Endoscopic endonasal transsphenoidal surgery: implementation of an operative and perioperative checklist

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Endoscopic endonasal surgery relies heavily on specialized operative instrumentation and optimization of endocrinological and other critical adjunctive intraoperative factors. Several studies and worldwide initiatives have previously established that intraoperative and perioperative surgical checklists can minimize the incidence of and prevent adverse events. The aim of this article was to outline some of the most common considerations in the perioperative and intraoperative preparation for endoscopic endonasal transsphenoidal surgery. The authors implemented and prospectively evaluated a customized checklist at their institution in 25 endoscopic endonasal operations for a variety of sellar and skull base pathological entities. Although no major errors were detected, near misses pertaining primarily to missing components of surgical equipment or instruments were identified in 9 cases (36%). The considerations in the checklist provided in this article can serve as a basic template for further customization by centers performing endoscopic endonasal surgery, where their application may reduce the incidence of adverse or preventable errors associated with surgical treatment of sellar and skull base lesions.
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KEY WORDS • endoscopic endonasal transsphenoidal surgery • skull base •
endoscopy • pituitary neoplasms • checklist

SEVERAL studies and worldwide initiatives have previously established that intraoperative and perioperative surgical checklists can minimize the incidence of and prevent adverse events.^{5,9,15,16} Checklists for surgical procedures have been used on an international basis, and major reductions in morbidity and complication rates have been achieved.^{6,12} Endoscopic endonasal surgery is highly dependent on the technology and instrumentation that are integral to successful completion of the operation; the unavailability or dysfunction of any of these components may prevent the operation from being completed.⁴ Although surgical practices in endonasal endoscopic surgery may vary greatly from one institution to another, we aimed to develop and pilot a working model for an intraoperative and perioperative checklist for the surgical treatment of pituitary tumors and other parasellar lesions. As endoscopic transsphenoidal surgery becomes more commonplace, and with its increasing complexity with respect to imaging, instrumentation, and endocri-

nological testing, it will probably become increasingly important to standardize this procedure by implementing an intraoperative checklist. The aims of this article were to outline the necessary considerations in the perioperative and intraoperative period prior to performing an endoscopic endonasal approach to the sellar region and to describe our early experience with implementation of this surgical checklist.

Methods

A 3-part surgical checklist was devised, consisting of preoperative, intraoperative, and immediate postoperative sections. Data points for each section (summarized in Tables 1 and 2) were entered into a Web-based questionnaire completed prior to and at the conclusion of endoscopic endonasal skull base cases between August 2013 and June 2014. The online questionnaire was stored on a REDCAP database with password protection. All cases were treated by the same neurosurgical attending physician; an otolaryngologist was present for the extended approaches and for those requiring pedicled nasoseptal flap reconstruction.¹⁰ An extended timeout was conducted as part of the routine institutional surgical timeout. In addition, a closeout portion was filled out at the end of each operation. All missing data, near misses, and perioperative errors were recorded and analyzed.

Abbreviations used in this paper: ACTH = adrenocorticotrophic hormone; BMP = basic metabolic panel; CBC = complete blood count; CD = Cushing's disease; DDAVP = desmopressin; DI = diabetes insipidus; FSH = follicle-stimulating hormone; GH = growth hormone; IGF-I = insulin-like growth factor-I; LH = luteinizing hormone; PRL = prolactin; PT = prothrombin time; PTT = partial thromboplastin time; TSH = thyroid-stimulating hormone; T4 = thyroxine.

The checklist is described in detail below to discuss the rationale behind each data point for each of the 3 sections (preoperative, intraoperative, and immediate postoperative).

Preoperative Checklist Considerations (Table 1)

History and Physical Examination. Prior to any consideration for surgical intervention for pituitary adenomas or other sellar lesions, a focused patient history and detailed physical examination is required. In many cases, close collaboration with an endocrine specialist has already been established. Detailed questions should always be asked to screen for Cushing's disease (CD), acromegaly, fatigue, amenorrhea/galactorrhea, diminished libido, headache, visual loss, and other common symptoms and conditions associated with pituitary lesions. The preoperative workup should also include ophthalmology, otolaryngology, and endocrinology consultations as needed. Any patients harboring lesions in proximity to the optic apparatus should undergo formal visual testing, including visual field examination, by a neuroophthalmologist.

Laboratory Tests. Once a thorough history and physical examination is completed, a routine preoperative laboratory panel that includes complete blood count (CBC), basic metabolic panel (BMP), prothrombin time (PT), partial thromboplastin time (PTT), and a type and screen should be obtained. In addition, an endocrine panel including prolactin (PRL), fasting morning cortisol, adrenocorticotrophic hormone (ACTH), thyroid-stimulating hormone (TSH), free thyroxine (T4), growth hormone (GH), insulin-like growth factor-I (IGF-I), luteinizing hormone (LH), follicle-stimulating hormone (FSH) (in women), and free testosterone level (in men) should be part of the preoperative workup to identify any underlying hormonal

abnormality. One major consideration is to always ensure that a PRL level has been checked to avoid surgically treating a tumor that may be treatable with medications. A serum PRL level $> 200 \mu\text{g/L}$ is typically diagnostic of a prolactinoma—these can be treated medically and will need to be identified prior to any surgical decision making. A serum PRL $\leq 200 \mu\text{g/L}$ in a patient with a macroadenoma points to pituitary stalk effect (decreased delivery of dopamine) rather than tumor secretion of PRL. Furthermore, one must always consider the potential for a phenomenon known as the hook effect, which may occur in macroprolactinomas with extremely high levels of circulating PRL that may overwhelm the immunoassay and result in an artificially low or even normal PRL level. Dilution of serum samples must be specifically requested if suspicion of the hook effect is high enough.^{8,13,14}

Of the major anterior pituitary hormonal axes, the two that typically require the most attention with regard to hormonal replacement prior to any intervention are the cortisol and thyroid axes. Medical replacement of hypo-functioning cortisol or thyroid axes should be implemented prior to any operation, typically in collaboration with an endocrinologist. A fasting morning cortisol test should be included in the preoperative workup and determines the need for stress-dose steroids in the operating room. Ideally, these levels should be measured between 8:00 and 9:00 a.m., when basal cortisol levels are at a peak. Appropriate stimulation testing, such as a cosyntrophin stimulation test, should be performed on an as-needed basis prior to any operation.^{8,13,14} Free T4 and TSH levels should also be checked prior to any intervention and treated according to the findings.

Imaging. Imaging should include an MRI study of the brain and sellar region with and without contrast. For the

TABLE 1: Preoperative checklist for endoscopic endonasal surgery*

Category	Item	Subitem
History & Physical Exam		
Laboratory Tests	general labs	CBC, BMP, PT/PTT, INR, type & screen
	hormonal labs	PRL, a.m. cortisol, ACTH, TSH, free T4, FSH, LH, free testosterone, GH, IGF-I
	stimulation testing (as needed)	
	PRL level dilutions (as needed to rule out hook effect)	
Imaging	MRI of sella w/ or w/o contrast; sagittal & coronal sequences	
	CT (as needed)	
	MRA or CTA (as needed to rule out vascular lesion)	
	MRI or CT for neuronavigation	
Informed Consent	procedure	fat/fascial graft, lumbar drain
	tumor bank/clinical trial	
Meds	corticosteroid, thyroid replacement therapy	hydrocortisone, levothyroxine
	discontinue blood thinners	
Consultations	endocrinology	
	neuroophthalmology (visual field testing)	
	medical clearance	

* CTA = CT angiography; INR = international normalized ratio; Meds = medications; MRA = MR angiography.

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majority of sellar-based lesions, sagittal and coronal MRI sequences are preferred. A CT scan of the head obtained without contrast can also be helpful to detect intracranial calcification (i.e., with craniopharyngiomas) and is the preferred modality for patients who are unable to undergo MRI studies. A CT scan is also helpful for detailing the bony sphenoid sinus anatomy, including sphenoid septa, although an MRI study is also typically adequate for these purposes.¹⁷ Close attention should also be paid to the anatomy of the paranasal sinuses and configuration of any sphenoid sinus septations, degree of pneumatization of the sphenoid sinus, and morphology of the sellar floor. Furthermore, the course of the internal carotid arteries and intercarotid distance should always be considered prior to planning any endonasal endoscopic skull base approach. Of course, any prior surgical history and methods for reconstruction must always play a major role in consideration of one surgical approach over another. Based on the planned operation, anatomy of the sellar floor and paranasal sinuses, and prior surgical history, the surgeon should plan according to whether intraoperative neuronavigation will be used, and this imaging should be performed ahead of time. We routinely use intraoperative neuronavigation in direct sellar approaches where a “flat” sellar floor is identified, in most extended approaches, and in all repeat operations.¹⁷

Informed Consent. As with any neurosurgical procedure, a candid discussion regarding the goals, risks, and benefits of as well as alternatives to surgery must take place with the patient as part of the informed consent process. The consent should address additional measures such as an abdominal or thigh tissue graft or lumbar drain, as needed. Additional consent forms for the purpose of tumor analysis (i.e., genomic or molecular studies) and storage, or other clinical research protocols, should also be obtained prior to starting the intervention.

Intraoperative Checklist (Table 2)

Immediately prior to any endonasal endoscopic operation for pituitary lesions, consideration of some or all of the following factors may reduce or even prevent the development of intraoperative complications, align the workflow goals of the surgical and operating room team, and ensure that all required equipment is available and functional before commencing the procedure.

Surgical Timeout and Medications. As with most surgical checklists, initial confirmation of the patient, procedure, and operative site are critical, in addition to a review of patient allergies and medications to be administered prior to and during the operation. Close communication with the anesthesiology team is imperative to assure that the patient receives the correct doses of medications required. Perioperative antibiotics (most commonly cefazolin) should be administered. Patients with evidence of hypocortisolemia should receive cortisol replacement (hydrocortisone or dexamethasone) during surgery, whereas at our institution, patients with normal preoperative cortisol levels who are undergoing selective adenomectomy do not undergo routine cortisol replacement. For patients with CD who are undergoing resec-

tion of a pituitary adenoma, the checklist must include a reminder that no corticosteroids are to be administered.

Imaging. The surgical team should ensure that the desired imaging is available and easily accessible in the operating room prior to starting the operation. For a majority of sellar-based lesions, sagittal and coronal MRI studies are preferred. Close attention should again be paid to the anatomy of the paranasal sinuses and configuration of any sphenoid sinus septations, degree of pneumatization of the sphenoid sinus, and morphology of the sellar floor. Furthermore, the course of the internal carotid arteries and intercarotid distance should be reviewed prior to surgery. The degree of tumor invasion into surrounding structures, proximity of critical blood vessels, and location of the normal pituitary gland and stalk relative to the lesion should be reviewed. If intraoperative neuronavigation is to be used, the team should ensure that the correct image sequences and equipment is available.

Adjunctive Measures. Once the patient is intubated, the endotracheal tube should be mobilized to the left side of the mouth. An arterial line is preferred for blood pressure monitoring. An orogastric tube is inserted, which will be used once surgery is completed to suction any surgical fluid that was swallowed. Another alternative is to pack the oropharynx with moist throat packs or gauze. If throat packs are used, they will need to be included in the surgical count at the beginning and end of the operation. Additional adjunctive measures that require planning and discussion with the anesthesiology and nursing teams include insertion of a Foley catheter, which we use only for extended procedures, and plans for inserting a lumbar drain. If a lumbar drain is inserted prior to the operation, clear communication with the anesthesia team must take place to assure that the drain settings are optimized.

Positioning. The patient is placed in the supine position with the head mildly flexed and rotated approximately 10° toward the surgeon, with the head elevated above the thorax to optimize venous outflow. Intraoperative neuronavigation can then be registered to verify accuracy. At this point, the nose is packed with lidocaine-soaked cottonoids or a nasal decongestant such as oxymetazoline. The nose is then prepared with povidone-iodine or another cleansing agent after the cottonoids are removed. The abdomen (or lateral thigh) should also be prepared and draped for a potential fat and/or fascia graft. Any plans for a pedicled nasoseptal flap should be discussed prior to starting the operation.

Equipment. Prior to any operation, it is mandatory that the surgeon and operating team confirm that the surgical instruments and equipment necessary to perform the procedure are available and sterile. Endoscopic skull base surgery requires that each component of the visualization system, which includes the telescope, camera, light source, fiberoptic cable, and display monitor, functions in an ideal fashion. If any of these components are not working properly, the ability to perform the operation may be compromised. This has been referred to as a “clock-gear” mechanism, in which the entire endoscopy setup relies heavily on each individual component.² In addition to the

TABLE 2: Intraoperative checklist for endoscopic endonasal surgery*

Category	Item	Subitem
Surgical Timeout	patient ID, procedure, allergies, meds	
Meds	antibiotics	Ancef, vancomycin
	corticosteroids	hydrocortisone, dexamethasone
Imaging	MRI of sella w/ or w/o contrast; sagittal & coronal sequences displayed in OR	
Adjunctive Measures	endotracheal tube positioning	routine
	radial arterial line	routine
	orogastric tube or oral packing	routine
	lumbar drain	extended approaches
	Foley catheter	extended approaches
Positioning	head elevated above thorax	
	flexion/extension for extended approaches	
Neuronavigation	registration performed w/ good accuracy	
Preparation	nasal	Afrin, lidocaine w/ epinephrine, iodine prep
	abdomen or thigh for fat/fascial harvest	
	pedicled nasoseptal flap	extended approaches
Equipment	endoscopy system	0°, 30°, & 45° telescopes
		camera
		light source & fiberoptic cable
		HD monitor
		Clearvision or other lens irrigator
		recording equipment
		as needed for backup
	microscope	
	sinus debrider	
	sinus & skull base instruments	
	micro-Doppler	
	tumor resection instruments	Nico Myriad, CUSA, SonoPet
	reconstruction materials	DuraSeal, fibrin glue, Porex plate
Surgical Terminus	removal of throat packs or OGTT suctioning	
	pupillary/visual check (prior to leaving OR)	

* CUSA = Cavitron ultrasonic surgical aspirator; HD = high definition; OGTT = oral glucose tolerance test; OR = operating room; prep = preparation.

endoscopy system, the surgeon should ensure that the correct skull base and transsphenoidal instruments are available, in addition to the sinus debrider, high-speed drill, lens irrigating systems, micro-Doppler instrument for carotid localization,⁷ and/or additional mechanical tumor resection devices such as the ultrasonic aspirator.

Surgical Terminus. Once surgery is completed and a sling dressing is in place, the throat packs must be removed. If an oral glucose tolerance test was used, the anesthesiologist will suction out gastric contents prior to extubation. Immediately following extubation and prior to transfer to the recovery room, visual status is always verified to ensure that no acute compression of the optic apparatus has occurred secondary to an expanding hematoma or graft insertion.

Postoperative Checklist Considerations (Table 3)

Postoperative Examination and Orders. Postoperative care begins with an immediate neurological exami-

nation with attention to visual acuity and fields. Postoperative orders should include screening parameters for diabetes insipidus (DI), which include checking sodium levels every 6–12 hours. In addition, the nursing staff should be instructed to send an immediate urine sample for specific gravity and sodium tests for urine output > 250 ml/hour for 2 consecutive hours. If a patient has low preoperative cortisol axis function, high-dose hydrocortisone should be tapered down to a physiological dose over the next week or so.

Postoperative Day 1 laboratory tests should include close monitoring for new hypocortisolemia in patients with normal preoperative hypothalamic-pituitary-adrenal axis function who were not given intraoperative corticosteroids; this is often done by obtaining daily morning fasting cortisol levels and initiating cortisol replacement for patients with low values and/or symptoms consistent with hypocortisolemia. In patients with acromegaly, a fasting morning GH level should be obtained on postop-

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TABLE 3: Postoperative checklist for endoscopic endonasal surgery*

Category	Item	Subitem
Physical Exam	general neurological exam	
	visual acuity & fields	
Laboratory Tests Ordered	sodium levels	every 6 or 12 hrs
	monitoring for DI	if UOP >250 ml/hr for 2 consecutive hrs, send immediate specific gravity & sodium
	next-day a.m. labs	CD: cortisol level every 6 hrs
		acromegaly: a.m. GH level
		HPA axis monitoring: cortisol level every a.m.
		prolactinoma: PRL level every a.m.
Imaging	MRI of sella w/ or w/o contrast; sagittal & coronal sequences	either w/in 72 hrs or in 3 mos
Special Orders	lumbar drain specifications	
	set time for removal of nasal packing (if used)	
Meds	antibiotics	
	hormone replacement	
	DDAVP	
Discharge Planning	sodium level on postop Day 7	
	follow-up w/ endocrinologist & ophthalmologist	

* HPA = hypothalamic-pituitary-adrenal; UOP = urine output.

erative Days 1 and 2; levels < 2 ng/ml typically predict long-term remission, whereas higher levels are associated with higher rates of recurrence.¹¹ Additional laboratory tests include cortisol levels every 6 hours in patients with CD and daily morning PRL levels for patients with prolactinomas.^{1,3} If early DI develops, we prefer to use subcutaneous desmopressin (DDAVP) initially, and then transition to oral or nasal spray DDAVP as needed, in anticipation of discharge planning.

Special Orders. Although nasal packing is not routinely used, additional instructions include removal of nasal packing at any specified postoperative time point when used and specific lumbar drain management specifications. For standard pituitary adenomas, we typically obtain an MRI study of the sella 3 months after surgery. However, for nonadenomatous lesions or extended approaches we often obtain postoperative imaging within 72 hours of surgery. A repeat sodium level, obtained on an outpatient basis, should be checked on or around postoperative Day 7 to evaluate for delayed hyponatremia.¹⁸ Discharge planning should include follow-up with the neurosurgeon, endocrinologist, and ophthalmologist.

Results

We surveyed a total of 25 patients (Table 4) with 16 endoscopic endonasal approaches for pituitary adenomas, 3 for Rathke cleft cysts, 1 arachnoid cyst, and 1 case of lymphocytic hypophysitis. The checklist was also applied to additional anterior skull base endoscopic cases, including 3 anterior fossa CSF leak reconstructions and 1 clival chordoma. Twenty-three cases were direct endoscopic transsphenoidal approaches and two were extended endonasal cases. We used nasoseptal flap reconstruction in 7 cases.

The checklist was readily adopted by nursing and anesthesia colleagues without any barriers to implementation.

Our preoperative checklist survey (Table 5) had no missed or incomplete sections. A majority of checkpoints in this section are part of our institutional preoperative checklist and therefore were redundant checkpoints. It is important to note that thyroid replacement and steroid therapy are not part of our institutional list and therefore might be missed or overlooked if not thoroughly reviewed before an operation.

During implementation of the intraoperative checklist (Table 6), no major surgical errors were identified.

TABLE 4: Patient clinical data

Finding & Procedure	No. of Patients
total	25
diagnosis	
pituitary adenoma	16
Rathke cleft cyst	3
arachnoid cyst	1
lymphocytic hypophysitis	1
CSF leak repair	3
chordoma	1
procedure	
standard endoscopic transsphenoidal	23
extended approach	2
lumbar drain (inserted prior to procedure)	1
abdominal fat graft (site prepped)	14
thigh graft (site prepped)	11
nasoseptal flap	7

TABLE 5: Preoperative checklist results*

Checklist Item	No. of Patients
preop workup	
history & physical	25
basic labs (CBC, BMP)	25
coagulation studies (PTT, INR)	25
chest radiograph	25
EKG	25
pregnancy test	12
blood type & screen	25
blood available	8
PRL	17
a.m. cortisol	18
thyroid studies	18
IGF-I	15
consent	25
tumor bank consent	14
meds	
blood thinners discontinued	7
thyroid replacement therapy	3
intraop steroids	6
antibiotics	25

* EKG = electrocardiogram.

However, 9 missing surgical components (near misses) that could have delayed or impeded progress during surgery were identified. These items (Table 7) included missing neuronavigation setup/equipment, Clearvision or other lens irrigator, micro-Doppler, recording equipment, and selected endoscopic skull base instruments.

Discussion

We implemented a standardized and customized perioperative checklist designed for endoscopic pituitary and skull base surgery. The checklist was successfully used in 25 nonconsecutive cases over a 9-month period as a pilot analysis. We aimed to share our early experience and the specifics of our checklist as we move toward routine implementation of the checklist in all endoscopic endonasal cases. In our experience, the preoperative checklist proved to be redundant with the institutional checklist except for the endocrinological workup. The checklist was most useful in ensuring that all necessary equipment was available and functional prior to commencement of the operation. Although no major errors were detected (e.g., failure to detect a prolactinoma prior to transsphenoidal pituitary operation), the checklist was valuable in identifying missing key components of the operation in 9 cases (36% of operations). This checklist is especially helpful for new operating room personnel or in institutions that are just beginning to use endoscopy.

The limitations of this pilot prospective study are its implementation in a single center by a single surgeon in a

TABLE 6: Intraoperative checklist*

Checklist Item	No. of Patients
surgical start	
timeout	25
neuronavigation available	22
MRI available	22
CT	3
CTA/MRA	1
surgical positioning & adjuncts	
endotracheal tube positioned/taped	25
Mayfield pins	18
head above thorax	25
leg squeezers/SCDs	25
radial artery line	25
Foley catheter	10
lumbar drain	3
OGTT	2
throat packs	23
surgical prep	
Afrin in nasal cavity	25
Betadine prep	25
abdomen prepped	14
thigh prepped	11
endoscopy equipment	
0°, 30°, & 45° scopes	25
camera	25
light source/fiberoptic cable	25
HD monitor	25
Clearvision lens irrigation	23
recording	24
surgical equipment	
sinus debrider	25
skull base instruments	24
micro-Doppler	23
tumor resection: Nico Myriad	2
FloSeal/hemostatic agent	6
reconstruction materials: DuraSeal/Duragen	3
surgical terminus	
throat packs removed	23
vision checked	25
counts correct	25

* SCD = sequential compression device.

nonconsecutive pattern. More widespread and consistent analysis following routine use of this checklist via a multi-institutional format will provide more valid information pertaining to the benefits of its adoption. Nevertheless, we believe that reporting the early results of this pilot analysis and sharing our experience with the customized checklist may facilitate this process and lead to more rapid adoption of similar checklists worldwide.

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TABLE 7: Incomplete or missing components constituting “near misses”

Component	No. of Cases
recording equipment	1
neuronavigation	3
Clearvision lens irrigation	2
micro-Doppler	2
skull base tray	1

Conclusions

A successful approach to pathological entities in the sellar region begins in the preoperative period with a thorough workup and attention to the patient's endocrinological and visual function. Intraoperatively, ensuring availability and functionality of the right equipment, positioning, and any adjunctive measures is likely to optimize workflow and improve patient outcomes. The considerations in the checklist provided in this review can serve as a basic tool for further customization by individuals performing endoscopic transsphenoidal or anterior skull base surgery, and the use of such tools may reduce the incidence of adverse or preventable errors associated with surgical treatment of sellar and skull base lesions.

Disclosure

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

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