A Sustainable and Scalable Multidisciplinary Airway Teaching Mission: The Operation Airway 10-Year Experience

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Abstract

Objective. To address whether a multidisciplinary team of pediatric otolaryngologists, anesthesiologists, pediatric intensivists, speech-language pathologists, and nurses can achieve safe and sustainable surgical outcomes in low-resourced settings when conducting a pediatric airway surgical teaching mission that features a program of progressive autonomy.

Study Design. Consecutive case series with chart review.

Setting. This study reviews 14 consecutive missions from 2010 to 2019 in Ecuador, El Salvador, and the Dominican Republic.

Methods. Demographic data, diagnostic and operative details, and operative outcomes were collected. A country’s program met graduation criteria if its multidisciplinary team developed the ability to autonomously manage the preoperative huddle, operating room discussion and setup, operative procedure, and postoperative multidisciplinary pediatric intensive care unit and floor care decision making. This was assessed by direct observation and assessment of surgical outcomes.

Results. A total of 135 procedures were performed on 90 patients in Ecuador (n = 24), the Dominican Republic (n = 51), and El Salvador (n = 39). Five patients required transport to the United States to receive quaternary-level care. Thirty-six laryngotracheal reconstructions were completed: 6 single-stage, 12 one-and-a-half-stage, and 18 double-stage cases. We achieved a decannulation rate of 82%. Two programs (Ecuador and the Dominican Republic) met graduation criteria and have become self-sufficient. No mortalities were recorded.

Conclusion. This is the largest longitudinal description of an airway reconstruction teaching mission in low- and middle-income countries. Airway reconstruction can be safe and effective in low-resourced settings with a thoughtful multidisciplinary team led by local champions.

Keywords

global health, surgical mission, surgical teaching, low and middle income country, pediatric airway

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As of 2017, 1.7 billion children remain without access to surgical care. In fact, <3% of the pediatric population in low-income countries and <8% in lower-to-middle-income countries have access to surgical care, according to criteria from the Lancet Commission on Global Surgery. This profound gap in access to health care for...
such a vulnerable population has led to a call from the commission to achieve a target of 80% coverage of essential surgical and anesthesia services per country by 2030. Improving surgical access to care can be a very cost-effective solution to improving disability-adjusted life years.

Unfortunately, despite the best intentions, many international efforts have failed to achieve their desired long-term effect. Short-term surgical mission trips have lacked adequate publication of long-term outcomes data, often due to limited record keeping during these trips. Additionally, poor coordination with local health care professionals can prevent even a well-organized surgical team from improving long-term surgical care in a region. The field of otolaryngology is no different, and appropriate, thoughtful interventions are necessary to improve the burden of otolaryngologic disease in the developing world.

Global health engagement efforts in pediatric otolaryngology are a growing trend, with >50% of humanitarian travel grants awarded by the American Academy of Otolaryngology–Head and Neck Surgery Foundation going to pediatric otolaryngology. Pediatric airway surgery is, by nature, fundamentally different in a low-resourced setting than in the technology- and resource-rich environments in which many US-trained providers are used to practicing. The first multidisciplinary pediatric airway surgical mission in a low-resourced setting was described in 2014 by Rogers et al. Since that time, this effort has expanded and evolved as we have learned valuable lessons from our host countries. Here, we describe the long-term outcomes data for this teaching mission, the specific low-resource airway modifications that the team has utilized, and the interventions and educational model necessary to graduate countries into pediatric surgical airway autonomy.

**Methods**

A consecutive case series with chart review was performed of the past 10 years of missions conducted by Operation Airway, a multidisciplinary pediatric aerodigestive and airway reconstruction team. The team consists of a pediatric otolaryngologist, a pediatric intensivist, an anesthesiologist, an intensive care and floor nursing staff, speech-language pathologists, and a respiratory therapist. This project received Institutional Review Board approval through the Massachusetts Eye and Ear Infirmary.

**Selection Criteria**

A preintervention team meeting was held among the mission coordinator and the 2 codirectors of the program (C.J.H., P.H.Y.) prior to selecting a country. Country selection was based on the following criteria: local surgeon interest, presence of a stand-alone children’s hospital, intensive care unit capacity, and surgical and anesthesia capacity for complex cases. Once a country was identified and the interest was mutual, a preintervention needs assessment was conducted in person by the 2 codirectors and the mission coordinator. This included touring the hospital facilities and gauging the local needs and expectations to ensure that the country was a good fit for our model. After a country was formally selected, the local surgeons traveled to Boston for a premission meeting to map out the specific plan and discuss goals and expectations for that country’s particular needs. To facilitate appropriate communication between teams and ensure cultural competency of the host team, the mission coordinator was an individual employed from the local site.

**Graduation Criteria**

As the primary nature of this mission is surgical teaching, we created criteria that a country’s team was required to meet to graduate from the Operation Airway experience (Table 1). To do so, the local team needed to achieve the ability to autonomously manage the clinical workup, including appropriate diagnoses and treatment plans. It was required to autonomously manage a preoperative huddle to ensure that surgeons, anesthesiologists, and operative nursing staff were on the same page prior to surgery. Additionally, it needed to be able to complete the surgical
procedures of bronchoscopy, LTR (including costal cartilage graft harvest), tracheal resection, and slide tracheoplasty independently and safely. The anesthesia team was required to appropriately identify and complete procedures that required spontaneous ventilation, tubeless anesthesia, and/or total intravenous anesthetic. The local team was required to successfully manage the postoperative care of these patients, including use of local pediatric intensive care unit resources and personnel. This included facilitating appropriate family understanding of the surgical intervention and necessary postoperative care. Independent management of patients from their preoperative workup to surgical reconstruction and postoperative care without the presence of the teaching team (to be done between visiting missions from the host country) Commitment to continuing to treat the underserved and impoverished

Results
A total of 135 procedures were performed on 90 patients during 14 consecutive missions from 2010 to 2019 in Quito, Ecuador; San Salvador, El Salvador; and Santa Domingo, Dominican Republic. The mean ± SD age of the patients at the time of their operation was 7.8 ± 6.8 years, and 63% were male. Children who received operations were from Ecuador (n = 24), the Dominican Republic (n = 51), and El Salvador (n = 39). Some children received multiple operations (ie, bronchoscopy then LTR); therefore, the total number of cases is more than the number of children.

A variety of airway surgery was performed in each country (Table 2). Five patients required transport to the United States for quaternary-level care (2 cricotracheal resections, 1 LTR, 1 tracheopexy, and 1 bronchoscopy/juvenile recurrent respiratory papillomatosis debridement). A total of 36 LTRs were performed: 6 single-stage, 12 one-and-a-half-stage, 18 double-stage.

The decannulation rate for all eligible patients was 82%. Of the eligible surgery done in Ecuador, patients achieved a 100% decannulation rate (13 of 13); in the Dominican Republic, 83% (20 of 24); and in El Salvador, 71% (10 of 14). Decannulation rates by operation were 83% (5 of 6) for single-stage LTR, 92% (11 of 12) for one-and-a-half-stage

### Table 1. Graduation Criteria, Expectations of the Local Team, and How the Host Team Is to Assess Completion.

<table>
<thead>
<tr>
<th>Local team to demonstrate</th>
<th>Host team means of assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous management of the clinical workup, including appropriate diagnoses and treatment plans</td>
<td>Assessed during preoperative workup and plan provided by the local team to the host team at the beginning of mission by the host otolaryngologist team</td>
</tr>
<tr>
<td>Autonomous management of a preoperative huddle to ensure that surgeons, anesthesiologists, and operative nursing staff were on the same page prior to surgery</td>
<td>Assessed by direct observation of preoperative huddle by the host surgical team, nursing team, and anesthesia team</td>
</tr>
<tr>
<td>Sufficiency in surgical bronchoscopy, laryngotracheal reconstruction (including costal cartilage graft harvest), tracheal resection, and slide tracheoplasty (when applicable) independently and safely</td>
<td>Assessed by direct observation of patient outcomes by the host surgical team</td>
</tr>
<tr>
<td>Appropriately identify and complete procedures that require spontaneous ventilation, tubeless anesthesia, and/or total intravenous anesthetic (administered via the anesthesia team)</td>
<td>Assessed by direct observation of patient outcomes by the host anesthesia team</td>
</tr>
<tr>
<td>Successful management of the postoperative care of these patients, including use of local pediatric intensive care unit resources and personnel</td>
<td>Assessed by direct observation of patient outcomes and care by the host pediatric intensivist team (including pediatric intensive care nursing)</td>
</tr>
<tr>
<td>Appropriate family understanding of the surgical intervention and necessary postoperative care</td>
<td>Assessed by direct observation of patient outcomes by the host floor nursing team</td>
</tr>
<tr>
<td>Independent management of patients from their preoperative workup to surgical reconstruction and postoperative care without the presence of the teaching team (to be done between visiting missions from the host country)</td>
<td>Assessed by chart review and communication with local providers by the host otolaryngology team and the mission coordinator</td>
</tr>
<tr>
<td>Commitment to continuing to treat the underserved and impoverished</td>
<td>Assessed by the host mission coordinator</td>
</tr>
</tbody>
</table>
LTR, and 66% (12 of 18) for double-stage LTR. When the decannulation rate was corrected to include only surgery done >1 year ago (to allow a year for the patient to decannulate), the decannulation rate improved from 83% to 89% in the Dominican Republic. This was the only country in which this number changed, as all other missions were >1 year ago.

Two countries met graduation criteria after assessment by our multidisciplinary team and were deemed to be self-sufficient in pediatric airway surgery and management (Ecuador in 2014 and the Dominican Republic in 2019). Teaching efforts in El Salvador are ongoing, and the decannulation rate will likely improve as this cohort of patients is given more time after their surgery to recover and decannulate. Our most robust surgical trip in El Salvador took place recently, and although these data were excluded from this study, these results will likely improve the country’s statistics. Notably, there have been no mortalities during these surgical efforts.

**Low-Resource Airway-Specific Tool Modifications**

To facilitate safe, sustainable practices after the teaching team left, we developed several airway-specific modifications that utilize local resources. As flexible and rigid fiberscopes, video-assisted laryngoscopy, and so on are not as readily available in low- and middle-income countries, the mission team has relied on alternate means to secure an airway in an emergency. Each technique was taught to the local team in person.

A needle cricothyrotomy kit can be assembled with a 3-mL saline syringe (lure lock), a saline flush, a 14-gauge angiocatheter, and a 7-0 ETT (Figure 1). The inner lumen of the 3-mL syringe is removed, and the top half of the syringe is cut off to remove dead space. This connects to the top of the 7-0 ETT. We have found that a 7-0 ETT has an airtight seal when placed inside a 3-mL syringe. The 14-gauge angiocatheter is connected to the saline flush. The practitioner can then insert the 14-gauge angiocatheter into the airway, drawing back on the saline flush to ensure that the catheter is in the airway. Once this has been achieved, the angiocatheter remains in the airway and can be attached to the 3-mL syringe, and the ventilator will connect to the 7-0 ETT.

A tube within a tube is necessary for older patients with a subglottic stenosis that may require intubation with a smaller-diameter ETT (Figure 2). Depending on the age of

<table>
<thead>
<tr>
<th>Type of surgery performed</th>
<th>El Salvador</th>
<th>Dominican Republic</th>
<th>Ecuador</th>
<th>United States</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Laryngotracheal resection</td>
<td>10</td>
<td>19</td>
<td>6</td>
<td>1</td>
<td>36</td>
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<tr>
<td>Cricotracheal resection</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Tracheal resection</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Tracheopyex</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Tracheotomy</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Suprastomal granuloma excision</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Four gland duct ligation</td>
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<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Tracheocutaneous fistula closure</td>
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<td>2</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Bronchoscopy</td>
<td>18</td>
<td>16</td>
<td>11</td>
<td>1</td>
<td>46</td>
</tr>
<tr>
<td>Balloon dilation</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>JRRP debridement</td>
<td>6</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>2</td>
<td>7</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td>55</td>
<td>30</td>
<td>5</td>
<td>132</td>
</tr>
</tbody>
</table>

Abbreviation: JRRP, juvenile recurrent respiratory papillomatosis.

![Figure 1. Needle cricothyrotomy kit assembly. A saline flush connected to a 14-gauge angiocatheter is used to enter the airway. This is connected to a 3-mL saline syringe connected to the end of a 7-0 ETT.](image1)

![Figure 2. A tube within a tube is necessary for older patients with a subglottic stenosis that may require intubation with a smaller-diameter ETT.](image2)
the patient, the smaller ETTs that may be necessary to intubate an older patient with a grade 2 or 3 subglottic or tracheal stenosis have inadequate length. Therefore, a 5-0 ETT can be sutured to the cut end of a 3-0 ETT to facilitate intubating this patient population. Similarly, a 4-5 ETT and a 2.5 ETT can be used should one need a smaller size. A pediatric stylet is used as the guide for determining the appropriate length of the modified ETT.

Portable suction machines are a necessity for patients with recent tracheotomy or airway surgery. Suction machines that rely on electricity are not feasible in an environment where consistent electricity is a luxury. Therefore, our team has introduced handheld suction machines that generate vacuum action from the hand-pumping motion (Figure 3).

Educational Resources

Our educational methods evolved after suggestions from the local team. In-person educational sessions were useful; however, after the team left, the local team sought a way to continue its medical education. Internet and cell phone distribution have become nearly ubiquitous in even the most underresourced areas. Therefore, we created an educational video module series accessible to any practitioner with a cell phone and internet access via QR codes (quick response). Modules included the following: operating room setup, evaluation and management of neonatal and pediatric airway stenosis, airway surgery and reconstruction, complications in airway surgery, swallowing disorders and aspiration prevention, proper sizing and use of cuffed ETTs, taping the ETT in place, care of the intubated child and perioperative considerations of the surgical airway patient, and postoperative tracheotomy care. All video modules were created in Spanish and English, with subtitles available in English, French, Arabic, and Spanish. A prior study, via pre- and postcurriculum testing, validated provider improvement after these video modules. Additionally, patient and family teaching modules included video demonstration of the following: how to adjust your infant’s tracheostomy ties, how to change your infant’s tracheostomy ties, inserting your infant’s new tracheostomy, positioning your baby to care for the tracheostomy, and suctioning your infant’s tracheostomy (Figure 4).

A specific nurse-based curriculum was created to improve nurse competencies and confidence—a critical part of developing autonomy. A nurse-to-nurse curriculum that teaches the fundamental care of children with tracheostomy was
informed by premission online testing of their knowledge of tracheostomy care. Training of floor nurses, medical students, and house staff to independently manage suction machines, oxygen masks, and basic monitoring equipment was completed and supplemented with video training. Parents who share care responsibilities are encouraged to watch the videos. Nurses are tested for knowledge of tracheostomy care before and after the nursing curriculum is presented, and follow-up teaching is directed at areas in which knowledge is lacking. Additionally, feeding therapists and parents were trained to implement diet modifications using local resources and ingredients, when applicable, to maintain pulmonary stability. Last, in El Salvador and the Dominican Republic, local radiologists were trained with local equipment to perform basic videofluoroscopic swallow studies, which facilitated safe oral feeding recommendations.

Learners were from multiple disciplines (surgeons, anesthesiologists, intensivists, nursing, and speech-language pathologists) and were educated at multiple levels of training in each country. For example, in El Salvador, attendings (n = 7), residents (n = 39), and fellows (n = 7) all participated in the educational program. The ratio of residents to attendings/fellows was dependent on the country’s medical education model. A prior study in El Salvador validated this educational module and showed improved pre- to postcurriculum education scores (18%), a change that was significant among all disciplines (surgeons, anesthesiologists, intensivists, and speech-language pathologists).14

Discussion

This is the first report of long-term outcome data in a multidisciplinary pediatric airway teaching mission. The 82% decannulation rate achieved by the mission is similar to those in developed countries with vastly different health care and telecommunication infrastructure.16 Our rate of decannulation for single-stage LTR was 83%, and that for double-stage LTR was 66%. The one-and-a-half-stage approach, which was developed for low-resourced settings, had the best decannulation success at 92%.12,17 As most developed countries are not utilizing the one-and-a-half-stage approach, our true decannulation rate of a double-stage procedure should include the one-and-a-half-stage approach. Therefore, the combined approach (one-and-a-half stage and double stage) is 77%. Additionally, many of the double-stage procedures were of higher grade (many grade 4 stenoses), a factor likely contributing to the lower decannulation rate. This stenosis grade was excluded from the study due to inconsistent reporting in the earliest missions.

Given the resource limitations in each country and the teaching nature of the missions, the slightly lower decannulation rate of 82% is quite reasonable. In fact, this rate is similar to that of other countries with limited resources that have reported outcomes after LTR (Brazil, 86%).18 Additionally, our data include surgery done on recent missions. As more time passes, these patients will have time to heal from surgery and ultimately decannulate. This is evidenced by the significant improvement in the decannulation
rate (82% to 89%) in the Dominican Republic when surgery completed <1 year ago was excluded. Therefore, we expect that the decannulation rate in El Salvador, the most recent country in which a mission was undertaken, will improve with time. The 2 countries with the higher decannulation rates (Ecuador, 100%; Dominican Republic, 89%) have met graduation criteria.

Pediatric airway surgery is inherently dangerous due to the tenuous patient population, especially when performed in a setting with limited resources. Our team has recorded no mortalities during the 10 years in which we have been teaching airway surgery. This is possible due to the team approach to patient care. Pediatric intensive care units in the developing world are fraught with challenges. In fact, in El Salvador, there is a 24% all-cause mortality for any pediatric patient in the intensive care unit.14 Although the elevated mortality rate was multifactorial, the accidental decannulation/extubation rate was 31%. Therefore, although teaching the subtle nuances of complex pediatric airway surgery is important, additional public health measures can significantly decrease airway-related mortality in these regions. These cost-effective interventions include appropriately sizing and securing ETTs.14

This study is limited in that it is a retrospective review of multiple types of medical records (written and electronic). As such, information that was inconsistently documented from year to year, due to changing forms of charting and intercountry variances, was not reported. The decision to exclude this information was made to ensure that the data reported were clean and accurate. However, this prevents this study from drawing conclusions about the effect that comorbidities, grade of stenosis, and presenting diagnosis have on decannulation. Major and minor morbidities are recorded in the electronic health record; however, this was introduced only partially through the 10-year experience, and so these data are not included in this report.

The lack of access to surgical pediatric airway care among children in low- and middle-income countries is vast.1,19 Surgical competency in the pediatric airway in which a local team autonomously manages the preoperative workup, operative care, and postoperative management (including family-centered care) can be facilitated by multidisciplinary teaching missions. Future directions include expanding this scalable mission to other low-income countries in need of comprehensive multidisciplinary pediatric airway management.

Conclusion
Airway reconstruction can be safe and effective in low-resourced settings with a thoughtful multidisciplinary team led by local champions. Strategies such as online education in the local language, discipline-to-discipline teaching, and graduated autonomy foster a scalable and sustainable model.

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Author Contributions
Asitha D. L. Jayawardena, study design, data collection, analysis, manuscript drafting, editing, and finalization; Zelda J. Ghersein, data collection, analysis, manuscript editing and finalization; Marcos Mirambeaux, data collection, analysis, manuscript editing and finalization; Jose A. Bonilla, data collection, analysis, manuscript editing and finalization; Ernesto Quiñones, data collection, analysis, manuscript editing and finalization; Evelyn Zablah, study design, manuscript editing, finalization; Kevin Callans, data collection, analysis, manuscript editing and finalization; Marina Hartnick, data collection, analysis, manuscript editing and finalization; Nita Sahani, data collection, analysis, manuscript editing and finalization; Makara Cayer, data collection, analysis, manuscript editing and finalization; Cheryl Hersh, data collection, analysis, manuscript editing and finalization; Thomas Q. Gallagher, data collection, analysis, manuscript editing and finalization; Phoebe H. Yager, study design, data collection, analysis, manuscript editing and finalization; Christopher J. Hartnick, study design, data collection, analysis, manuscript editing and finalization

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