upjohn, Kalamazoo, MI) to reduce the amount of CSF leak. For “low” flow CSF leaks, the closure was then performed as described in the surgical technique for each cohort. For “high” flow leaks, an additional covering by an autologous tissue (turbinate cartilage or septal bone) of the sellar opening was used before classical closure for each cohort. Before 2015, we used in our practice a conventional sellar closure technique with the dural sealant closure (DuraSeal). In 2015, as we aimed to reduce the incidence of postoperative CSF leaks, we opted for a promising alternative method using a fibrin-coated collagen fleece (TachoSil).

Postoperative care. All patients were admitted to the intensive care unit (ICU). On the first postoperative day, patients were transferred to the ward if they were clinically stable and did not present complications.

Statistical analysis. Continuous variables are summarized by means and standard deviations (SD) and qualitative variables as numbers and percentages. Differences in continuous variables means between two groups were compared using classical Student t-tests or Welch’s t-tests in case of variance inequality. Differences in qualitative variables were compared between groups using Pearson’s exact chi-square tests. Statistical significance was considered when \( p \) was < 0.05. All statistical tests were two-sided and performed using IBM-SPSS version 26.0 software (I.B.M. Corp, Armonk, NY, USA) and MedCalc Statistical Software version 14.12.0 (MedCalc Software bvba, Ostend, Belgium).

Ethical approval. For this type of study informed consent was waived with the acceptance of ULB-Erasmus university hospitals’ ethic committee.

Declaration of helsinki. All methods were carried out in accordance with relevant guidelines and regulations of the ‘Declaration of Helsinki’.

Results

Patient characteristics. A total of 219 EETS for pituitary adenoma resection were performed on 198 patients at our institution between February 2007 and July 2018. Twenty patients underwent repeat transsphenoidal surgeries for recurrent or residual adenoma. Nineteen patients underwent two operations and one patient three operations. Sellar closure with TachoSil was applied in 65 surgeries, and conventional packing with...
DuraSeal was applied in the remaining 154 surgeries (Table 1). There were no statistically significant differences between groups for gender, age, and histopathologic diagnoses.

Preoperative characteristics of adenomas are shown in Table 2. There were no statistically significant differences between cohorts to the number of macroadenomas, tumor size, modified Hardy’s classification for sellar invasion, and the number of previous surgeries. However, the suprasellar extension was significantly more likely in the TachoSil treatment group when compared to the conventional packing group (40% versus 25.3%; \( p = 0.036 \)) based on the modified Hardy’s system.

Complications related to EETS according to the closure method are shown in Table 3. There was no statistically significant difference between the TachoSil application group and conventional technique to the amount of “high” flow intraoperative CSF leaks (16.7% versus 40%, respectively; \( p = 0.176 \)). A non-statistically significant reduction of postoperative CSF leaks in the TachoSil application group compared to conventional technique

| Demographics variables | Tachosil application group | DuraSeal packing group | \( p \) value |
|------------------------|---------------------------|------------------------|-------------|
| Number of patients | 61 | 137 | |
| Male (%) | 29 (47.5%) | 68 (49.6%) | 0.878 |
| Mean age, year ± SD | 50.7 ± 14.6 | 50.7 ± 14.6 | 1.000 |

| Histopathologic diagnoses |
|---------------------------|
| Nonfunctioning adenomas | 30 (49.2%) | 72 (52.6%) | 0.760 |
| Functioning adenomas | 23 (37.7%) | 50 (36.5%) | 0.875 |
| Apoplexies | 0 (0%) | 4 (2.9%) | 0.314 |
| Unknown diagnoses (loss of sample, hemorrhage, insufficient sampling) | 8 (13.1%) | 11 (8.1%) | 0.302 |

Table 1. Demographics variables.

| Preoperative variable | Tachosil application group | DuraSeal packing group | \( p \) value |
|-----------------------|---------------------------|------------------------|-------------|
| Number of surgery | 65 | 154 | |
| Macroadenoma | 56 (86.2%) | 129 (83.8%) | 0.690 |
| Mean size, mm ± SD | 20.9 ± 8.5 | 21.9 ± 10.6 | 0.441 |

| Modified Hardy’s classification |
|------------------------------|
| I | 9 (13.8%) | 25 (16.2%) | 0.690 |
| II | 52 (80%) | 104 (67.5%) | 0.730 |
| III | 1 (1.5%) | 12 (7.8%) | 0.115 |
| IV | 3 (4.6%) | 13 (8.4%) | 0.404 |

| Modified Hardy’s system |
|------------------------|
| 0 | 12 (18.5%) | 54 (35.1%) | 0.016 |
| A | 26 (40%) | 39 (25.3%) | 0.036 |
| B | 14 (21.5%) | 28 (18.2%) | 0.577 |
| C | 13 (20%) | 33 (21.4%) | 0.858 |

| Previous surgery | 12 (18.5%) | 41 (26.6%) | 0.153 |

Table 2. Preoperative characteristics of adenomas.

| Surgical variable | Tachosil application group | DuraSeal packing group | \( p \) value |
|-------------------|---------------------------|------------------------|-------------|
| Intraoperative CSF leak | 12/65 (18.5%) | 35/154 (22.7%) | \( p = 0.590 \) |
| Low flow | 10/12 (83.3%) | 21/35 (60%) | |
| High flow | 2/12 (16.7%) | 14/35 (40%) | \( p = 0.176 \) |
| Postoperative CSF rhinorrhea | 5/65 (7.7%) | 28/154 (18.2%) | \( p = 0.062 \) |
| Diamox | 5/65 (7.7%) | 25/154 (16.2%) | \( p = 0.131 \) |
| Postoperative lumbar drainage | 2/65 (3.1%) | 11/154 (7.1%) | \( p = 0.353 \) |
| Revision repair | 0/65 (0%) | 4/154 (2.6%) | \( p = 0.321 \) |
| Meningitis | 1/65 (1.5%) | 4/154 (2.6%) | \( p = 1.000 \) |
| Death | 0/65 (0%) | 2/154 (1.3%) | \( p = 1.000 \) |
| Mean length of hospital stay, days ± SD | 7.1 ± 4.1 | 7.8 ± 4.6 | \( p = 0.280 \) |

Table 3. Complications related with transsphenoidal approach surgery according to closure method. CSF cerebrospinal fluid.

DuraSeal was applied in the remaining 154 surgeries (Table 1). There were no statistically significant differences between groups for gender, age, and histopathologic diagnoses.

Preoperative characteristics of adenomas are shown in Table 2. There were no statistically significant differences between cohorts to the number of macroadenomas, tumor size, modified Hardy’s classification for sellar invasion, and the number of previous surgeries. However, the suprasellar extension was significantly more likely in the TachoSil treatment group when compared to the conventional packing group (40% versus 25.3%; \( p = 0.036 \)) based on the modified Hardy’s system.

Complications related to EETS according to the closure method are shown in Table 3. There was no statistically significant difference between the TachoSil application group and conventional technique to the amount of “high” flow intraoperative CSF leaks (16.7% versus 40%, respectively; \( p = 0.176 \)). A non-statistically significant reduction of postoperative CSF leaks in the TachoSil application group compared to conventional technique
using Duraseal was observed (7.7% and 18.2%, respectively; p = 0.062; Pearson exact test). Cohorts were not significantly different when secondary outcomes were analyzed. Specifically, there were no differences in the use of Diamox (7.7% and 16.2%, respectively; p = 0.131), lumbar drainage (3.1% and 7.1%, respectively; p = 0.353) or surgical revision repair (0% and 2.6%, respectively; p = 0.321). The length of hospital stay was also not significantly different between the groups; p = 0.280. Two patients died in the intensive care unit postoperatively. The first is due to an unrelated aneurysm rupture, the second following iatrogenic vascular injury.

**Discussion**

EETS has become the preferred method for the treatment of many pituitary adenomas. However, the approach has limitations; chief among them is the risk of CSF leak. In our study, we compared two types of sellar closure techniques following EETS. A decreased postoperative CSF leaks occurrence rate in the TachoSil group compared to Duraseal group was observed but did not reach the prespecified significance level. Along these lines, the Tachosil cohort required lumbar drainage in 2 cases (3.1% versus 7.1%), and no patient required revision repair surgery (0% versus 2.6%) without significance.

Interestingly, there were significantly more patients with suprasellar extension in the Tachosil cohort, a known predictor of postoperative CSF leaks. In this context, our findings are more striking and may suggest that Tachosil closure has greater efficacy at preventing CSF leak than Duraseal packing alone. Other predictors of postoperative CSF leak, such as intraoperative CSF leak, tumor size, and repeat surgery, were not significantly different between the cohorts.

TachoSil has several potential advantages for sellar reconstruction when compared to other techniques. First, it serves as a reliable barrier by attaching firmly to dura. Its placement can be performed in a narrow field with straightforward surgical handling. From our experience, it can be easily removed in recurrent tumor surgery. Finally, it provides hemostasis with antigenicity—a feature associated with a lower incidence of postoperative infection.

While our study found fewer postoperative CSF leaks in the Tachosil cohort, it remains higher than other studies using the same material for sellar closure (Table 4). A possible explanation is a difference in technique. Hong et al. used Tachosil as part of a "sandwich technique" in 101 patients during EETS, and only two (1.9%) developed postoperative CSF rhinorrhea. In another study performed on 19 grade 3 intraoperative CSF leaks, postoperative CSF leakage following Tachosil repair utilizing the "sandwich technique" was 5.3%. Tamasauskas et al. performed a sellar closure using Tachosil and Surgicel (Ethicon, NJ, USA) in 29 patients who underwent EETS, and none had a postoperative CSF leak.

Numerous other techniques of sellar floor reconstruction have been described, and all have potential benefits and limitations. Classically, surgeons have used autologous materials such as abdominal fat, muscle, or free mucosal graft with or without support for the graft from nasal bone or cartilage to prevent postoperative CSF rhinorrhea. These methods are effective for this purpose, with a rate of postoperative CSF leaks ranging from 0 to 10%, similar to our study. Fat may also interfere with the interpretation of the sellar content on postoperative MRI. Inadequate packing may aggravate the arachnoid tearing and compress the optic chiasm. These limitations are partially

| Closure technique | Approach | Material | N patient exposed | Intraoperative CSF leak | PO CSF leak | LD | Surgery | Remark |
|-------------------|----------|----------|-------------------|-------------------------|-------------|----|---------|--------|
| TACHOSIL          | EETS (present study) | One layer Tachosil + Tissue | 65 | 12 | 7.7% (5/65) | 2 | 0 | Cost: Virus transmission + easily removed in revision repair + immunologically well tolerated + hemostasis + lower postoperative infection |
|                   | MTS ± endoscope13 | Sandwich technique | 101 | 18 | 1.9% (2/101) | 0 | 0 | |
|                   | MTS20          | Sandwich technique | 19 | 19 | 5.3% (1/19) | 0 | 0 | |
|                   | MTS – EETS21   | Surgicel + Tachosil | 29 | 29 | 0% (0/29) | 0 | 0 | |

Table 4. Summary of studies using Tachosil for sellar closure during transsphenoidal surgery. N number, PO postoperative, LD lumbar drainage, EETS endonasal endoscopic transphenoidal surgery, MTS microscopic transsphenoidal surgery.
addressed by using cadaveric materials (acellular dermis or cadaveric fascia lata)\(^7,11,12\). A postoperative CSF leak rate of 5.5 and 7.6% was demonstrated in two retrospective studies using AlloDerm (LifeCell Corporation, Woodlands, TX) for sellar floor reconstruction in transsphenoidal surgery (Table 2)\(^7,11\). However, no postoperative CSF leak was encountered in the study performed by Fiorindi et al. using a cadaveric fascia lata for sellar closure\(^12\). These grafts also have limitations and may not encourage healing as autologous grafts and may cause MRI interference\(^13,14\).

Vascularized flaps are currently thought to be the most effective technique for endoscopic endonasal reconstruction\(^15,16\). In a systematic review of 38 studies by Harvey et al., 609 patients with significant dural defects were identified\(^16\). From this cohort, 326 underwent free graft reconstruction while 283 underwent vascularized reconstruction, resulting in a significantly different postoperative CSF leak rate of 15.6% (51 of 326) and 6.7% (19 of 283), respectively\(^16\). In a series of 151 patients with intraoperative CSF leaks of whom 144 received Hadad-Bassagestaguy nasoseptal flaps, only 3.3% developed postoperative CSF leak (Table 2)\(^17\). Another retrospective study using NSF in thirty-one grade III CSF leaks demonstrated a persistent postoperative CSF leak rate of 6.4% (Table 2)\(^1\). Barger et al. have developed a minimal posterior NSF technique with a postoperative CSF leak rate of only 2.3% (Table 2)\(^10\). This type of vascularized flap does not seem to prolong the duration of surgery or generate postoperative nasal complications as much as larger flaps\(^10\). Due to the limitations of the techniques mentioned above, many authors have attempted to obviate autologous and cadaveric tissue grafts. Indeed, fibrin sealants have been used for sellar floor closure with comparable postoperative CSF leakage rates of between 0 and 12.5% and appear to be effective with an acceptable safety profile\(^13–17,20\). However, they have limitations, including the possibility of viral transmission and ethical concerns from patients, as these are derived from animals\(^13,17\). DuraSeal is entirely synthetic and is reabsorbed\(^17\). Thus, unlike fibrin sealants, the potential for viral transmission is eliminated\(^1\). Pereira et al. have demonstrated a postoperative CSF leakage rate of only 5.6% with the use of DuraSeal in 180 sellar closures during EETS (Table 2)\(^17\). Our study has shown a postoperative CSF leak rate of 18.2% using DuraSeal alone, with 11 patients requiring lumbar drainage and four repairs surgery. However, unlike our study where DuraSeal alone was used for packing, Pereira et al. utilized DuraSeal in combinations with fat, Spongostan (Ethicon, NJ, USA), and Floseal (Baxter Inc, IL, USA). Nevertheless, our results suggest a significantly higher rate of postoperative CSF leak when using DuraSeal alone.

Some authors have advocated a sellar reconstruction algorithm using a combination of methods, depending on the significance of the CSF leak\(^17\). For example, Zhou et al. have demonstrated that only 6 of the 492 (1.2%) cases using a graded repair method subsequently developed postoperative CSF leak (Table 5)\(^17\). Jalles et al. analyzing 240 cases, reported a postoperative CSF leak rate of 0.8%, despite 44% of cases presenting intraoperative CSF leak (Table 5)\(^22\). Similarly, Esposito et al., has a postoperative CSF leak rate of 2.5% utilizing a graded repair method (Table 5)\(^24\). In these studies, lumbar drainage was placed at the end of surgery if a high output intraoperative CSF leak was identified\(^21,22\). While lumbar drains reduce intracranial pressure and may hasten the healing of the sellar floor, they may also be associated with severe complications\(^6,17\). In our study the TachoSil cohort only required two lumbar drainages, compared to 11 in the DuraSeal cohort.

In a laboratory study, Chauvet et al. found the mean pressure at which a leak visually occurred with Bioglue (CryoLife, Inc, GA, USA), DuraSeal, TachoSil and Tissucol (Baxter Healthcare, IL, USA) was 16.78, 28.31, 27.09 and 10.03 mmHg, respectively, which suggest that DuraSeal and TachoSil may be superior for closure\(^25\). Two types of leaks were reported: those occurring between the sealant and the dura (Bioglue, DuraSeal and Tissucol) and those occurring through the sealant (TachoSil)\(^25\). These results could explain why ‘the sandwich technique,’ using two layers of TachoSil, seems superior to the single-layer technique, as it prevents the second time of the trans-graft leak.

Besides its retrospective design, the main limitation of this study is the sequential use of the two different techniques investigated (i.e. DuraSeal then TachoSil). One could expect that experience gained during the first part of the study (i.e. DuraSeal) may lead to bias in favor of the last technique used (i.e. TachoSil). However, this potential bias is limited by the extensive prior experience of the operators—although mainly microscope-assisted pituitary surgeries.

**Conclusion**

Fibrin-coated collagen fleece patching may be a valuable method to prevent CSF leaks during EETS for pituitary adenoma resection. This study reports fewer postoperative leaks in the TachoSil cohort compared to the DuraSeal cohort without reaching significance. This observation dovetails with previous surgical series and experimental data but powered studies to achieve higher levels of evidence are required to confirm these results.
| Closure technique | Approach | Material | N patient exposed | Intraoperative CSF leak | PO CSF leak | LD | Surgery | Remark |
|-------------------|----------|----------|------------------|------------------------|-------------|----|---------|--------|
| Free autologous graft | MTS⁸ | Muscle + septal cartilage | 23 | 23 | 0% (0/23) | 0 | 0 | | |
| | MTS – EETS⁹ | Fat + autologous bone | 29 | 29 | 10% (3/29) | 2 | 1 repair | + Totally compatible | |
| | EETS⁹ | Fat graft + artificial dura | 55 | 55 | 7.3% (4/55) | 4 | 2 repairs | + Free of charge | |
| | EETS – METS + endoscope¹⁰ | Fat graft + fibrin glue | 54 | 15 | 9.3% (5/54) | 22 | – | Additional discomfort | |
| | MSTS – EETS – hybrid¹¹ | Fat | 87 | 7 | 9.2% (8/87) | – | 2 repairs | – MRI interference | |
| | EETS¹² | Fat + autologous bone/cartilage + glue | 235 | – | 1.7% (4/235) | 4 | 1 repair + LD | | |
| | EETS¹² | Collagen dural graft + nasal cavity floor free mucosal graft + oxidized cellulose + polyethylene glue + Biore sorbable packing | 50 | 20 | 0 (0/50) | 0 | 0 | | |
| Cadaveric graft | EETS¹³ | Fat + cadaveric fascia lata + Fibrin glue | 16 | 16 | 0% (0/16) | 9 | 0 | + No separate incision | |
| | MSTS – EETS – hybrid¹¹ | Alloderm | 163 | 8 | 5.5% (9/163) | – | 2 repairs | – MRI interference | |
| | MTS – EETS⁴ | Alloderm + cartilage/bone autograft + fibrin glue | 13 | 5 | 7.6 (1/13) | 1 | 0 | – Not support healing as living tissue | |
| Pediculized flap | 3 EETS¹²,¹³ | Various pediculized flap (144 NSF) | 151 | 151 | 3.3% (5/151) | | | + Rapid/effective integration | |
| | | Fascia graft + fat graft + NSF | 31 | 31 | 6.4% (2/31) | 2 | 1 repair | – Healing period | |
| | | Posterior NSF (If leak: Alloderm + NSF # fat graft ± LD) | 43 | 21 | 2.3% (1/43) | 2 | 1 repair + LD | – Nasal complaints (crusting) | |
| Fibrin sealant | 5 EETS³–⁵,¹⁴,¹⁷ | Gelatin sponge | 28 | 28 | 3.6% (1/28) | 0 | 1 VPS | + Reabsorbed | |
| | | Collagen fleece | 29 | 29 | 6.9% (2/29) | 6 | 0 | | |
| | | – | 40 | 40 | 0% (0/40) | 0 | 0 | | |
| | | Collagen foil | 15 | 9 | 6.7% (1/15) | 0 | 1 repair | | |
| | | Different combinations: fat – spongostan – floseal | 16 | – | 12.5% (2/16) | – | – | | |
| Duraseal | EETS¹⁵ | Different combinations: fat – spongostan – floseal | 180 | – | 5.6% (10/180) | – | – | + Synthetic: no disease transmission | |
| Grade repair method | EETS¹⁶ | Stage I: Surgical + Gelfoam Stage II: fat + fascia + same as Stage I Stage III: same as Stage II + surgical glue ± LD | 240 | 107 | 0.8% | 1 | 1 | LD complications | |
| | | Grade 0: collagen sponge Grade 1: collagen sponge + titanium mesh buttress Grade 2: fat grafts + same as grade 1 Grade 3: same as Grade 2 ± LD | 668 | 380 | 2.5% (17/668) | 6 | 11 | LD complications | |

Table 5. Summary of various techniques for sellar closure during transsphenoidal surgery. N number, PO postoperative, LD lumbar drainage, MTS microscopic transsphenoidal surgery, EETS endonasal endoscopic transsphenoidal surgery, NSF nasoseptal flap, VPS ventriculoperitoneal shunt, + advantage, – disadvantages.
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Competing interests
The authors declare no competing interests.

Additional information
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