Learning Curve for Transoral Robotic Surgery
A 4-Year Analysis

Hilliary N. White, MD; John Frederick, BS; Terence Zimmerman, BS, MPH; William R. Carroll, MD; J. Scott Magnuson, MD

Importance: As new institutions incorporate transoral robotic surgery (TORS) into their everyday practice, it is helpful to have a timeline reference of expected goals to follow as their experience increases. This article evaluates a single tertiary care academic institution’s experience with TORS for head and neck tumors and reports its 4-year learning curve.

Objective: To evaluate a single institution’s experience with TORS over a 4-year period and report treatment trends and clinical outcomes.

Design: Prospective case study.

Setting: A single tertiary care academic institution.

Participants: A total of 168 patients underwent TORS for tumors of the head and neck at University of Alabama at Birmingham between March 2007 and September 2011. The total group was subdivided into 4 consecutive groups (42 patients each). Patients were monitored throughout their hospital stay and up to 4.5 years postoperatively (mean follow-up duration, 14 months).

Intervention: Transoral robotic surgery.

Main Outcomes and Measures: Data points were collected and compared over time, including feasibility, operative time, tumor type, stage, subsite, length of intubation, need for tracheostomy, feeding tube use, hospital stay, margin status, neck dissection performed, and postoperative complications.

Results: Significant decreases in operative time, length of intubation, and hospital stay were seen as TORS experience increased. Overall, the mean operative time decreased by 47% (group 4, 86 minutes; group 1, 183 minutes). Total mean intubation time decreased by 87% (group 1, 12.9 hours; group 4, 1.7 hours) and mean hospital stay decreased from 3.0 days to 1.4 days. There was not a significant difference between groups in number of cases unable to be performed robotically (7-9 per group), tumor stage (majority T1/T2), tumor subsite (majority oropharynx), positive margin status (2-5 per group), number of salvage cases performed (7-9 per group), and number of tracheostomies (2-4 per group) or feeding tubes (22-25 per group) required.

Conclusions and Relevance: This is the first multiyear prospective study to document a single institution’s TORS experience over time and demonstrate particular areas of expected improvement as case number increases.

A total of 168 patients were included in this study (108 male [64%]; mean age, 59 years [range, 29-86 years]). The majority of patients had tumors of the oropharynx: 61 (36%) were located in the tonsil and 50 (30%) in the floor of mouth, and 2 (1%) in the pyriform sinus. There were similar numbers of each subsite in each of the 4 groups.

The majority of patients underwent a successful robotic-assisted resection, with 31 patients (7-9 patients per group) being deemed poor candidates for robotic resection, requiring their case to be aborted (Figure 1). There was no statistically significant difference in the number of aborted cases between group 1 and group 4 (P > .99).

Most patients had malignant (95%), early T-stage tumors (T1/T2), and this was consistent over time across all groups, as given in the Table. There was no statistically significant difference over time in initial positive margin status (2-5 per group), number of salvage cases performed (7-9 per group), number of tracheotomies required (2-4 per group), or feeding tubes required (22-25 per group) (P > .99 for all). A similar number of patients in each group underwent a neck dissection either concurrently with robotic resection of the primary tumor or in a staged manner (Figure 1).

We also evaluated the number of TORS cases performed per month. The case frequency varied from month to month, but there was an overall increase in the number of cases performed per month as experience increased (Figure 2A). When evaluating total operative time, there was a significant decrease over time (P < .001). The mean operative time for group 4 was 86 minutes (range, 32-203 minutes), which was 47% shorter than the mean time for group 1 of 183 minutes (range, 24 minutes–6 hours 7 minutes) (Figure 2B). The mean total intubation time for group 4 patients was 1.7 hours (range, 1.2 hours), which was an 87% decrease from the mean intubation time in group 1 (12.9 hours [range, 1-72 hours]). This difference was statistically significant (P = .001) (Figure 2C). Length of hospital stay significantly decreased over time as well (P < .001). The mean hospital stay decreased from 3.0 to 1.4 days (Figure 2D).

There was no significant difference in the number of patients requiring tracheostomy or feeding tubes between the groups. All groups had between 2 and 4 patients that required a tracheostomy either at the time of or after the procedure. On average, between 22 and 25 patients per group required some form of feeding tube, for varying lengths of time.

We also documented and compared the number of postoperative TORS-related complications in each group. These consisted of postoperative airway edema requir-
ing an intervention and postoperative bleeding. The majority of complications, as expected, occurred in group 1. Seven patients experienced bleeding and 6 had airway edema in this group. The number of patients with either complication was much less in group 4 (2 had postoperative bleeding and 1 had airway edema). These postoperative complication trends are depicted in Figure 3.

**DISCUSSION**

This is a multiyear, prospective study that documents a single institution’s TORS learning curve. A learning curve can be defined as the changing rate of learning for a given activity or tool over time. It is typically steepest in the beginning as new knowledge is being acquired and then eventually reaches a plateau phase once maximum efficiency and/or expert level of performance is reached. The slope of the learning curve, or the speed by which a new technique is perfected, is dependent on numerous factors. These include, but certainly are not limited to, the surgeon performing the technique, the ancillary staff, the patient population available, the frequency of cases, and most importantly the number of cases performed.
A recent report in the literature discussed the implementation of a TORS program in a tertiary academic medical center and outlined a suggested plan to rapidly achieve an acceptable “steady-state of efficiency.” One of the goals of this article was to highlight certain expected milestones that may reasonably be achieved after a set number of cases are performed. Programs that are in the beginning phase of their TORS experience commonly want to know how many cases it will take to achieve a reasonable operative time, among other end points.

We demonstrated particular areas of expected improvement as case number increased in the following end points: (1) decrease in operative time, (2) decrease in postoperative intubation time, (3) decrease in hospital stay, and (4) decrease in overall TORS-related complications. As experience with TORS increased, we noticed improved efficiency in placement of the mouth retractor, robot docking, as well as actual tumor resection. All of these variables contributed to the overall decrease in operative time.

A decrease in total length of intubation was seen as the operative time decreased and as our confidence with airway management of this new group of patients increased. Early on in our series, many patients were routinely left intubated overnight, but as our experience increased, we were able to comfortably extubate nearly all patients in the immediate postoperative period. A decrease in mean hospital stay was noted as patients were increasingly found to have early postoperative pain control, tolerance of enteral nutrition, and minimal risk of complications. Most patients were comfortably discharged after an average of 2 nights stay. Most recently at our institution, the majority of patients are spending less than 24 hours in the hospital following a routine TORS procedure.

It is critical to also note the decrease in number of TORS-related complications, particularly those that may be attributed to technical error. There were significantly fewer patients with airway edema requiring postoperative interventions over time. We believe that this was likely multifactorial. The routine use of intravenous glucocorticosteroids both intraoperatively and postoperatively, the significant decrease in operative time, as well as the introduction of the thulium laser for supra-glottic resections all played a role in minimizing postoperative edema. The incidence of postoperative bleeding was variable in groups 1 to 3 but was significantly lower in group 4 compared to group 1.

As we move forward with rapidly advancing medical technology, it is important to monitor our progress over time to ensure that our progress is in a positive direction along the learning curve. The trend toward a “pay-for-performance” health care model, where reimbursement is dictated by clinical excellence is on us. Learning curve studies, such as this one, are needed to provide evidence-based measures by which performance may be assessed.

Submitted for Publication: January 9, 2013; final revision received February 22, 2013; accepted March 1, 2013.

Published Online: May 16, 2013. doi:10.1001/jamaoto.2013.3007

Correspondence: J. Scott Magnuson, MD, Head and Neck Surgery Center of Florida, Florida Hospital Celebration Health, 410 Celebration Pl, Ste 305, Celebration, FL 34747 (Scott.Magnuson@fhhosp.org).

Author Contributions: Drs White and Magnuson 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: White, Carroll, and Magnuson. Acquisition of data: White, Frederick, Zimmerman, and Carroll. Analysis and interpretation of data: White, Frederick, and Magnuson. Drafting of the manuscript: White. Critical revision of the manuscript for important intellectual content: White, Frederick, Zimmerman, Carroll, and Magnuson. Statistical analysis: White and Frederick. Administrative, technical, and material support: Magnuson. Study supervision: Carroll and Magnuson.

Conflict of Interest Disclosures: Dr Magnuson is a consultant for Intuitive Surgical Inc.

Previous Presentation: This study was presented orally at the American Head & Neck Society Eighth International Conference on Head and Neck Cancer; July 22, 2012; Toronto, Ontario, Canada.

REFERENCES