Endoscopic Endonasal Reconstruction of Skull Base: Repair Protocol

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Abstract

Background Endoscopic endonasal skull base reconstructions have been associated with postoperative cerebrospinal fluid (CSF) leaks.

Objective A repair protocol for endoscopic endonasal skull base reconstruction is presented with the objective of decreasing the overall leak rate.

Methods A total of 180 endoscopic endonasal skull base reconstructions were reviewed. Reconstructions were classified I to IV according to the reconstruction method, determined by severity of intraoperatively encountered CSF leaks for types I to III, and planned preoperatively for type IVs, which required nasoseptal flap.

Results A total of 11 patients (6%) had postoperative leaks: 0 in type I (0%), 2 in type II (5%), 7 in type III (18%), and 2 (4%) in type IV reconstruction. Type III leak rate was higher than all other reconstructions. Total 31 intraoperative and 16 postoperative lumbar drains were placed. More patients had lumbar drains placed postoperatively for type III and intraoperatively for type IV than all other groups. There were significant overall differences in postoperative CSF leaks and lumbar drain placement between the four reconstruction types. No patient with type III reconstruction and intraoperative lumbar drain had postoperative CSF leak.

Conclusions A repair protocol for endoscopic endonasal reconstructions determined by intraoperative CSF leak and preoperative planning minimizes unnecessary repair materials and additional morbidity. Our experience leads to a routine prophylactic lumbar drain placement in all type III leak and reconstructions. We also favor the type III reconstruction for minor intraoperative leaks, and a more generous use of type IV reconstructions in expectation of significant intraoperative CSF leak. The option of rescue flap technique in type III leaks should be strongly considered.

Keywords

- endoscopic endonasal
- nasoseptal flap
- pituitary adenoma
- transsphenoidal
- expanded endoscopic

Introduction

Cerebrospinal fluid (CSF) leaks pose a formidable obstacle to skull base repair, and endoscopic endonasal skull base reconstructions (EER) have historically been associated with high-postoperative leak rates.^{1–4} Although the advent of

vascularized nasoseptal flaps (NSFs) for EER have reduced these rates, not every EER requires a repair to this extent. The NSF itself is not without significant morbidity^{5–9} nor is it often necessary in EERs with no or low flow leaks. As endoscopic techniques become increasingly popular,

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development of more systematic methods for repairing skull base defects should maximize repair efficacy and minimize morbidity. Presently, there is a limited and diverse consensus to guide repair.^{10–12}

We hereby describe our experience using a skull base reconstruction repair protocol based on a simple algorithm according to the severity of CSF leaks encountered intraoperatively, or for selected cases planned preoperatively.

Methods

A retrospective review of prospectively recorded data for 180 consecutive EERs from May 2009 to June 2013 at Geisinger medical center was conducted. Operative and clinical notes were reviewed for demographic data, description of surgical pathology, presence of CSF leak (intraoperatively and postoperatively), and requirement of lumbar CSF diversion (placed intraoperatively for prophylaxis, or postoperatively for treatment). Endoscopic endonasal reconstructions were graded I to IV based on actual reconstruction performed (►Table 1). The choice of reconstruction types I to III was determined intraoperatively based on severity of any CSF leaks. Type IV repairs included a harvested NSF and therefore were planned preoperatively. These were utilized forexpanded endoscopic exposures (nonpituitary pathologies) and selected based on factors such as lesion size (tumors > 3 cm), anatomical location (intradural, intra-arachnoidal lesions), an increased likelihood of a high-flow CSF leak or major potential skull base defect occurring, and recurrent pituitary tumor cases if the nasal septum was not damaged by previous surgery. All patients underwent endoscopic endonasal surgery performed by the lead author (A. R. D.). Descriptions of each repair grade are outlined below and summarized in ►Table 2.

Type I reconstructions were utilized where no intraoperative CSF leaks was observed. These were used for standard pituitary adenomas and Rathke cleft cysts. The sellar floor was reconstructed using one layer of Surgicel (Ethicon, Johnson and Johnson Co., Somerville, New Jersey, United

Table 2 Cerebrospinal fluid leak reconstruction protocol

Repair grade	Reconstruction protocol
I	Surgicel, Evicel, and Gelfoam
II	Surgicel and Evicel, Alloderm covered by a thin layer of Evicel, multilayers of Gelfoam and Evicel
III	Avitene wrapped in Surgicel over leak site, intrasellar fat graft followed by Alloderm buttress additional peripheral fat grafts, Evicel and Gelfoam, and lumbar drain placement
IV	Duragen, fat graft, Alloderm, Evicel, and posterior nasoseptal flap. Lumbar drain for high flow cerebrospinal fluid exposures

Note: Surgicel (Ethicon, Johnson and Johnson Co., Somerville, New Jersey, United States); Evicel (Ethicon, Johnson and Johnson Co., Somerville, New Jersey, United States); Gelfoam (Pharmacia and Upjohn Co., Kalamazoo, Michigan, United States); Avitene (Bard Inc., Warwick, Rhode Island, United States); Duragen (Integra LifeSciences Corp., Plainsboro, New Jersey, United States).

States) followed by multiple layers of Evicel (or fibrin glue) (Ethicon), and Gelfoam (Pharmacia and Upjohn Co., Kalamazoo, Michigan, United States).

Type II reconstructions were used when a minute CSF leak was encountered during surgery that either spontaneously subsided, or was persistent but very minor. There were also no obvious openings in the sellar diaphragm. Surgicel and Evicel were first layered to cover the intrasellar component. Alloderm (LifeCell Corp., Woodlands, Texas, United States) was then added and positioned flush to the sellar floor followed by a thin layer of Evicel and multilayers of Gelfoam and Evicel.

Type III repairs were used if a persistent, obvious intraoperative CSF leak was observed, or if there was an unexpected major opening of the sellar diaphragm. These were repaired with a combination of Avitene (Bard Inc., Warwick, Rhode Island, United States) wrapped in Surgicel to cover the specific site of the leak, followed by the addition of autologous fat graft placed in the intrasellar compartment. Alloderm was then used to cover the sellar floor, with further fat grafts placed to buttress the periphery. Evicel and Gelfoam were then applied.

Type IV reconstructions included a posterior NSF, harvested at the beginning of the procedure. An appropriate size DuraGen (Integra LifeSciences Corp., Plainsboro, New Jersey, United States) was used as inlay. Fat graft and Alloderm were then added, and the NSF was placed over the sella, covering the Alloderm and anterior skull base with the mucosal side facing out. Evicel and Gelfoam were then layered over the NSF to buttress it in place. A 14F Foley catheter was used to keep the reconstruction in place for 24 hours. The technique of harvesting NSF is described elsewhere.¹² As previously explained, the NSF was utilized for planned expanded exposures, selective pathology as described above, or if the senior author ARD felt that there was a likelihood of high-flow CSF leak occurring, especially with large or recurrent adenomas or intra-arachnoidal pathology.

Table 1 Endoscopic endonasal skull base reconstruction algorithm

Description of leak	Repair type
No intraoperative cerebrospinal fluid leak observed	I
Minor leak. No significant diaphragmatic openings	II
Moderate/severe persistent leak. Unexpected opening of the arachnoid of diaphragma sellae	III
Large skull base exposure or high-flow leak predicted to occur as part of planned expanded approach, tumor larger than 3 cm, or recurrent pituitary adenomas	IV

Our utilization of lumbar drain (LD) was primarily case-based. Instances in which LD was utilized intraoperatively (in the operating room before starting the surgery) included expected opening of the third ventricle or a major cistern in expanded exposures. Instances in which LD was utilized intraoperatively but at the end of the procedure were persistent obvious CSF weeping after any type of reconstruction (II, III, or IV), inadequacy of the harvested NSF (size, shape, or position), unexpected opening of a major cistern, or concerning patient-specific factors such as obstructive sleep apnea. For type III reconstruction, the use of LD became systematic and routine toward the end of the study period.

LDs were left in place between 48 and 72 hours at a rate of 5 mL/h.

No postoperative nasal packing was employed in any of the reconstructions.

Statistical Analysis

Data for 180 patients was included in the analysis. The rates of postoperative CSF leaks and LD placement (intraoperative vs. postoperative placement) for the four types of sellar reconstructions were calculated. Overall and pairwise differences between the reconstruction types were tested using chi-square or Fisher exact tests. Since the tumor size and age data was not normally distributed, median size was reported for each reconstruction type and tests for differences were conducted using a nonparametric Wilcoxon rank sum test. Each reconstruction type was then compared with the others in a pairwise manner for the above two main outcomes of interest. Tumor size, age, and gender were also compared for the four types of reconstruction. The *p* values for all pairwise tests were not adjusted for multiplicity.

Results

Data from 180 patients undergoing the four types of sellar reconstructions were analyzed. There were 83 males and 97 females included. The average age was 50.5 years and the median age was 53 years (range, 7–88 years). Overall, there were 49 type I, 42 type II, 39 type III, and 50 type IV reconstructions. Type of pathology included 128 pituitary adenomas (92 nonsecreting and 36 hormonally active), 10 Rathke cleft cysts, 13 craniopharyngiomas, 12 meningiomas, 6 chordomas, 2 cases of lymphocytic hypophysitis, 2 cases of basilar invagination, 1 schwannoma, 1 clival plasmacytoma, 1 chondrosarcoma, 1 germinoma, 1 lymphoma, 1 metastatic prostate cancer, and 1 sphenoid encephalocele (with no evidence of high-intracranial pressure) repair. Mean and median tumor sizes were 23.3 and 22 mm, respectively, as measured in the coronal plane on magnetic resonance imaging. Since the data was skewed to the right for these two variables, the median values were used as a representation of central tendency. There were no significant differences for age or gender between the four types of reconstructions. The smaller number of cases per each nonpituitary tumor group prevented a robust statistical analysis of leak rate per pathology. Furthermore, for all nonpituitary tumors and expanded approached, the type IV reconstruction was systematically performed.

Cerebrospinal Fluid Leaks

A total of 11 patients (6%) were considered to have postoperative CSF leaks. There were zero (0/49, 0%), two (2/42, 5%), seven (7/39, 18%), and two (2/50, 4%) postoperative CSF leaks for types I to IV, respectively (►Table 3). The postoperative CSF leak rate for type III reconstructions (18%) was greater than for all of the other reconstructions. There was a significant overall difference in postoperative CSF leaks between the four reconstruction types ($p < 0.001$). Pairwise comparison between groups revealed significant differences in postoperative CSF leak rates between groups I and II ($p = 0.043$), between groups I and III ($p < 0.001$), and between reconstruction types III and IV ($p = 0.001$).

Lumbar Drain Cerebrospinal Fluid Diversion

Overall, 47 patients (47/177, 26%) required LD placement in the perioperative period. In total, there were 0 (0/49, 0%), 4 (4/42, 9%), 18 (18/39, 46%), and 25 (25/50, 50%) LDs placed for types I to IV, respectively. A total of 31 intraoperative and 16 postoperative LDs were placed (►Table 4). For type II repairs, three LDs were placed postoperatively. For type III repairs, 10 LDs were placed intraoperatively and 8 LDs were placed

Table 3 The incidence of CSF leak in types I to IV reconstruction

Type of reconstruction	I	II	III	IV
Total number of patients	49	42	39	50
CSF leak	0 (0%)	2 (5%)	7 (18%)	2 (4%)
Significance (<i>p</i> value)		< 0.043	< 0.001 ^a	

Abbreviation: CSF, cerebrospinal fluid.

^aPairwise comparison between groups revealed significant differences in postoperative CSF leak rates between groups I and II ($p = 0.043$), between groups I and III ($p < 0.001$), and between reconstruction types III and IV ($p = 0.001$).

Table 4 Lumbar drain placement according to reconstruction type

	Type I N = 49	Type II N = 42	Type III N = 39	Type IV N = 50
Total LD				
	0 (0.0%)	4 (9%)	18 (46%)	25 (50%)
Intraoperative				
	0 (0.0%)	1 (25%)	10 (55%)	20 (80%)
Postoperative				
	0 (0.0%)	3 (75%) ^a	8 (45%) ^a	5 (20%) ^{ab}

Abbreviation: CSF, cerebrospinal fluid; LD, lumbar drain.

^aOne postoperative lumbar drain in the type II group, one in the type III, and three in the type IV were placed for a suspicion of CSF leak which was confirmed to be nasal drainage and the drain removed within 48 hours.

^bOne lumbar drain in the type IV group was placed on day 10 for a noncompliant patient with vigorous nose blowing.

postoperatively. Of the type IV repairs, most were placed intraoperatively (20/25, 80%).

There were significant differences between intraoperative placement for types II and IV ($p = 0.033$), and for types III and IV ($p = 0.021$). There was also a significant difference in postoperative requirement of LD between reconstruction types III and IV ($p = 0.014$). More patients had LDs placed postoperatively for type III and intraoperatively for type IV than all other groups combined.

Patients received LD if there was any suspicious nasal drainage. A significant CSF leak or pneumocephalus were not considered appropriate indications for LD placement without repeat surgical repair. However, the CSF leaks in this series were deemed mild to moderate and therefore LD strategy was decided as the first step to address the repair failure. In five cases as detailed below, CSF testing (via $\beta 2$ transferrin) was later found to be negative and suspected leaks were determined to be due to postoperative nasal discharge but still considered to be a CSF leak at the time of occurrence and treated as such. The LD in those cases was thus removed earlier. In the type II repair group, despite two postoperative CSF leaks occurring, three LDs were placed postoperatively. In the type III repairs, there were seven CSF leaks however eight postoperative LDs placed. For type IV repairs, two patients developed a CSF leak, however there were five LDs placed.

All postoperative CSF leaks resolved after placement of LD without requiring a repeat surgical repair.

One important finding was the absence of postoperative CSF leak in the 10 patients with reconstruction type III in whom a LD was placed intraoperatively.

Two patients with type III reconstruction developed delayed CSF leak and meningitis (2/180, 1%). They were treated with intravenous antibiotics. The infection was unrelated to LD placement as it was diagnosed before LD placement. There were no other incidences of infection. There were no significant or symptomatic pneumocephalus in this series.

Tumor Size

The overall median tumor size was 22 mm. Pairwise comparisons of tumor size were completed for individual reconstruction types. Type IV patients overall had significantly larger tumors than those in other reconstruction groups. There were significant differences in median tumor size between reconstruction types I and III (14 vs. 21.5 mm, $p < .001$), between types I and IV (14 vs. 31 mm, $p < 0.001$), between groups II and IV (19.5 vs. 31 mm, $p < 0.001$), and between groups III and IV (21.5 vs. 31 mm, $p = 0.007$).

During the course of this study, we did not use the rescue flap strategy for type III reconstructions in cases with higher flow leak. Out of the 49 cases in group III reconstruction, seven had repeat surgery. Reviewing the operative report revealed that in four patients in this group with postoperative leak, the septum was perforated or damaged not allowing a NSF. As we had not adopted the rescue flap strategy yet, we did not use a NSF for the other three cases.

Discussion

According to a national survey, the average CSF leak rate for standard transsphenoidal surgery (TSS) was found to be 3.9%,¹³ with ranges from 0 to 30% for expanded TSS.^{6,14–21} Endoscopic endonasal reconstructions have comparable values, with over 90% success rates for smaller dural defects,^{1,22} and leak rates ranging from 5 to 35% for expanded approaches.^{4,6,13,21,23–25} The most common implicating factors described include extent of dural resection, type of reconstruction, and CSF flow dynamics. In a 2012 meta-analysis by Harvey et al,¹ multilayered, pedicled flap reconstructions for larger dural defects were shown to have an overall leak rate of 6.7%, comparing favorably to other expanded approaches. Esposito et al,¹⁰ proposed a graded protocol for repair of intraoperative CSF leaks after microscopic TSS, utilizing the degree of intraoperative CSF leak observed to guide their repair algorithm. They proposed utilizing an “exit strategy” of avoiding postoperative CSF leaks and other complications via a minimalist closure when appropriate, and a maximal, multiple-measures repair when warranted.

There are a variety of repair methods cited in the literature with acceptable closure rates for EER.^{26,27} In our series, relatively simple closure methods were used, with results comparable to acceptable CSF rates found in the literature. The initial higher rate of CSF leak in type III repair have prompted us to revise our protocol by adding routine LD placements or more generous use of the type IV reconstruction when deemed appropriate. With this revision, the leak rate in the type III significantly decreased as no patient with intraoperative LD placement had postoperative CSF leak.

It has been shown that there is relatively minimal difference in outcome for the majority of smaller skull base defects encountered after endonasal skull base surgery or trauma, regardless of specific method or material when multilayered free graft closures are utilized.^{1,6,23,24} It seems that for repairs without an obvious intraoperative leak and for the smaller CSF leaks, there are multiple means to construct adequate repairs. Fat grafts and free mucosal flaps or fascia lata are often utilized, however donor-site minor/moderate morbidity and reconstruction failure remain a challenge in these cases. In our series, we demonstrated that for reconstructions without a CSF leak, as in type I group, and reconstructions with smaller, weeping CSF leaks, such as for type II repairs, it is unnecessary to utilize autologous grafts. There were no patients in type I repair group that required LD placement or developed a postoperative CSF leak. For patients with small, weeping intraoperative CSF leaks (type II reconstruction), the addition of a manufactured dural onlay graft was sufficient. Alloderm, an acellular dermal allograft, was used with the types II, III, and IV repairs in our series, and has been shown to be an effective adjunct to closures of large dural defects.^{28–30} Germani et al used it as the sole graft material in 55% of endoscopic reconstructions of large anterior skull base defects (> 2 cm), with 97% graft success in the Alloderm group, and only minor complications reported.²⁸ Additionally, they found no statistical differences

in their complication rates based on the type of repair or defect size, which was not the case in our series, in which our type III repair group was associated with significantly increased rates of CSF leak despite utilizing Alloderm in conjunction with autologous fat graft. Given the results from our series, we would not recommend the use of acellular dermal allograft as a sole graft material and support for EER in the presence of a persistent, moderate-to-high flow, intraoperative CSF leak.

Nasoseptal Flap

A variety of multilayered reconstruction techniques for skull base defects have been described in the literature, however they are often insufficient for higher flow CSF leaks.^{5,6,15,28–34} A solution to this problem came with the advent of the NSF.^{5,12,14,15,31} While the NSF has been shown to be a reliable and effective EER technique, comparable CSF leak rates have been obtained with a more minimalistic approach, especially for minor leaks.^{5–9} Furthermore, NSF harvesting is not without significant morbidity, with nasal crusting, loss of smell, and nasal discharge cited as all relatively common problems encountered.^{1,35} An additional consideration is that the NSF is ideally harvested before the posterior septectomy, as the exposure might destroy the vascularized pedicle, so the decision to utilize this repair method might not be suitable to be made intraoperatively.

In a meta-analysis of 38 studies regarding endoscopic reconstruction of large dural defects by Harvey et al, the authors found that larger skull base defects (those > 3cm), were associated with higher CSF leak rates (overall 11.5%), but that those repaired with vascularized reconstructions were associated with significantly lower leak rates (6.7% overall vs. 15.6% for free graft reconstructions).¹ Our study's findings are similar. Despite the fact that our type IV repairs were for significantly larger lesions than that of our type III repairs, our overall rate of CSF leaks for the type IV group was significantly lower. In some instances, utilization of a type III repair was necessitated due to inability to harvest a NSF for reoperation of recurrent lesions, which may account for this group's higher leak rate in these circumstances.

In a retrospective review of 32 EERs for large dural defects comparing NSF repairs versus single-layer reconstructions with fascia lata or fat graft, Horiguchi et al found a significantly higher incidence of postoperative CSF leaks in the nonflap group as compared with the NSF group (27.3 and 9.5%, respectively).⁶ Their repair failure rates were higher than our type III and IV reconstructions (18 and 4%, respectively). Despite the statistical significance achieved in their study, the small sample size was a major limiting factor. Furthermore, while the authors provided data supporting the superiority of NSF to single-layer reconstructions, they did not compare the merit of NSF against that of multilayered free graft closures, as did our study.

Although Esposito et al proposed a graded repair protocol for transsphenoidal skull base repair, their specific repair strategy and technique (microscopic vs. endoscopic) was somewhat dissimilar from our study.¹⁰ They utilized collagen sponge followed by titanium mesh buttress for small weeping CSF leaks,

with the addition of abdominal fat graft for moderate leaks with definite diaphragmatic defect, and for their larger defects and expanded approaches, the addition of lumbar CSF diversion for 48 hours. As with our repair protocol, their grade III repair (for large diaphragmatic and/or dural defects for extended approaches) was associated with the highest failure rate, which was greater than all other repair types combined. Additionally, their repairs were determined only according to presence and degree of intraoperative CSF leak, a “reactive” reconstruction algorithm without the “preemptive” element of our type IV repairs. Nevertheless, although they did not utilize NSFs for their expanded approaches, their CSF leak rates remain well within acceptable range for expanded transsphenoidal approaches.^{6,12,14–20}

More recently, Patel et al described the Cornell closure protocol, which also utilized a graded approach applying different repair methods to various pathological entities and yielded excellent results. Of 209 patients, 125 had intraoperative CSF leaks, 35 of which were high-flow.³⁶ The authors reported a 0% postoperative CSF leak rate with their algorithm for all repairs, which included harvesting of NSF and fascia lata grafts for specific cases.

Lumbar Drain Insertion

The diversion of CSF for prevention and treatment of spinal fluid leaks has been well documented in the literature with mostly successful results, although not without significant morbidity. Complications commonly seen with LD include infection, spinal headache, nerve root irritation, and pneumocephalus from over drainage. Although several LDs placed for suspected leaks were later determined (via β 2 transferrin) to be negative, this aggressive approach did not result in untoward consequences and LDs were removed within 24 to 48 hours. It seems that our protocol still has a more selective indication for LD utilization, and therefore obviates the need for potential unnecessary placement. There were no complications secondary to LD in our series.

The overall intraoperative LD placement was significantly higher in type IV reconstructions, indicating type IV LDs were placed more for prophylaxis than treatment. Type IV reconstructions were also associated with the lowest postoperative CSF leak among reconstruction types II to IV. The use of a vascularized flap along with the preemptive strategy of intraoperative LD placement is likely responsible for the lower rate of postoperative CSF leaks in this group. As we became more systematic with intraoperative utilization of LD for our type III closures, the incidence of postoperative CSF leak has significantly declined. The fact that no patient in the type III reconstruction group with intraoperative placement of LD had CSF leak is indicative of this. In a retrospective review of 32 patients with large dural defects, Horiguchi et al found that only 4.8% of patients in their NSF group required lumbar CSF diversion compared with 81.8% of patients in the single-layered nonflap reconstruction group.⁶ Additionally, the authors note that the only patients with NSF closures that they felt consistently required LD were craniopharyngioma patients, due to the direct connection between the third ventricle and suprasellar cistern after removal of the tumor.

Esposito et al also routinely placed intraoperative LD in for all grade III repairs after 2003, when before that their use was inconsistent.¹⁰

Reconstruction techniques are evolving. We have currently adopted a relatively novel technique by saving the pedicle of the nasospetal flap during every endonasal endoscopic exposure for a potential use later, if needed as previously described by Rivera-Serrano et al.³⁷ The implication of this rescue flap will be helpful in some cases where there is an unexpected major CSF leak and the desire to use a flap at the end of the procedure. We are currently evaluating our experience with this new modification.

Conclusion

A repair protocol which stratifies patients based on anticipated and intraoperative CSF leaks has the potential to minimize cost of unnecessary repair materials, graft harvesting morbidity, and lumbar CSF diversion for patients with smaller or no CSF leaks, and maximize postoperative success rates.

The addition of routine LD placement in our type III reconstruction seems to lower the postoperative CSF leak. Based on our experience, we advocate for a more generous use of type IV reconstructions when one can anticipate a greater risk of higher flow CSF leak occurrence. We also advocate a more robust reconstruction for type II leak by performing a type III reconstruction as the 5% postoperative leak rate in type II is still relatively high. Alternatively, the use of rescue flap at the end of the procedure for unexpected significant CSF leak is strongly recommended considering the high rate of leak rate in type III reconstruction. It is obvious that experience plays a role in this decision-making process, as more type IV reconstructions, and intraoperative placement of LD for type III were utilized toward the end of the present series, with greater success and significantly lower postoperative CSF leak rates.

Declaration of Interest

None.

Authors' Contribution

All the five authors contributed in the concept, study design, data collection/interpretations, and A. D. and J. K. approved the final format.

References

- Harvey RJ, Parmar P, Sacks R, Zanation AM. Endoscopic skull base reconstruction of large dural defects: a systematic review of published evidence. *Laryngoscope* 2012;122(2):452–459
- Kassam A, Carrau RL, Snyderman CH, Gardner P, Mintz A. Evolution of reconstructive techniques following endoscopic expanded endonasal approaches. *Neurosurg Focus* 2005;19(1):E8
- Locatelli D, Rampa F, Acchiardi I, Bignami M, De Bernardi F, Castelnovo P. Endoscopic endonasal approaches for repair of cerebrospinal fluid leaks: nine-year experience. *Neurosurgery* 2006;58(4, Suppl 2):ONS-246–ONS-256, ONS-256–ONS-257
- Dehdashti AR, Ganna A, Witterick I, Gentili F. Expanded endoscopic endonasal approach for anterior cranial base and suprasellar lesions: indications and limitations. *Neurosurgery* 2009;64(4):677–687, discussion 687–689
- Harvey RJ, Sheahan PO, Schlosser RJ. Inferior turbinate pedicle flap for endoscopic skull base defect repair. *Am J Rhinol Allergy* 2009;23(5):522–526
- Horiguchi K, Murai H, Hasegawa Y, Hanazawa T, Yamakami I, Saeki N. Endoscopic endonasal skull base reconstruction using a nasal septal flap: surgical results and comparison with previous reconstructions. *Neurosurg Rev* 2010;33(2):235–241, discussion 241
- El-Sayed IH, Roediger FC, Goldberg AN, Parsa AT, McDermott MW. Endoscopic reconstruction of skull base defects with the nasal septal flap. *Skull Base* 2008;18(6):385–394
- Fortes FS, Carrau RL, Snyderman CH, et al. The posterior pedicle inferior turbinate flap: a new vascularized flap for skull base reconstruction. *Laryngoscope* 2007;117(8):1329–1332
- Zanation AM, Carrau RL, Snyderman CH, et al. Nasoseptal flap reconstruction of high flow intraoperative cerebral spinal fluid leaks during endoscopic skull base surgery. *Am J Rhinol Allergy* 2009;23(5):518–521
- Esposito F, Dusick JR, Fatemi N, Kelly DF. Graded repair of cranial base defects and cerebrospinal fluid leaks in transsphenoidal surgery. *Neurosurgery* 2007;60(4, Suppl 2):295–303, discussion 303–304
- Georgantopoulou A, Hodgkinson PD, Gerber CJ. Cranial-base surgery: a reconstructive algorithm. *Br J Plast Surg* 2003;56(1):10–13
- Hadad G, Bassagasteguy L, Carrau RL, et al. A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap. *Laryngoscope* 2006;116(10):1882–1886
- Ciric I, Ragin A, Baumgartner C, Pierce D. Complications of transsphenoidal surgery: results of a national survey, review of the literature, and personal experience. *Neurosurgery* 1997;40(2):225–236, discussion 236–237
- Harvey RJ, Nogueira JF, Schlosser RJ, Patel SJ, Vellutini E, Stamm AC. Closure of large skull base defects after endoscopic transnasal craniotomy. *Clinical article. J Neurosurg* 2009;111(2):371–379
- Kassam AB, Thomas A, Carrau RL, et al. Endoscopic reconstruction of the cranial base using a pedicled nasoseptal flap. *Neurosurgery* 2008;63(1, Suppl 1):ONS44–ONS52, discussion ONS52–ONS53
- Cook SW, Smith Z, Kelly DF. Endonasal transsphenoidal removal of tuberculum sellae meningiomas: technical note. *Neurosurgery* 2004;55(1):239–244, discussion 244–246
- Couldwell WT, Weiss MH, Rabb C, Liu JK, Apfelbaum RI, Fukushima T. Variations on the standard transsphenoidal approach to the sellar region, with emphasis on the extended approaches and parasellar approaches: surgical experience in 105 cases. *Neurosurgery* 2004;55(3):539–547, discussion 547–550
- Kato T, Sawamura Y, Abe H, Nagashima M. Transsphenoidal-tuberculum sellae approach for supradiaphragmatic tumours: technical note. *Acta Neurochir (Wien)* 1998;140(7):715–718, discussion 719
- Kouri JG, Chen MY, Watson JC, Oldfield EH. Resection of suprasellar tumors by using a modified transsphenoidal approach. Report of four cases. *J Neurosurg* 2000;92(6):1028–1035
- Laws ER, Kanter AS, Jane JA Jr, Dumont AS. Extended transsphenoidal approach. *J Neurosurg* 2005;102(5):825–827, discussion 827–828
- Dehdashti AR, Karabatsou K, Ganna A, Witterick I, Gentili F. Expanded endoscopic endonasal approach for treatment of clival chordomas: early results in 12 patients. *Neurosurgery* 2008;63(2):299–307, discussion 307–309

- 22 Hegazy HM, Carrau RL, Snyderman CH, Kassam A, Zweig J. Transnasal endoscopic repair of cerebrospinal fluid rhinorrhea: a meta-analysis. *Laryngoscope* 2000;110(7):1166–1172
- 23 Cappabianca P, Cavallo LM, Esposito F, Valente V, De Divitiis E. Sellar repair in endoscopic endonasal transsphenoidal surgery: results of 170 cases. *Neurosurgery* 2002;51(6):1365–1371, discussion 1371–1372
- 24 Cavallo LM, Messina A, Esposito F, et al. Skull base reconstruction in the extended endoscopic transsphenoidal approach for suprasellar lesions. *J Neurosurg* 2007;107(4):713–720
- 25 Dehdashti AR, Ganna A, Karabatsou K, Gentili F. Pure endoscopic endonasal approach for pituitary adenomas: early surgical results in 200 patients and comparison with previous microsurgical series. *Neurosurgery* 2008;62(5):1006–1015, discussion 1015–1017
- 26 Briggs RJ, Wormald PJ. Endoscopic transnasal intradural repair of anterior skull base cerebrospinal fluid fistulae. *J Clin Neurosci* 2004;11(6):597–599
- 27 Harvey RJ, Smith JE, Wise SK, Patel SJ, Frankel BM, Schlosser RJ. Intracranial complications before and after endoscopic skull base reconstruction. *Am J Rhinol* 2008;22(5):516–521
- 28 Germani RM, Vivero R, Herzallah IR, Casiano RR. Endoscopic reconstruction of large anterior skull base defects using acellular dermal allograft. *Am J Rhinol* 2007;21(5):615–618
- 29 Leong JL, Citardi MJ, Batra PS. Reconstruction of skull base defects after minimally invasive endoscopic resection of anterior skull base neoplasms. *Am J Rhinol* 2006;20(5):476–482
- 30 Lorenz RR, Dean RL, Hurley DB, Chuang J, Citardi MJ. Endoscopic reconstruction of anterior and middle cranial fossa defects using acellular dermal allograft. *Laryngoscope* 2003;113(3):496–501
- 31 Gagliardi F, Boari N, Mortini P. Reconstruction techniques in skull base surgery. *J Craniofac Surg* 2011;22(3):1015–1020
- 32 Zanation AM, Snyderman CH, Carrau RL, Kassam AB, Gardner PA, Prevedello DM. Minimally invasive endoscopic pericranial flap: a new method for endonasal skull base reconstruction. *Laryngoscope* 2009;119(1):13–18
- 33 Cappabianca P, Cavallo LM, Mariniello G, de Divitiis O, Romero AD, de Divitiis E. Easy sellar reconstruction in endoscopic endonasal transsphenoidal surgery with polyester-silicone dural substitute and fibrin glue: technical note. *Neurosurgery* 2001;49(2):473–475, discussion 475–476
- 34 El-Banhawy OA, Halaka AN, Altuwaijri MA, Ayad H, El-Sharnoby MM. Long-term outcome of endonasal endoscopic skull base reconstruction with nasal turbinate graft. *Skull Base* 2008;18(5):297–308
- 35 de Almeida JR, Snyderman CH, Gardner PA, Carrau RL, Vescan AD. Nasal morbidity following endoscopic skull base surgery: a prospective cohort study. *Head Neck* 2011;33(4):547–551
- 36 Patel KS, Komotar RJ, Szentirmai O, et al. Case-specific protocol to reduce cerebrospinal fluid leakage after endonasal endoscopic surgery. *J Neurosurg* 2013;119(3):661–668
- 37 Rivera-Serrano CM, Snyderman CH, Gardner P, et al. Nasoseptal “rescue” flap: a novel modification of the nasoseptal flap technique for pituitary surgery. *Laryngoscope* 2011;121(5):990–993