

A checklist for endonasal transsphenoidal anterior skull base surgery

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OBJECTIVE Approximately 250 million surgical procedures are performed annually worldwide, and data suggest that major complications occur in 3%–17% of them. Many of these complications can be classified as avoidable, and previous studies have demonstrated that preoperative checklists improve operating room teamwork and decrease complication rates. Although the authors' institution has instituted a general preoperative "time-out" designed to streamline communication, flatten vertical authority gradients, and decrease procedural errors, there is no specific checklist for transnasal transsphenoidal anterior skull base surgery, with or without endoscopy. Such minimally invasive cranial surgery uses a completely different conceptual approach, set-up, instrumentation, and operative procedure. Therefore, it can be associated with different types of complications as compared with open cranial surgery. The authors hypothesized that a detailed, procedure-specific, preoperative checklist would be useful to reduce errors, improve outcomes, decrease delays, and maximize both teambuilding and operational efficiency. Thus, the object of this study was to develop such a checklist for endonasal transsphenoidal anterior skull base surgery.

METHODS An expert panel was convened that consisted of all members of the typical surgical team for transsphenoidal endoscopic cases: neurosurgeons, anesthesiologists, circulating nurses, scrub technicians, surgical operations managers, and technical assistants. Beginning with a general checklist, procedure-specific items were added and categorized into 4 pauses: Anesthesia Pause, Surgical Pause, Equipment Pause, and Closure Pause.

RESULTS The final endonasal transsphenoidal anterior skull base surgery checklist is composed of the following 4 pauses. The Anesthesia Pause consists of patient identification, diagnosis, pertinent laboratory studies, medications, surgical preparation, patient positioning, intravenous/arterial access, fluid management, monitoring, and other special considerations (e.g., Valsalva, jugular compression, lumbar drain, and so on). The Surgical Pause is composed of personnel introductions, planned procedural elements, estimation of duration of surgery, anticipated blood loss and fluid management, imaging, specimen collection, and questions of a surgical nature. The Equipment Pause assures proper function and availability of the microscope, endoscope, cameras and recorders, guidance systems, special instruments, ultrasonic microdoppler, microdebrider, drills, and other adjunctive supplies (e.g., Avitene, cotton balls, nasal packs, and so on). The Closure Pause is dedicated to issues of immediate postoperative patient disposition, orders, and management.

CONCLUSIONS Surgical complications are a considerable cause of death and disability worldwide. Checklists have been shown to be an effective tool for reducing preventable errors surrounding surgery and decreasing associated complications. Although general checklists are already in place in most institutions, a specific checklist for endonasal transsphenoidal anterior skull base surgery was developed to help safeguard patients, improve outcomes, and enhance teambuilding.

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KEY WORDS endonasal; transsphenoidal; checklist; skull base; endoscopic; microscopic; pituitary surgery

ABBREVIATION SSC = Surgical Safety Checklist.

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SURGICAL complications have long been a major and well-documented source of morbidity and mortality. In the earliest days of neurosurgery, mortality rates reached as high as 80% for some operations, and complications were exceedingly common.²⁴ Even in the best of hands, the transsphenoidal approach to the skull base had mortality rates as high as 5.6% in the early 1900s.²⁰ Subsequently, there has been a significant decline in complication and mortality rates as a result of the vast expansion of medical knowledge, improved technologies, and higher standards of care.²⁰ Nevertheless, approximately 250 million surgical procedures are performed annually as a crucial part of comprehensive health care worldwide, with major complications arising in 3%–17% of patients (7.5–42.5 million).^{5,16} When considering all complications, the rate increases to 27%–42% of patients, with many coming from high-risk specialties such as neurosurgery, thoracic/cardiovascular surgery, and orthopedic surgery.¹⁷

In neurosurgical procedures, these complications can vary widely.^{34–38} In endonasal transsphenoidal neurosurgical procedures, complications include CSF leak, vision loss, hemorrhage, epistaxis, postoperative infection, and, rarely, death.²¹ Although these transsphenoidal operations are considered relatively safe in comparison with open cranial procedures, overall complication rates nevertheless are reported as around 20% for primary endoscopic transnasal operations, with repeat operations having slightly higher rates.^{2,19} Limiting the number and severity of surgical complications in endonasal transsphenoidal procedures therefore continues to be a major goal in improving patient safety and maximizing patient outcomes.

One relatively recent strategy for decreasing the surgical complication rate has been the introduction of the surgical checklist.^{6,9,12,13,14,17,23,32} These checklists, inspired by the aviation industry, have been widely adopted in the US and internationally as a way to avoid surgical complications.^{9,15,28,29} Similar to those used in aviation, the checklists serve 3 main functions: first, to ensure that basic safety checks have been performed; second, to ensure that all necessary equipment is present and functioning properly; and third, to promote teambuilding and effective communication. Although these checklists can never substitute for proper, thorough training or surgical experience, studies have shown that the use of checklists in surgical procedures significantly improves response to intraoperative and anesthetic crises, flattens vertical authority gradients, and decreases complication rates.^{1,3,9,11,15,23,24,27,37} The implementation of checklists in both inpatient and surgical settings is also cost-effective, has improved the medical-legal environment, and has increased health care efficiency.^{8,26} Patients also view checklists favorably.²⁵

As a discipline, neurosurgery is exploring more precise standardization methods and more comprehensive approaches for tracking patient outcomes. Recent evidence indicates the role for additional, procedure-specific checklists, which could standardize treatment and reduce neurosurgical risk.^{34–38,40} The purpose of this study was to develop a checklist that is highly specific to endonasal transsphenoidal anterior skull base procedures and can be modified in accordance with a variety of surgical practice settings.

Methods

A committee was formed that included all team members of a typical endonasal endoscopic transsphenoidal anterior skull base operation. These included neurosurgeons from the US and Europe, anesthesiologists, circulating nurses, scrub technicians, surgical operations managers, and technical assistants. Many members of the committee, including a neurosurgeon, an anesthesiologist, and a circulating nurse, were part of an operative team that has performed more than 700 of these operations over an 8-year period. The senior author (E.R.L.), who served as chair of the committee, has personally performed more than 5700 transsphenoidal operations.

Once formed, the committee was directed to determine the contents of a concise, procedure-specific checklist for transsphenoidal operations, with the intention of decreasing the surgical complication rate and improving patient outcomes. The WHO's Surgical Safety Checklist (WHO SSC) was used as a template. Adapting the successful design strategy of checklists in aviation and manufacturing procedures, the development of the checklist was carried out in several stages: content and format, timing, trial and feedback, formal testing and evaluation, and local modification.³³

After early discussions, a prototype of the checklist was developed and evaluated independently by each member of the committee for verification and modification. The resultant second-stage checklist was then used in a surgical setting at our institution to verify the checklist's functionality and to improve its contents by trial and feedback.

Results

The final comprehensive transsphenoidal operation checklist is presented in Fig. 1. The checklist includes all aspects of the WHO SSC, with additional items categorized into 4 pauses. These correlate with the natural pauses in a typical transsphenoidal operation. It is meant to be a structured guide that can readily be modified and shortened when applied to different practice settings. As stated, it reflects the nuances of practice in our multidisciplinary setting.

Anesthesia Pause

The first pause, the Anesthesia Pause, is read aloud prior to the induction of anesthesia. This section of the checklist includes the preanesthesia elements of the SSC (e.g., patient identification, allergies), in addition to concerns of particular importance in transsphenoidal operations. Comorbidities associated with acromegaly and Cushing's disease are common in transsphenoidal operations for pituitary conditions. They have very particular effects on the ease of intubating the patient, accessing the sphenoid, and ultimately performing a successful procedure. This checklist provides for identification of these concerns prior to the beginning of the operation. Laboratory values and medications related to these comorbidities are also particularly important to discuss when patients have a dysfunctional pituitary axis; thus, they were added to this checklist.

Several other items were added to this pause to ensure

ANESTHESIA PAUSE	SURGICAL PAUSE	EQUIPMENT PAUSE	CLOSURE PAUSE
Patient Identification	Team Identification	Microscope	Post-Operative Destination
<input type="checkbox"/> Name	<input type="checkbox"/> Personnel introductions (anesthesia, nursing, scrub techs, surgeons, other)	<input type="checkbox"/> Set up and balanced, with observer head on the left	<input type="checkbox"/> Disposition (ICU, Floor)
<input type="checkbox"/> Hospital Record Number			<input type="checkbox"/> Nasal Packing
<input type="checkbox"/> Allergies			<input type="checkbox"/> Steroid Management
Diagnoses	Operative Procedures Planned	Endoscopes	
<input type="checkbox"/> Surgical Diagnosis	<input type="checkbox"/> Operation type (initial or recurrent)	<input type="checkbox"/> Light source ready	
Anesthesia Concerns (Airway classification, Cushing's/Acromegaly, Diabetes, Hypertension, Cardiovascular/Pulmonary)	<input type="checkbox"/> Tissue grafts anticipated (fat, fascia lata)	<input type="checkbox"/> Monitors	
<input type="checkbox"/> Pertinent Labs (Cortisol, T4, CBC, Coags)?	<input type="checkbox"/> Nasal septal flap anticipated	<input type="checkbox"/> Camera/Video	
	<input type="checkbox"/> Lumbar intrathecal drain anticipated		
Medications	<input type="checkbox"/> Estimated duration of surgery	Image Guidance	
<input type="checkbox"/> Antibiotics		<input type="checkbox"/> Stealth/Stryker/Brainlab/etc.	
<input type="checkbox"/> Steroid use (stress dosing?)	Blood		
<input type="checkbox"/> Insulin	<input type="checkbox"/> Anticipated blood loss		
<input type="checkbox"/> Avoid Decadron for nausea	<input type="checkbox"/> Type and crossmatch, units requested	Electrocautery	
	<input type="checkbox"/> Coagulation state	<input type="checkbox"/> Suction Monopolar, Pistol Grip Bipolar	
	<input type="checkbox"/> Special issues (e.g., Jehovah's witness)	<input type="checkbox"/> Suctions	
		<input type="checkbox"/> Colorado tips	
Surgical Preparation	Specimens Anticipated	Other	
<input type="checkbox"/> Pre-operative nasal decongestant spray	<input type="checkbox"/> Cultures	<input type="checkbox"/> Microdebrider	
<input type="checkbox"/> Nasal Pledgets—cocaine, lidocaine, epinephrine	<input type="checkbox"/> Tissue Specimens (frozen and standard)	<input type="checkbox"/> Ultrasonic microdoppler	
	<input type="checkbox"/> Research specimens	<input type="checkbox"/> High speed drill (diamond bits)	
Positioning, Airway, and Access	<input type="checkbox"/> Questions or concerns from anyone on team	<input type="checkbox"/> Additional Equipment	
<input type="checkbox"/> Mayfield or Horseshoe headrest in place			
<input type="checkbox"/> Image Guidance (if available/desired)			
<input type="checkbox"/> ET tube fixated to left corner of the mouth and jaw			
<input type="checkbox"/> Avoid tape on upper lip			
<input type="checkbox"/> Thorax elevated			
<input type="checkbox"/> Eye protection in place			
<input type="checkbox"/> Orogastric tube in place			
<input type="checkbox"/> Pad and tuck right arm			
<input type="checkbox"/> Avoid BP cuff on right arm, if possible			
<input type="checkbox"/> TEDS or pneumatic boots on legs			
<input type="checkbox"/> Patient prepped for potential graft (fat and/or fascia lata)			
Fluid Management			
<input type="checkbox"/> Careful I/O			
<input type="checkbox"/> DI present or anticipated			
Monitoring			
<input type="checkbox"/> Central/Arterial line (usually not necessary)			
<input type="checkbox"/> Urinary Catheter (often not necessary)			
Special Considerations			
<input type="checkbox"/> Patient protocolled for blood and tissue samples to pathology			

FIG. 1. A checklist for transnasal transsphenoidal anterior skull base surgery is shown. BP = blood pressure; DI = diabetes insipidus; ET = endotracheal; I/O = intake/output; Pertinent Labs = Pertinent Laboratory Values; TEDS = thromboembolic deterrent stockings. Figure is available in color online only.

appropriate patient preparation before commencement of the operation. The administration of preoperative nasal decongestants is helpful to ease access and control bleeding; fiducials for image guidance allow for a more precise approach to the sphenoid; preparation of potential tissue graft sites allows for more efficient access and excision later in the procedure; and avoidance of tape or other mechanical barriers on the upper lip, elevation of the thorax, and proper placement of the endotracheal and orogastric tubes all permit easier access to the nostrils by the surgical team. Similarly, proper placement of the patient's right arm, patient's body, and bed orientation allow for a more ergonomic operating posture for the chief surgeon.

Manipulation of the posterior pituitary gland increases the incidence of intra- and postoperative syndrome of inappropriate antidiuretic hormone secretion and diabetes insipidus during transsphenoidal operations. Careful monitoring of fluid intake and output before, during, and after the operation is crucial to proper diagnosis of these electrolyte disturbances. Arterial lines and urinary catheters are generally unnecessary for routine transsphenoidal

operations, but should be considered prior to induction of anesthesia if they are required. The final section of the Anesthesia Pause ensures proper protocol for collection of tissue and blood samples for pathology and/or research.

Surgical Pause

The Surgical Pause should be read aloud prior to surgical commencement. As in the WHO SSC, this pause prioritizes identification of the type, location, and estimated duration of the operation. Preparation for possible blood transfusion remains as important in this checklist as in the WHO SSC, with specific provisions to ensure that blood is available, appropriate to the patient, and properly labeled. Specific maneuvers common in transsphenoidal operations, such as tissue grafts, nasal septal flaps, and lumbar intrathecal drains, should be discussed aloud prior to beginning the operation, as well as the potential need for research sample collection.

Equipment Pause

Transsphenoidal operations require a novel set of in-

struments compared with typical intracranial operations. Some of these instruments may be unfamiliar to surgical teams that perform few endoscopic procedures. Transsphenoidal operations occasionally require the support of both endoscope and microscope. As such, both should be properly prepared and available, and both are included in the checklist. The preparation of the endoscope is of particular importance in transsphenoidal operations; proper functioning of the monitors, cameras, video recording software, and light source, as well as preparation with Clearvision (Karl Storz), helps to ensure adequate visualization of the sella and the surgical target. Similarly, preparation of the image guidance system in use (e.g., Stryker, Brainlab) allows for a safer and more precise approach.

The final section of the Equipment Pause covers several crucial instruments in transsphenoidal operations. Electrocautery, suction, and microdebrider allow access to the sphenoid through the nasal cavity; a microdoppler instrument enables localization and subsequent avoidance of the cavernous carotid arteries; and a drill with 3–4-mm diamond bits allows for more aggressive bone preparation, if necessary.

Closure Pause

The final pause in the checklist, the Closure Pause, should be read aloud before the patient leaves the operating room. It is mostly concerned with finalizing the procedure and determining the destination of the patient postoperatively (e.g., to a neurosurgical floor, the neurosurgical intensive care unit, and so on), pertinent disease-specific postoperative orders, and any other perioperative management issues.

Discussion

In general, the aviation industry has used preflight checklists to enhance safety and teambuilding, for reliability and reproducibility of results, as a precaution against untoward events, and for clarification of roles and responsibilities.^{3,33} Although checklists are not a substitute for experience and technical expertise, they are steadily growing in popularity and usefulness in surgical practices worldwide.^{10,16,30} These general checklists serve an important function in averting catastrophic surgical complications, such as wrong-site, wrong-procedure, or wrong-patient operations.^{22,39} They similarly help prevent adverse surgical outcomes by ensuring basic steps for patient safety, such as identifying a patient's allergies and encouraging sterility in the operating room.^{4,14,16,34}

Systematic reviews of the introduction and implementation of these checklists have been overwhelmingly positive, with general decreases in surgical complication rates and reports of improved operating room teamwork and communication.²⁶ In a randomized, controlled trial of safety checklist use in 5 disciplines (cardiothoracic, neurological, orthopedic, general, and urological surgery), Haugen et al. reported a decrease in complication rates from 19.9% to 11.5% ($p < 0.001$) between 2212 control procedures and 2263 procedures under the WHO SSC.¹⁵ Even after adjusting for confounding factors, the effect of the WHO SSC on surgical complications was significant,

with an OR of 1.95. The mean hospital stay also decreased by almost a day.

In a separate study, de Vries et al. compared 3760 patients before implementation of a surgical safety checklist with 3820 patients observed after implementation.¹⁰ They reported a decrease in number of complications per 100 patients from 27.3 to 16.7, an absolute risk reduction of 10.6, and a decrease in in-hospital mortality from 1.5% to 0.8%.¹⁰

Checklists have also been shown to improve patient safety specifically in neurosurgery. Lepänluoma et al. reported a reduction in unplanned readmissions from 25% to 10% ($p = 0.02$) after implementation of a neurosurgical safety checklist, while wound complications decreased from 19% to 8% ($p = 0.04$).²³ Operating room personnel were also surveyed regarding the implementation of the surgical checklist; an improvement in communication was found among team members as well as improved procedural documentation. Although their adoption into practice has been somewhat slow, it is clear from the data that surgical safety checklists have had a positive impact on patient safety.^{22,31}

Procedure-specific checklists similar to those designed here help standardize specific operations, act as a quality-control mechanism, improve efficiency, and can help to ensure the best possible outcomes for patients. They are more detailed in nature than general safety checklists and build upon the role that these checklists have played by ensuring not only safety but also promoting the highest standard of care. One extension beyond the simple safety checklist is the concept of phase-change checklists.¹⁸ Neurosurgical cases have critical phases, and taking a moment to stop and prepare for the next phase is helpful. The transsphenoidal checklist presented here incorporates this temporal aspect and has been designed with 4 pauses, or stages.

Although the checklist seeks to be procedure specific, it cannot be all inclusive. At some point, a line must be drawn between what is crucial to patient safety during a transsphenoidal skull base operation and what is simply a straightforward part of all neurosurgical operations. The instrument developed here is a middle ground between detailed surgical instructions and a general safety checklist. It ensures that the most basic and critical elements of any transsphenoidal operation are accounted for, while remaining concise enough to be used during the flow of an operation.

Nevertheless, the checklist developed here may appear unwieldy to some. Indeed, many experts recommend limiting the size of checklists to fewer than 10 items per pause point to avoid so-called "checklist fatigue."^{13,33} Procedure-specific checklists necessarily deviate from this recommendation, because they are designed specifically to account for many different aspects of a particular operation that are at risk for being forgotten. The checklist developed here could serve as a crucial verification of preparedness, promoting consistent and uniform performance. Although the checklist designed here cannot replace the benefits of thorough training and an experienced surgeon, it can help ensure that catastrophic disaster, undue delay, and poor communication are avoided to the greatest ex-

tent possible. Neurosurgical procedures are not amenable to “cookbook” procedural lists or “autopilot” mentalities. There will be significant variation among neurosurgical centers and treatment teams, and this checklist reflects one center’s experience only, providing a framework for modification by other centers.

Neurosurgery is a high-risk surgical discipline. Nevertheless, many of the complications that result from these operations should be considered preventable. In a review of adverse outcomes in neurosurgical procedures, researchers found that many complications resulted from difficulties in communication or variations in equipment.³⁴ Although some risks may be considered avoidable, problems with equipment and communication can largely be countered by effective implementation and regular use of a surgical checklist.^{4,7,10} By implementing procedure-specific checklists such as the one developed here, the benefits of a safety checklist can be combined with the expertise of a skilled neurosurgical team to provide multidisciplinary patient care of the highest quality and effectiveness.

Studies are underway to determine the effects of this checklist on patient outcomes during transsphenoidal operations and to determine whether implementation of such a checklist has any effect on the complication rate. Should the data indicate successful improvement in patient safety, further investigations are planned to develop appropriate checklists for other neurosurgical operations.

Conclusions

Surgical complications are a considerable cause of death and disability worldwide. Checklists have been shown to be an effective tool for reducing preventable errors surrounding surgery and decreasing associated complications. Although general checklists are already in place in most institutions, a specific checklist for endonasal transsphenoidal anterior skull base surgery can safeguard patients by ensuring that proper safety measures have been followed, team members are fully briefed for the procedure, and patients are assured optimal outcomes.

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Author Contributions

Conception and design: all authors. Drafting the article: Smith, Laws, Cote. Critically revising the article: Smith, Laws, Wong, de los Reyes, Cote, Gawande. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Smith. Administrative/technical/material support: Cote. Study supervision: Smith, Laws, Gawande.

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