Since the safety and feasibility of transoral robotic surgery (TORS) was established several years ago, its role in head and neck surgery has been rapidly expanding. Transoral robotic surgery has been shown to be a safe and effective option in the diagnosis and treatment of oropharyngeal carcinoma, as well as for obstructive sleep apnea in the adult population. Another application of TORS includes removal or biopsy of the lingual tonsils, an anatomic location that has presented a challenge to visualize with the traditional surgical approach.

While there is a clearly established role in adult head and neck surgery, little is known with respect to the role of TORS in the pediatric population. Rahbar et al first described robotic surgery as a feasible option for the pediatric airway, but access to oropharyngeal structures was limited by the size of the surgical instruments. Since that time, advances in robotic technology have allowed miniaturization of the instrumentation, which has dramatically expanded the scope of surgical options.

We have recently performed TORS resection of the tongue base in the pediatric population without complications and with acceptable functional outcomes. Here we present our experience with TORS lingual tonsillectomy, with spe-
specific attention to describing the learning curve and complication profiles in this patient population.

Methods

With institutional review board approval from the University of Pittsburgh Medical Center, the operative medical records for 16 children who underwent robotic-assisted lingual tonsillectomy from March 1, 2011, through December 31, 2012, at a tertiary care children’s hospital were searched. Patients undergoing secondary procedures at the time of surgical intervention were also included. Collected outcome measures included demographic data, comorbidities, robot docking time, operative time, estimated blood loss, and postoperative course, including complications in the immediate and longer-term postoperative period.

All patients underwent oral or nasal endotracheal tube intubation that did not obstruct the necessary view of the oropharyngeal anatomy. The surgeon (U.D.) selected the retractor used based on individual patient anatomy, choosing the Feyh-Kastenbauer, Dingman, or McIvor retraction device. The da Vinci Surgical System (Intuitive Surgical, Inc) was brought into the operative field (Figure 1 and Figure 2). In all cases, a 5-mm Maryland blade, 5-mm spatula cautery, and a 12-mm 3-dimensional endoscope were used. Surgical technique did not differ from lingual tonsillectomy methods previously described in the literature.6,9

For purposes of data analysis, the 16 patients were divided into 3 groups: the first 5 surgical cases performed, the next 5 cases, and the final 6 cases. These 3 groups were then compared head-to-head with respect to robot docking time, operative time, and estimated blood loss to assess each parameter as a function of increasing case number. With respect to robot docking time, 2 patients had no recorded docking time and were excluded from docking time analysis. For operative time, 1 patient had an inaccurately recorded time and was excluded from operative time analysis. One-way analysis of variance and Tukey-Kramer post hoc testing were used to analyze the results, with \( P < .05 \) considered significant. Calculations were completed using GraphPad Prism software, version 5.0 (GraphPad Software, Inc).

Results

Of the 16 patients who underwent robotic-assisted lingual tonsillectomy, 11 (69%) were male and 5 (31%) were female. Mean age was 12 years (range, 5-19 years). Indications for surgery were obstructive sleep apnea (11 patients, 69%), dysphagia (2 patients, 13%), upper airway obstruction (1 patient, 6%), recurrent tonsillitis (1 patient, 6%), and exercise-induced breathing difficulty (1 patient, 6%). Comorbidities in our population included gastroesophageal reflux disease (6 patients, 38%), Down syndrome (4 patients, 25%), obesity (4 patients, 25%), asthma (2 patients, 13%), Noonan syndrome (1 patient, 6%), and congenital idiopathic dystonia (1 patient, 6%). Two patients had a preexisting tracheotomy tube and percutaneous endoscopic gastrostomy tube in place. All patients had failed medical therapy before surgery was considered. Eleven patients (69%) had undergone a prior tonsillectomy and adenoidectomy without adequate resolution of symptoms.
With respect to anesthesia, all patients were intubated with an endotracheal tube. Oral and nasal endotracheal intubation was performed in 8 and 6 patients, respectively; a preexisting tracheostomy was cannulated in 2 patients. Intubation did not significantly obstruct visualization of the oropharyngeal anatomy or limit the ability of the robotic instruments to perform optimally. No patient required the placement of a tracheotomy tube.

The optimal view of the oropharynx was achieved with a retraction device that depended on individual patient anatomy. The Dingman retractor was used in 9 patients, the McIvor retractor in 6 patients, and the Feyh-Kastenbauer retractor in 1 patient. After achieving an optimal view, the da Vinci Surgical System was docked to the bedside. Mean docking time for all cases was 6 minutes. The mean docking time for the first 5 cases performed was 9 minutes (Figure 3). This shortened to a mean of 3 minutes for the next 5 cases and 4 minutes for the final 6 cases. A statistically significant difference was observed ($P < .05$) between cases 1 to 5 and 6 to 10, as well as between cases 1 to 5 and 11 to 16, while the difference between cases 6 to 10 and 11 to 14 was not significant.

Robotic-assisted lingual tonsillectomy was then successfully performed in all patients. A mean of 5.9 mL (range, 2-10 mL) of estimated blood was lost. The first 5 cases had a mean estimated blood loss of 7.4 mL, which decreased to 4.4 mL and 5.8 mL ($P < .05$) during the next 5 and last 6 cases, respectively (Figure 4). While estimated blood loss decreased with increasing case number, this difference was not statistically significant. Mean operative time for robotic-assisted lingual tonsillectomy was 34 minutes (range, 13-51 minutes). The first 5 cases had a mean operative time of 38 minutes; the next 5 cases, 30 minutes; and the last 6 cases, 34 minutes (Figure 5). These times were not statistically different from one another ($P > .05$).

With the exception of 1 patient (see the Discussion section), all patients were extubated without complication in the operating room on completion of the case. Median length of hospital stay among all patients was 1 day (range, 1-13 days). Ten patients (63%) were admitted to the intensive care unit from the operating room and had a median stay of 1 day (range, 0.5-13 days) in the intensive care unit before transfer. Ten patients (63%) were discharged on the first postoperative day.

Following discharge, the postoperative course was complicated by bleeding from the operative site (2 patients), pneumonia (2 patients), fever of unclear etiology (1 patient), and poor pain control (4 patients). Follow-up visits were scheduled 4 to 6 weeks after surgical intervention. Complications were minimal at this time, with 2 patients experiencing weight loss secondary to poor oral intake in the initial postoperative weeks and 1 patient experiencing a gagging sensation when eating. The remaining patients tolerated a full preoperative diet without complications. No patients required percutaneous endoscopic gastrostomy tube placement or tracheostomy in the postoperative period.

Discussion

In 2007, Rahbar et al attempted laryngeal cleft repair in 5 children, but 3 cases could not be completed because of limitation of visualization and insufficient space to maneuver instruments. While our population of patients consisted of children undergoing lingual tonsillectomy rather than laryngeal cleft repair, each case attempted was successfully completed. Although the surgical intervention differed, our success is also likely attributable to the use of smaller tools (5-mm instruments and a 12-mm endoscope), as well as the retractor, which provided maximal visualization and creation of space in the oropharynx. Likewise, since space is a premium in pediatric airway cases, endotracheal tube use may seem to impede access to key structures. However, placement of an oral or a nasal endotracheal tube of the appropriate size in each of our patients did not hinder the ability of the instruments to attain maximal freedom of movement.
With the introduction of the da Vinci Surgical System into surgical practice, a certain learning curve is to be expected. Robot docking times were consistent with the expected learning curve, showing a mean time that significantly decreased from the first 5 cases to the next 5 cases. Times then plateaued as operating room staff became proficient at docking. Estimated blood loss also correlated with experience as case number increased, although this trend was not significant. A similar trend would be expected for operative times, which differ from that seen in our data. In our series, the primary surgeon (U.D.), who had performed many adult robotic head and neck cases, performed each case with a pediatric otolaryngologist (D.M.). This initial familiarity with the equipment and procedure allowed for a steep learning curve.

Two patients had a postoperative course complicated by bleeding from the operative site. These patients were readmitted for observation, during which no further bleeding occurred. Neither child required further surgical intervention. Another patient with a medical history of congenital idiopathic dystonia was readmitted on postoperative day 6 with fever of unclear etiology and severe agitation. While the tongue base showed no evidence of infection, he was started on antibiotics, and the source of the febrile illness was not elucidated. Two patients were discharged home on nasal cannula oxygen, which was discontinued by the time of follow-up.

One patient with a complex medical history, including Noonan syndrome, percutaneous endoscopic gastrostomy tube feeding requirements, and a tracheotomy tube, had a postoperative course complicated by respiratory failure secondary to atelectasis and pneumonia. He spent 13 days in the intensive care unit and was successfully extubated on postoperative day 6. He was transitioned back to his preoperative tube feeding regimen and had no long-term sequelae.

While polysomnography is not the current standard of care, it is strongly advised following surgical intervention indicated for obstructive sleep apnea. Two patients in our cohort who underwent lingual tonsillectomy for obstructive sleep apnea had a postoperative polysomnogram that showed resolution of obstruction and an apnea-hypopnea index within normal limits.

The 3-dimensional endoscopic view, freedom of motion of microinstruments, and filtering of tremor are well-established advantages of robotic surgery for head and neck cases. With respect to performing lingual tonsillectomy, the surgical robot allows the creation of a clean dissection plane, which provides unmatched exposure of the tongue base musculature. In addition, the 3-dimensional endoscopic view affords magnification of the working area, allowing visualization of fine structures, including the glossopharyngeal nerve, that are difficult to identify otherwise (Figure 6).

While robotic surgery has clear-cut advantages over the traditional approach, the economic feasibility of this novel technology is the principal limitation for widespread adoption as a treatment modality. With a high initial cost for equipment and training, the necessity to replace proprietary instrumentation for continued use is even more worrying to some. While these costs are theoretically offset by the decreased operating room time, shorter length of hospital stay, and lower readmission and complication rates, to our knowledge, no large-scale cost analysis studies have been performed to date. However, of the 25% of US hospitals that own a da Vinci Surgical System, an estimated 65% of departments do not use the available technology. This speaks to the need for proper hospital selection—namely, large, referral-based tertiary care centers that will generate the caseload to make this expensive technology an economically sound investment.

Conclusions

Our institution’s experience with robotic-assisted lingual tonsillectomy has shown positive, consistent results with an acceptable operative course and postoperative complication profile. Our data showed a definite surgical learning curve.
with respect to robot docking time, and a similar trend was demonstrated with respect to estimated blood loss. Operative time would presumably follow this same trend assuming the surgeon had no previous experience with robotic surgery. Overall, the learning curve plateaued by completion of the first 5 cases, indicating that the robotics skill set is acquired within the first several operative cases. As such, the learning curve associated with robotic surgery should not be viewed as a barrier to successful incorporation in surgical practice.

While our experience has shown encouraging results for performing pediatric robotic-assisted lingual tonsillectomy, we believe TORS holds great potential for a multitude of pediatric airway interventions. Although space continues to demonstrate exciting potential. technology, robotic incorporation in otolaryngology surgical practice will undoubtedly continue to expand. While large-scale cost analysis studies are still needed to fully elucidate the cost vs benefit of this novel technology, robotic incorporation in otolaryngology surgical practice continues to demonstrate exciting potential.