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Utilization and Dissection for Endoscopic Sinus Surgery Training in the Residency Program

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Objective: To develop an animal cadaver model that would allow residents to learn functional endoscopic sinus surgery as a complementary model.

Study Design: Prospective experimental study.

Patients and Methods: Two of our first-year residents were included in the study, and each operated on 5 sheep noses. All the routine steps of endoscopic sinus surgery were performed, except for sphenoidotomy, and their success and complication scores were recorded. The residents' performance for maxillary antrostomy, ethmoidectomy, and frontal sinusotomy in sheep cadaver noses were evaluated by the authors. Predissection and postdissection computer tomography assessed the completeness of dissection. Images were analyzed for maxillary antrostomy, frontal sinusotomy, residual ethmoid cells and partitions, and residual frontal recess cells. The first and last 5 sides of residents were analyzed together as the first 10 sides (group 1) and last 10 sides (group 2).

Results: Group 2 had significantly better outcomes for frontal sinusotomy and ethmoidectomy ($P = 0.011$ and $P = 0.003$, respectively). The mean duration of procedures for group 1 was 15.7 minutes and that for group 2 was 10.3 minutes ($P = 0.000$). The difference was not significant between the 2 groups when comparing the success rates of maxillary antrostomy and the complication rates ($P > 0.05$).

Conclusions: The nasal cavity of the sheep is anatomically similar to the human nasal cavity, and the model using sheep cadaver for endoscopic sinus surgery training is a cost-effective and useful model for the first step of the learning curve.

Key Words: Endoscopic sinus surgery, sheep nasal cavity, residency

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Endoscopic sinus surgery (ESS) has revolutionized the approach for surgery of the paranasal sinuses. The popularity of ESS has increased rapidly since its conception by Messerklinger in the late 1970s.[1] Teaching ESS in residents has become a challenge in this period.

With respect to ethical issues and practice, an attempt for live operation should not be considered as the ideal place to learn ESS. Endoscopic sinus surgery may lead to major complications, such as injury to the orbit, optic nerve, internal carotid artery, and other intracranial structures.[2] The incidence of morbidity and mortality among patients undergoing ESS has been reported to range between 4% and 17%.[3]

Gross et al[4] reported in 1979 that the ESS complication rates for nontrainees were decreasing compared with trainees. To perform a successful ESS, Stammberger advised in his speech at the 12th International ESS course in Graz that trainees should have an experience of 30 cadaver head dissections before attempting any live operation.

The standard method for teaching ESS is human cadaver head dissections. However, in many countries, supplying human body cadavers is very difficult. This may be due to the low number of cadaver donations and high costs.

There is a lack of data on the suitability of animal cadaver models for the purposes of teaching ESS. We aimed to develop a cheap and practical model using sheep nose, which can be used to teach ESS operations to residents.

MATERIALS AND METHODS

Two of our first-year residents were supervised by the authors while performing an ESS procedure on 10 sheep noses and 20 sides. Before training, theoretical information regarding sheep paranasal sinus anatomy and the steps in ESS were discussed. They also participated as assistant surgeons in many ESS operations. The sheep heads were purchased fresh from an abattoir at a cost of $5 each. The anterior 10 cm of the muzzle was removed with a saw to shorten the nasal cavity and make it resemble more like that of the human. The heads were then unfrozen, mounted in a complex instrumentation. Before any dissection, imaging of sheep heads was performed with a dual computed tomography (CT) scanner (General Electric) at 120 kV (peak) and 30 mA s. The images were obtained in the axial and coronal planes with sections of 2-mm thickness. Special attention was paid to optimal visualization of the osteomeatal complex and the frontal recess of each cadaver. The axial sections were obtained parallel to the hard palate. The coronal sections were obtained parallel to the oblique axis of the middle turbinate with the gantry tilted to 15 degrees to the canthomeatal line. Owing to the lack of a sphenoid sinus in the sheep head, the coronal images were terminated at the level of the posterior frontal sinus wall. The images obtained before any dissection were proposed as preoperative CT scans. AQ1

The participants were then asked to complete a formal endoscopic dissection on both sides of the cadaver sheep head, including maxillary antrostomy with uncinectomy, total ethmoidectomy, and frontal sinusotomy with opening of all the cells in the frontal recess. Rigid 0- and 45-degree endoscopes were used with a beam splitter

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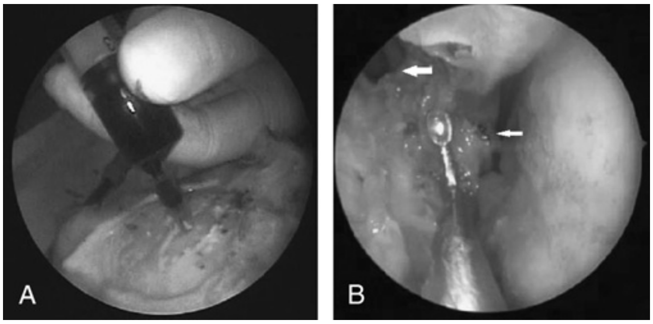

FIGURE 1. A, Supply of methylene blue into the vertex of the skull. B, Endoscopic view of the frontal sinusotomy and the skull base injury with the methylene blue leak.

attached to a television camera, allowing continuous observation by the trainer. A small hole was made externally into the vertex of the skull with the drill (Fig. 1A). A cannula was placed, and methylene blue, which was previously used for the frontal sinusotomy exercise, was then connected to run intracranially. Should the skull base be injured, it may be noted through the methylene blue leak (Fig. 1B). All these steps were observed by the authors, and complications, if any, were recorded. After each operation, the possible causes for complications were discussed. Ten cadaver heads were used for the study. Twenty cadaver sides were dissected and were included for analysis. The training period was divided into 2 steps: the first 10 and the second 10 sides for the residents. Two training periods were compared with preoperative and postoperative CT scans, success, and complication rates.

When the residents completed their dissections, the following parameters were determined by the authors: (1) site of the nose (right vs left), (2) duration of the procedure and duration of each step, and (3) complications when opening the frontal recess (cerebrospinal fluid [CSF] leak vs no complication).

Computed tomographic scans were then obtained for the second time and were designated as postoperative CT scans. All images were assessed by a radiologist blinded to the participant's subjective ESS practice level and years in practice. The comparison between preoperative and postoperative scans was made for the evidence of surgical maxillary antrostomy and frontal sinusotomy. These were designated as opened or unopened. The number of residual ethmoid and frontal recess cells and the presence of conchal iatrogenic injury were also recorded onto the database.

AQ2 Statistical analysis was performed using SPSS 15.0. The χ^2 test was used to compare the procedure's success and complication rates. The Mann-Whitney *U* test was used to compare other numerical parameters. $P < 0.05$ was considered significant.

RESULTS

Each of the 2 first-year residents performed ESS on 10 sides. For all the parameters, both residents had similar outcomes; therefore, the first and last 5 sides of residents were analyzed together as the first 10 sides (group 1) and the last 10 sides (group 2). There was no significant difference between the right and left sides ($P > 0.005$). The mean duration of the procedures for group 1 was 15.7 minutes, and for group 2, it was 10.3 minutes ($P < 0.005$). The mean duration of frontal sinusotomy and ethmoidectomy was significantly shorter for group 2. This significant difference was not present for the duration of maxillary antrostomy ($P > 0.005$). Cerebrospinal fluid leak occurred in 3 cases (30%) during frontal sinusotomy in group 1, whereas no CSF leak occurred in group 2. When comparing the success rates of maxillary antrostomy, ethmoidectomy, and frontal sinusotomy, the success rate was higher in group 2. In group 1, the success rate for maxillary antrostomy was 60%, and in group 2, it was 80%. The success rates for frontal sinusotomy were 40% and 100% for groups 1 and 2, respectively. There was a significant difference between 2 groups with regard to residual ethmoidal cells ($P = 0.003$). The mean number of unopened ethmoid cells was 1.3 for group 1 versus 0.1 for group 2. There was no significant difference for unopened frontal recess cells. The mean number of unopened frontal recess cells was 1 for group 1 versus 0.8 for group 2 ($P > 0.005$). The rate of iatrogenic injury to middle concha was 80% for group 1 and 50% for group 2. These data are presented in Table 1.

DISCUSSION

Endoscopic sinus surgery is a standard surgical intervention used to treat nasal and paranasal pathologies such as chronic sinusitis and nasal polyposis. It is commonly used in many surgical pathologies of the orbit and skull base. Complications of ESS include major complications such as injury of the orbit, optic nerve, internal carotid artery, CSF leak, meningitis, diplopia, blindness, major bleeding, and death, and minor complications such as infection, hemorrhage, synechia, osteal stenosis, loss of sense of smell, numb lips and teeth, and recurrence.[2] Endoscopic sinus surgery is a challenging surgical procedure technically because of the complex anatomic structure of the paranasal sinuses, a neighborhood with important structures, and frequency of variations, and success of surgery requires experience.[2,3] Mosher[5] described intranasal ethmoidectomy as "one of the easiest operations with which one can kill a patient" at the beginning of 20th century. Since then, many technological developments have been recorded in this field, mainly by the routine use of CT and image-guided surgery. Despite these developments, the complication rates have been reported to range between 2% and 17% in different publications.[3,6] The main factor affecting the complication rate is the experience of the surgeon. Every surgeon who learns ESS poses a certain inclination for complications.[3] Stankiewicz et al[6] reported that the complication rate of a surgeon performing ESS is 5% in the first 90 cases and 0.7% in the next 90 cases. Performing endoscopic surgery, different from open surgery, requires the use of both hands and being oriented to relations of surgical equipment and anatomic structures while using plain and angled endoscopes. In their study on participants of a cadaver dissection course, Zuckerman et al[7] assessed the effect of cadaver dissections and experience on increasing the success of surgery and reducing the complications of ESS. They found that experience was effective especially in frontal and sphenoid sinusotomy and complete ethmoidectomy. In the same study, it was reported that

TABLE 1. Outcome for Success Rates, Complication Rates, and Mean Durations of the Procedures

Parameters	Group 1	Group 2	P
Maxillary antrostomy, %	60	80	0.628
Frontal sinusotomy, %	80	100	0.011
Retained ethmoidal cells, mean	1.3	0.1	0.003
Retained frontal recess cells, mean	1	0.8	0.529
Maxillary antrostomy duration, min	5.7	4.4	0.339 AQ3
Ethmoidectomy duration, min	4.9	2.7	0.001
Frontal sinusotomy duration, min	5.1	3.2	0.002
Duration of total procedure, min	15.7	10.3	0.000
CSF leak, %	30	0	0.211
Middle turbinate injury, %	80	50	0.350

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postoperative CT investigations had a positive effect on the success of consequent surgical interventions. In our study, after each procedure, postoperative CT investigations were assessed by the residents under the supervision of the authors.

Training during ESS, which has many vital complications, causes an increase in complication rates and is ethically inconvenient.[8,9]

Resident training programs provide the opportunity for gaining surgery experience in a less stressful medium and less bloody surgical field. Resident training programs in ESS are focused on human cadaver dissections and endoscopic surgical simulations that provide the possibility of working in a bloodless field with real sinonasal anatomy.[7,10] Although human cadaver is the most convenient model for ESS training, many residents cannot perform this because of difficulties in finding cadavers and high costs. The cost of human cadaver head training per resident has been reported to be \$1520.[11] Another training model for ESS is the use of sheep cadaver model. Resident training programs on many topics have been implemented on cadaver sheep heads and reported to be beneficial.[8] The reasons for preferring cadaver sheep head have been the low cost (\$5), easy availability, resemblance of sheep's nasal cavity to that of human's, and easier manipulation as it is larger than human's.

The sheep proved to be the most useful nasal and paranasal sinus model for the eligibility to treat ESS. Before the study, the authors examined sheep's anatomy and explained the method and steps of surgery to the residents by performing ESS in sheep. The nasal cavity of the sheep was seen to be very similar in appearance, although somewhat wider, and the main sinuses lie at approximately
F2 the same orientation as they do in humans (Fig. 2). To minimize this disadvantage, the anterior part was shortened before the procedure. Maxillary antrostomy was more difficult because the middle concha was closer to the lateral wall and uncinate process than that of human, and the procedure was more difficult because of its spiral and bullous structure. In some procedures, it was necessary to perform partial resection on the middle concha. Therefore, the rate of complication of concha injury was higher both in the first and in the last 10 sides. Working in a bloodless field was an advantage for training, as it has been the case in all cadaver models, and it significantly shortened the operation time. The orbit was at the lateral side of the sheep, its medial wall was not adjacent to the lateral nasal wall, and these diminished the risk of orbital complication. The lack of a significant difference between the first and the second 10 sides for maxillary antrostomy supported this information. Owing to the lack of a sphenoid sinus, the sphenoidotomy procedure has no value. The head of the horse is a good model for the human sphenoid sinus. Obtaining horse heads is more difficult with respect to cost and

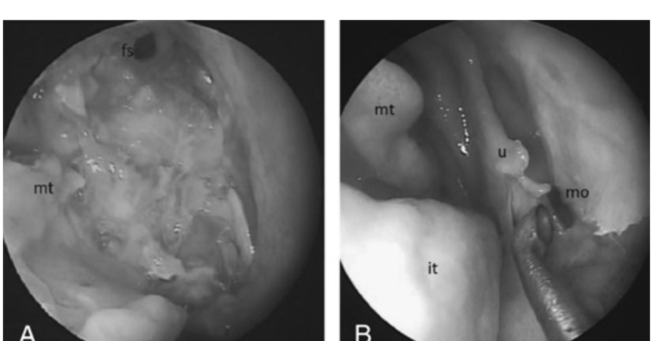

FIGURE 2. Endoscopic view of the maxillary antrostomy (A) and frontal sinusotomy (B) being performed on the model. fs, indicates frontal sinus; it, inferior turbinate; mo, maxillary ostium; mt, middle turbinate; u, uncinate process.

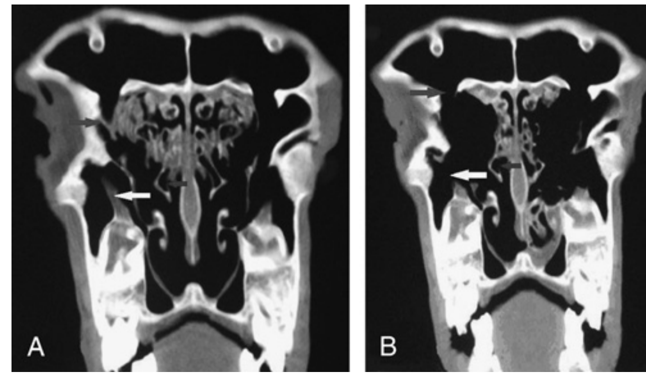

FIGURE 3. Participant ESS sheep cadaver dissection CT scans: before (A) and after (B) surgery. Maxillary antrostomy with uncinectomy (white arrow), frontal sinusotomy (green arrow), AQ5 and ethmoidectomy were successfully performed on the postoperative cadaver specimen. The specimen has no middle turbinate injury (red arrow).

ethical issues.[13] Gardiner et al[8] assessed the success of opening the frontal recess in a cadaver sheep study. They used frontal sinus trephination on the superomedial orbital rim for assessment. They reported that the sheep model was beneficial for comprehending the basic psychomotor skills in endoscopic surgery and for learning the basic steps of ESS. However, in the mentioned study, the surgical success or failure was not assessed with the objective criteria. We determined the success criteria by preoperative and postoperative CT scans (Fig. 3). One of the most important complications of ESS F3
is dura injury, CSF leak, and the increased risk for meningitis. In 3 procedures, the residents observed that methylene blue leaked to the nasal cavity through the hole in the skull, which had been opened previously by the residents to understand the relationship with the skull base when studying the frontal recess. All these 3 procedures occurred within the first 5 procedures. After these procedures, CT investigations were more carefully examined by the residents, and frontal sinusotomy was completed more successfully without the complication of opening the frontal recess cells during the last procedures, and the operation time was significantly shorter.

The first-year residents had no experience in the use of an endoscope in our study. However, they had assisted many ESS operations. Frontal sinus training was the most important step of the study. Residents had difficulty working with a 45-degree-angled endoscope during the first procedures. However, it was observed that they were more oriented toward the use of an angled endoscope during the last procedures. The rate of opening the frontal recess was significantly higher in the last 10 sides than in the first 10 sides in preoperative and postoperative CT comparisons, and the number of residual frontal recess cells was lower; these support the success of the sheep model in frontal sinus surgery and the skill for using the angled endoscope.

The cadaver sheep model is similar to the human nose, both in size and in anatomic structure, and is similar to the quality of human tissue in appearance. These are the properties of an ideal ESS training model. Surgical equipments have similar technical challenges to those used in real operations. However, it is necessary to work on human cadavers to learn human nasal and paranasal sinus anatomy and further endoscopic surgical techniques.

CONCLUSIONS

There was a significant difference between the first 10 sides and the second 10 sides in terms of frontal sinusotomy, residual frontal recess cells, and operation time in ESS that was performed

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by first-year residents in sheep cadavers. It was found to be beneficial to use the sheep cadaver model, an inexpensive and easily available material for teaching residents the basic steps of ESS and the orientation in working with plain and angled endoscopes.

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