Relative Hypotension and Image Guidance

Tools for Training in Sinus Surgery

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Objectives: To quantify the safety and efficiency of Postgraduate-Year II head-and-neck-surgery residents who perform endoscopic sinus surgery, to observe any changes that accompanied accrued experience, and to measure and correlate blood loss and temporal efficiency with anesthesia-induced relative hypotension.

Design: Retrospective study.

Setting: University of California, San Diego, Medical Center.

Patients: One hundred two patients with chronic rhinosinusitis operated on between July 1, 2005, and June 30, 2006, by 3 Postgraduate-Year II head-and-neck-surgery residents.

Intervention: Endoscopic sinus surgery.

Main Outcome Measures: Operative times, blood loss, case complexity, and anesthetic components were recorded and analyzed.

Results: One hundred two patients with chronic rhinosinusitis with and without polyposis received operative management. Mean operative time, with the inclusion of injection (10 minutes) and image guidance setup (5 minutes), was 77 minutes. Estimated blood loss averaged 42 mL for patients with chronic rhinosinusitis and 58 mL for patients with chronic rhinosinusitis and nasal polyps. The mean intraoperative blood pressure was 101/65 mm Hg. No major complications occurred.

Conclusions: Endoscopic sinus surgery may be safely performed by Postgraduate-Year II head-and-neck-surgery residents by means of hypotensive anesthesia techniques and image guidance. Outcome analysis demonstrates minimal blood loss, efficient operative times, and no significant complications.


Endoscopic sinus surgery (ESS) has become one of the most commonly performed otolaryngologic procedures in the United States. However, it remains a difficult procedure to learn and to teach; as late as the mid-1990s, only half of US residents were receiving training in ethmoid dissection. Complications of ESS can be serious because of the proximity of critical structures. Computer-aided or image-guided surgery, introduced for use in the early 1980s, has eliminated some of the inherent difficulty in the teaching of this procedure to surgical residents. Image-guided surgery aids in the identification and precise localization of anatomical landmarks, a crucial advantage in patients who have undergone previous surgery or whose condition has effected anatomical distortion.

Many authors at different institutions have reported on the instruction of the otolaryngologic resident in ESS. They provide data with regard to complications, operative time, and training procedures. Most reports address the operative performance of senior residents under conventional anesthetic practices, with the revelation of high intraoperative blood loss, multiple complications, and protracted operative times. Training in ESS is initiated during Postgraduate Year II (PGY2) of residency at the University of California, San Diego (UCSD), under the supervision of senior author T.M.D. A unique approach to surgical anesthesia contributes to the overall safety and efficiency in the academic environment by the support of the maintenance of a bloodless operative field. This study is a retrospective review of the PGY2 ESS operative experience, which reveals that sinus surgery can be taught to...
and then performed by surgical residents with relatively short operative times, low complication rates, and minimal blood loss.

METHODS

Resident training in ESS begins with coursework, such as a weekly rhinology conference and the study of a current textbook of sinus surgery. Residents participate in the human anatomy course at the UCSD School of Medicine during which time they review sinus anatomy in cadavers. The residents are also required to demonstrate proficiency in rigid nasal endoscopy in the clinic, to augment their familiarity with intranasal anatomy, and to refine their skills in the left-handed manipulation of a rigid endoscope. The residents are then brought to the operating room, where they first observe and then participate in sinus surgery. Image guidance (Landmarkx; Medtronic, Jacksonville, Florida) is used for all endoscopic sinus procedures at the UCSD. This approach facilitates the identification of key landmarks and navigation through the paranasal sinuses on the part of the resident and also improves the ability of the attending surgeon to monitor instrument position.

Anesthesia is a critical component of bloodless sinus surgery and paramount to safe learning. After the patient is brought to the operating room and positioned on the operating room table, routine monitors are applied in accordance with American Society of Anesthesiologists (ASA) guidelines. The patient is sedated by means of 25 to 100 μg of fentanyl citrate and 1 to 2 mg of midazolam and subsequently oxygenated with 100% oxygen for 3 to 5 minutes. Induction of anesthesia is achieved with 1 mg/kg of lidocaine hydrochloride and 1 to 2 mg/kg of propofol. In patients for whom it is deemed appropriate, endotracheal intubation is facilitated by the use of 1 mg/kg of succinylcholine chloride or 0.1 mg/kg of vecuronium bromide. Anesthesia is maintained with sevoflurane and nitrous oxide, with judicious use of fentanyl, generally not to exceed a total of 100 μg for the entire case. Dexamethasone, 10 to 20 mg, is administered after induction to reduce airway edema associated with surgical manipulation (a larger dose in patients with significant obstructive sleep apnea risk) and to minimize postoperative emesis. Ondansetron, 4 mg, is administered near the end of the surgical procedure for emesis prophylaxis.

After induction the patient is rotated 180° and the head of the operating room table raised 10 cm (via reverse Trendelenburg positioning) to decrease venous pressure. The nose is initially vasoconstricted by means of a 4% cocaine solution administered via four 1 × 6-cm neurosurgical paddies. Gold solution (1% lidocaine, 0.375% ropivacaine hydrochloride, and 1:100,000 epinephrine) is then injected intranasally through a 25-gauge spinal needle attached to intravenous tubing. This typically includes a first injection adjacent to the sphenopalatine artery, a second near the superolateral attachment of the uncinate process, another in the axilla of the middle turbinate, and a third near the superior attachment of the superior turbinate. Additional injections are made along the septum and/or inferior turbinates as the operative plan dictates.

Initially, the patient is maintained in a normotensive state. The transient increase in blood pressure that occurs with the intranasal injection is not treated unless extreme. After blood pressure returns to baseline, mild hypotension is induced with a combination of increased concentrations of a volatile agent, judicious use of fentanyl, and the use of vasoactive drugs, such as β-blockers and vasodilators.

Systolic blood pressure is ideally lowered below 100 mm Hg; however, mean arterial pressure is not decreased below 85% of the baseline of the patient. It is important to maintain the blood pressure at this level during the remainder of the surgical procedure and to avoid paroxysmal elevations in systolic pressure, which result in bleeding that obscures the surgical field. This requires careful attention to the surgical procedure and anticipation of increased surgical stimulation. Similarly, if the blood pressure decreases below the desired level, it is also important to avoid overtreatment with vasopressors, which will result in transient hypertension.

The surgical plan is conceived based on preoperative assessment, but it is occasionally modified in accordance with intraoperative findings. If a septoplasty is required, it is generally performed by the attending surgeon. Residents master aspects of sinus surgery in incremental steps. If there is difficulty with a particular step, the attending physician completes that step and the resident physician resumes the operation. Generally, residents are able to perform 90% or more of each surgery after approximately 5 cases. At the completion of surgery, the ethmoids and middle meatus are suctioned free of residual clot and then sprayed with fibrin sealant (Evicel; Johnson and Johnson, New Brunswick, New Jersey). Doyle splints coated with antibiotic ointment are inserted and sutured to the membranous septum after a septoplasty.

Approximately 15 minutes before the end of the surgical procedure, sevoflurane administration is discontinued and blood pressure is allowed to revert to its normal level. Vasoactive agents remain in use for the purpose of prevention of hypertension. At the completion of the surgical procedure, residual muscle relaxation is reversed with appropriate doses of neostigmine methylsulfate and glycopyrrolate and 100% oxygen is administered until the patient regains consciousness. The patient is extubated after careful oropharyngeal suctioning when standard extubation criteria are met. Smooth emergence is imperative, and coughing or “bucking” on the endotracheal tube should be avoided to reduce the risk of bleeding at the surgical site. Deep extubation may be preferred if determined safe for an individual patient. A significant portion of patients who undergo this surgical procedure are at increased risk for obstructive sleep apnea, which may complicate emergence and extubation.

After extubation, patients are brought to the recovery room and discharged home when safely awake. Antibiotics are not routinely used. The patients return to the clinic on postoperative day 4. Doyle splints are removed, and the patients are instructed to begin twice-daily pulsatile nasal irrigation for a total of 6 weeks. They return to the clinic 3 weeks after surgery, with additional follow-up tailored to the specific needs of the individual patient.

Included in this review were all patients who underwent ESS between July 1, 2005, and June 30, 2006. PGY2 residents had acted as primary surgeons, overseen by attending faculty. With UCSD investigational review board approval, the operative reports and anesthesia records were reviewed for intraoperative data, perioperative complications, surgical times, and estimated blood loss (EBL).

The medical records of all patients who underwent ESS during the period of interest were reviewed and key data points entered into a Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, Washington). Personal identifiers were removed, but patient age, sex, and ethnicity were recorded. Preoperative findings, previous sinus surgery, surgical time, postoperative packing procedures, and complications were all recorded. Major complications were identified as ones that left the patient with residual disability (blindness or diplopia, anosmia, intracranial bleeding, hemorrhage requiring transfusion, cerebrospinal fluid leak, meningitis), or resulted in his or her death. Minor complications included hemorrhage obliging cessation of the procedure, pain, or postoperative infection. Data gleaned from anesthesia records concerned method of intubation and mode of ventilation, mean and range of intraoperative blood pressures, anesthetics, vasoressors, antibiotics, and steroids, if they were administered. Data with re-
garding EBL were collected from surgical, nursing, and anesthesia notes. The surgical value was used if it was distinguished as the highest of the 3. If it was not, the 3 values were averaged. A value of 15 mL was used in place of entries of “minimal” or “0.”

To establish the severity of the disease of the patient before surgery, maxillofacial computed tomographic scans were independently evaluated by 2 of the authors (B.K.C. and S.D.) in accordance with the Harvard classification scale, and results were calculated as the mean of the 2 scores (Table 1). Procedures were quantified based on their involvement of the various sinuses: frontal, maxillary, anterior ethmoid, posterior ethmoid (divided in accordance with their position relative to the middle turbinate and grand lamella), and sphenoid. Other procedures performed during surgery were recorded; they included septoplasty, polypectomy, turbinate reduction, and palatal procedures for obstructive sleep apnea.

### RESULTS

One hundred two patients met inclusion criteria. Their ages ranged from 13 to 85 years (mean age, 46 years). Sixty-eight of the patients were white, 11 were Hispanic, 8 were of Asian/Pacific Islander descent, 4 were black, and 11 were classified as other than the 4 preceding categories. Twenty patients were returning for their first revision surgery, and an additional 2 had undergone more than 1 previous surgery. Although 90 of these patients had received diagnoses of chronic or recurrent rhinosinusitis, 66 of all included patients had more than 1 diagnosis that qualified them for sinus surgery. Twenty-four patients presented with nasal polyposis, 21 with deviated nasal septum, 20 had nasal obstruction, 9 had turbinate hypertrophy, 6 had obstructive sleep apnea or sleep-disordered breathing, and 5 had been diagnosed as having aspirin sensitivity (Sampter triad). Sinusitis staging in accordance with the Harvard criteria based on preoperative computed tomographic scans yielded a mean score of 2.628 (SD, 1.240). Fifty-one patients (50%) had scores of 3 and above. Of the remaining patients, 39 had their sinusitis scored: 14 received scores of 2 to 2.5, 22 received scores of 1 to 1.5, and the remaining 3 had scores of less than 1. Twelve patients did not have their conditions scored because their preoperative scans were unavailable at the time of review.

A total of 893 procedures were performed for 102 patients by PGY2 residents (Table 2). On average, 5.4 (SD, 2.2) sinuses were operated on in each patient. Fifty of these procedures were polypectomies, and 41 were septoplasties. Several of these patients underwent an additional nonsinus procedure, such as pharyngoplasty, palatal implantation, tonsillectomy and adenoidectomy, seotorhinoplasty, and uvulopalatopharyngoplasty, under the same anesthetic. A total of 84 of 102 patients underwent an additional procedure that was not turbinectomy or sinusotomy. Despite these additional procedures, the mean operative time for this cohort was 1 hour 17 minutes for all procedural combinations, with a range of 30 minutes to 3 hours 55 minutes. Operative time generally decreased during the year as resident efficiency increased (Figure 1).

All patients in this series received general endotracheal anesthesia with the exception of 1 patient, who received a laryngeal mask airway (LMA). All but 4 patients received mechanical ventilatory assistance throughout the procedure. The others received ventilatory assistance spontaneously through all or part of the procedure. The combination of anesthetics used included nitrous oxide, sevoflurane or isoflurane, propofol, and fentanyl. Blood pressure was monitored throughout each case in relative hypotension. The mean (SD) maximum systolic blood pressure recorded was 113 (13) mm Hg, whereas the mean (SD) systolic blood pressure was 101 (9) mm Hg. The mean (SD) maximum diastolic blood pressure was 65 (10) mm Hg, and the overall mean (SD) diastolic blood pressure was 55 (7) mm Hg. The mean systolic blood pressure was 102 mm Hg for 21 patients with ASA I conditions, 101 mm Hg for 64 patients with ASA II conditions, and 103 mm Hg for 7 patients with ASA III conditions. Hence, ASA status did not affect the outcomes. Ten patients were excluded from blood pressure calculations on the basis of incomplete or missing anesthesia records.

The mean EBL for this series was 48 mL. Only 9 operations were accompanied by an EBL of greater than 100 mL. Of these operations, all were in patients with preoperative disease severity of at least 3.5 or in patients who required additional procedures that involved multiple surgical fields (Figure 2). In no case was EBL higher than 250 mL, and no patients required blood transfusion for operative hemorrhage. Patients who underwent polypectomy (n = 50) generated an elevated mean (SD) EBL of 56 (63) mL compared with 38 (44) mL from patients without polyps (Figure 3). Mean EBL was 32 mL in the ASA I group, 56 mL in the ASA II group, and 30 mL in the ASA III group.

### Table 1. Computed Tomographic Staging

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
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<tbody>
<tr>
<td>0</td>
<td>Less than 2-mm mucosal thickening on any sinus wall</td>
</tr>
<tr>
<td>1</td>
<td>Unilateral disease or anatomical abnormalities</td>
</tr>
<tr>
<td>2</td>
<td>Bilateral disease limited to the ethmoid or maxillary sinuses</td>
</tr>
<tr>
<td>3</td>
<td>Bilateral disease that involves at least 1 sphenoid or frontal sinus</td>
</tr>
<tr>
<td>4</td>
<td>Pansinus disease</td>
</tr>
</tbody>
</table>

### Table 2. Number of Surgical Procedures Used in the Study

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Unilateral</th>
<th>Bilateral</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinusotomies</td>
<td>Frontal</td>
<td>Maxillary</td>
<td>Anterior ethmoid</td>
</tr>
<tr>
<td>Frontal</td>
<td>5</td>
<td>29</td>
<td>63</td>
</tr>
<tr>
<td>Maxillary</td>
<td>8</td>
<td>91</td>
<td>190</td>
</tr>
<tr>
<td>Anterior ethmoid</td>
<td>8</td>
<td>83</td>
<td>174</td>
</tr>
<tr>
<td>Posterior ethmoid</td>
<td>6</td>
<td>48</td>
<td>102</td>
</tr>
<tr>
<td>Sphenoid</td>
<td>5</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>Turbinates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>6</td>
<td>84</td>
<td>174</td>
</tr>
<tr>
<td>Inferior</td>
<td>3</td>
<td>26</td>
<td>55</td>
</tr>
<tr>
<td>Septoplasty</td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polypectomy</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pharyngoplasty</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palatal implant</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>895</td>
<td></td>
<td></td>
</tr>
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</table>
No major complications occurred during any of these procedures. One patient had persistent epistaxis after surgery that was successfully treated in the recovery room and did not require a return to the operating room. Four patients were hospitalized after their procedures. Two were admitted for routine observation because of their diagnoses of severe obstructive sleep apnea. One patient with severe sleep apnea underwent an elective tracheostomy concurrent with his ESS and was admitted for routine tracheostomy care and teaching. A final patient underwent sinus surgery as part of his treatment for an orbital abscess and remained in the hospital to complete his course of intravenous antibiotics.

**COMMENT**

Currently, ESS is accepted as a safe and necessary component of resident training. At our institution, the success of this procedure is largely attributable to the maintenance of a dry surgical field. A nonbleeding nasal cavity optimizes visualization for both the trainee and the supervising surgeon and improves operative efficiency by reduction of the time spent with the use of suction in the field. This is accomplished via topical application and local injection of vasoconstriction agents, the maintenance of a relatively hypotensive state throughout the procedure, and reverse Trendelenburg positioning. If the blood pressure is allowed to rise even a single time, vasoconstriction in the nose is lost, and although the blood pressure may again be reduced, the nasal mucosa will continue to bleed. Preservation of a dry field depends also on the effectiveness of the initial vasoconstriction. It has been observed that this local epinephrine-lidocaine injection itself contributes to the establishment of a relatively hypotensive state 5 to 15 minutes after the injection. However, even under conditions of constant relative hypotension, the vasoconstrictive effect of epinephrine, our favored agent, lasts between 45 and 60 minutes. Because of this pharmacokinetic effect, surgery must be completed within this period or its benefits are lost and visualization is compromised.

In the last 2 years, we have made 2 substantial improvements to our anesthetic technique. First, an appropriately sized flexible LMA has increasingly been used in place of an endotracheal tube if considered safe for an
individual patient. This technique is advantageous in that the LMA is much less stimulating than an endotracheal tube, which reduces catecholamine release. Thus, less anesthetic is required during the maintenance phase of anesthesia, which allows for a smoother and more rapid emergence. This technique was initially met with hesitation for fear of possible tracheal contamination with blood, secretions, and irrigation fluid with the use of an LMA during this procedure. This theoretic contamination has not been realized in our practice, and anesthetic literature supports the equivalence of an LMA with a traditional endotracheal tube for this surgery.

Maintenance of mild hypotension during LMA use typically relies more on vasoactive drugs than increased dosage of the anesthetic agent to avoid significant hypercarbia during spontaneous ventilation. Second, a propofol infusion has been substituted for part or all of the sevoflurane dose, which assists with the reduction of operative blood loss and postoperative nausea and arguably speeds emergence and shortens postanesthetic care unit stay.

Endoscopic sinus surgery is not without significant risk because of its combination of limited operative view and access and proximity to critical structures. As a result, many residency programs reserve these cases for residents in their fourth postgraduate year. However, the functional ESS skill set is unique and does not necessitate prerequisite surgical experience. Glaser et al demonstrated that even slight initial advantages, such as those gleaned through prior experience playing video games, are quickly neutralized as study participants continue to practice and advance through a simulated sinus surgical program. At our institution, the bulk of these surgical procedures are performed by PGY2 residents who demonstrate competent or superior results when compared with those detailed in the available literature. The EBL is extremely low, on average less than 50 mL in our series, with the inclusion of results from 3 different primary surgeons (2 of whom, G.C.B. and S.D., are co-authors). This is compared with an average of 101 to 128 mL in patients who receive a similar anesthetic combination and more than 200 mL in another series that used volatile anesthetics. Operative times also proved low, with an average of approximately 1 hour, and included many adjunctive procedures performed with the patient under the same anesthetic. Gibbons et al demonstrated a mean of almost 80 minutes in a series of 101 patients who underwent ESS with computer assistance. Operative times decreased for all trainees during the period of interest, a trend noted by other investigators to occur with experience.

Complication rates are reported throughout the literature. Major complications are generally accepted as those that leave the patient with residual disability, such as damage to vision, brain damage (pneumocephalus, encephalocoele, abscess), and sensory derangement. Minor complications, such as persistent bleeding, orbital hematoma, cerebrospinal fluid leak, and toxic shock syndrome, generally do not leave the patient with permanent disability but may require additional intervention. Data presented in several personal series and national surveys report major complications that occur at rates of no more than 0.85%. Reports of minor complications vary widely but most range from 1% to 14%. Both Marks and Gross et al found that minor complications are affected by experience, whereas major ones are not. Our major and minor complication rates for 102 patients compete favorably with the published averages, found to be 0 and 1, respectively, with the latter composed of a single minor postoperative hemorrhage.

Our series is different from many reported in the literature in that all procedures are performed under image guidance. Although it is generally rejected as standard of care in ESS, it is broadly appreciated as helpful in the setting of revision surgery or anatomical distortion. Image-guided surgery also provides distinct advantages within the setting of a residency training program. These advantages have been investigated by Casiano and Numa, who found that for inexperienced surgeons, image-guided surgery allows more accurate identification of anatomical landmarks and a reduction in the major complication rate. It enhances the 3-dimensional understanding of the inexperienced surgeon when presented with 2-dimensional data. Some have found it to lengthen the amount of operating room time and increase the cost of the procedure but with the allowance of fewer revisions, and it has been associated with fewer major complications.

In conclusion, although ESS is a challenging procedure, it can be taught and performed safely by PGY2 residents under appropriate supervision, with excellent results and low complication rates. These results depend on rigorous preparation of residents, optimization of the surgical view through careful injections, patient positioning, and anesthesia that ensures relative hypotension. Finally, the use of image guidance increases the comfort and confidence of the trainee and attending surgeons and supports the safety of the patient.

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Author Contributions: Drs Crawley and Dent had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Crawley, Barkdull, Dent, Bishop, and Davidson. Acquisition of data: Crawley, Dent, Bishop, and Davidson. Analysis and interpretation of data: Crawley, Barkdull, and Davidson. Drafting of the manuscript: Crawley, Barkdull, Dent, and Bishop. Critical revision of the manuscript for important intellectual content: Crawley, Barkdull, Bishop, and Davidson. Administrative, technical, and material support: Crawley, Barkdull, Dent, Bishop, and Davidson. Study supervision: Barkdull, Dent, and Davidson.

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REFERENCES


