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Adoption of Transoral Robotic Surgery Compared With Other Surgical Modalities for Treatment of Oropharyngeal Squamous Cell Carcinoma

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Abstract

Background and Objectives—Transoral robotic surgery (TORS) has increased for treatment of oropharyngeal squamous cell carcinoma (OPSCC). To define the adoption of TORS, we analyzed patterns of surgical treatment for OPSCC in the US.

Methods—Cases of T1–T3 OPSCC treated with surgery between 2010 and 2013 from the National Cancer Database were queried.

Results—Of 3,071 patients who underwent primary surgical management for T1–T3 OPSCC, 846 (28%) underwent TORS. On multivariable analysis, low tumor stage (T2 vs T1: OR 0.75, CI 0.37–0.51, $p < 0.0001$; T3 vs T1: O.R. 0.33, CI 0.28–0.38, $p < 0.0001$), treatment at an academic cancer center (O.R. 2.23, C.I. 1.29–3.88, $p = 0.004$) and treatment at a high volume hospital (34–155 cases vs 1–4 cases: O.R. 9.07, C.I. 3.19–25.79, $p < 0.0001$) were associated with increased TORS approach. Significant geographic variation was observed, with high adoption in the Middle Atlantic. Positive margin rates were lower when TORS was performed at a high volume vs. low volume hospital (8.2% vs 16.7% respectively, $p = 0.001$).

Conclusions—Tumor and non-tumor factors are associated with TORS adoption. This analysis suggests uneven diffusion of this technology in the treatment of OPSCC.

Keywords

oropharyngeal squamous cell carcinoma (OPSCC); trans-oral robotic surgery (TORS); positive margins

INTRODUCTION

In the right conditions, new technology will first be adopted by innovators, followed by diffusion into society through cumulative normal distribution [1, 2]. Transoral robotic surgery (TORS) as a primary surgical treatment modality for oropharyngeal squamous cell

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carcinoma (OPSSC) is in the early stages of this adoption curve. McLeod and Melder published the first clinical report of TORS utilizing the *da Vinci* robot (Intuitive Surgical Inc., Sunnyvale, CA) for the excision of a benign vallecular cyst [3]. The modality's extension to malignant tumors came in 2006, when in three patients, O'Malley, Weinstein and colleagues showed the efficacy of TORS in the treatment of three patients with carcinoma of the tongue base [4]. Subsequent reports from a prospective trial at the University of Pennsylvania demonstrating the safety and feasibility of performing radical tonsillectomy and partial pharyngectomy led to Food and Drug Administration (FDA) approval of TORS for management of early stage (T1 and T2) malignant disease in 2009 [4–7].

Historically, primary surgical approaches to the oropharynx involved open surgical resection with mandibulotomy. Alternatively, transoral oropharyngectomy with mouth gag and headlight has been used to reduce the morbidity of open surgery and transoral laser microsurgery (TLM) has augmented the ability to resect the base of tongue and tonsils in the hands of some surgeons [8, 9]. Nonetheless, the morbidity associated with open surgery, exposure challenges with transoral surgery, and studies demonstrating effective nonsurgical management [10] have resulted in many authors advocating for primary radiation treatment for OPSCC over the last several decades [11].

In order for new technology to be adopted, advantages over current strategies need to be demonstrated. Hockstein et al. reported benefits of TORS including: 3-dimensional imaging through a dual endoscope mechanism, enabling visualization at angles and reducing line of site issues; robotic instrumentation's wider range of motions compared to traditional endoscopic instruments; scaling of movement, allowing large movements of the hands that result in small corresponding instrument movements; and the dampening of hand tremors [6]. In contrast to TLM, TORS allows for an en bloc rather than a piecemeal or cutting procedure in addition to overcoming the line of sight limitations. Reported disadvantages of TORS include lack of tactile feedback from the *da Vinci* robot's EndoWrist Instruments, limited configuration options, and cost [12, 13]. Despite its disadvantages, TORS represents a standardized, easily adoptable, and reproducible method of surgical management of OPSCC. In addition to this new surgical technology, emerging understanding of the epidemiology of human papilloma virus (HPV)-related OPSCC has improved prognosis and increased rates of early presentation. These surgically amenable small tumors (T-classification disease) are well-suited for management transoral primary surgical treatment [14–18]. Further, the widespread acknowledgment of the significant morbidity and late toxicities associated with primary radiation strategies in a patient population poised to live for many years have laid the groundwork for a technology-driven paradigm shift in the treatment of OPSCC [19].

To date, only isolated, early time points have been analyzed regarding national trends of the adoption and diffusion of TORS compared to other primary surgical approaches in the treatment of OPSCC [20, 21]. We recently reported that primary surgical treatment of early stage OPSCC has risen.[22] It is unclear what contribution TORS has had in this increase and if this surgical approach has been uniformly adopted. We hypothesize that adoption of TORS nationally has increased, however, it is concentrated and associated with tumor and

non-tumor factors. To test this premise, we analyzed the surgical approach utilized in a large cohort of patients in the National Cancer Database who were diagnosed with OPSCC. In addition, we used margin positivity rates to determine what factors influence better surgical outcomes for those undergoing TORS.

MATERIALS AND METHODS

Study population

The data source for this study was the National Cancer Database (NCDB), a joint program of the Commission on Cancer and the American College of Surgeons that collects hospital-based registry data on over 80% of US oral cavity and pharynx cases [23]. The source files were used in accordance with the NCDB Participant User Files (PUF) data use agreement. We identified all patients 18 years diagnosed with clinically staged T1–T3 OPSCC from 2010–2013. We included ICDO codes for the “oropharynx” (ICDO C019, C090, C091, C098, C099, C100, C101, C102, C103, C104, C108, C109, C142) with histologically proven squamous cell carcinoma tissue examined by microscope. Patients who had received treatment outside of the NCDB reporting facility, whose treatment information was incomplete, and whose staging information was inconsistent with treatment information or could not be assessed were excluded. Patients were included in the analysis only if they underwent a primary surgical procedure, which we define as surgery before any radiation or chemotherapy. Local tumor excision such as excisional biopsy was not considered primary surgery. For tonsil and other oropharynx sites, all categories of pharyngectomy were used. For base-of-tongue tumors, primary surgical patients were those who underwent at least glossectomy and not local tumor excision. The total cohort with complete data was 3,071 patients (Figure 1).

Outcomes

The primary outcome assessed was surgical approach. Patients were categorized as receiving TORS or other surgical approach. Patients were defined as treated with TORS as the primary surgical approach if they were coded as “Robotic assisted or Robotic converted to open.” Other surgical approaches included the codes endoscopic or laparoscopic; endoscopic or laparoscopic converted to open, open or approach unspecified. The NCDB does not specify what other surgical approach was used (open, Bovie/headlight, TLM) and so this information could not be included in the analysis. Additionally the “surgical approach” item was first introduced into the NCDB in 2010, making that year the starting point of our analysis.

A secondary outcome was the presence of a positive margin resection in patients who underwent primary surgical treatment. For this analysis, we included only those records of patients undergoing TORS or other surgical approach with complete information on margin status.

Covariates

Covariates including patient sociodemographic factors including age, sex, race, insurance status (grouped as private, Medicare, Medicaid or uninsured), and comorbidities (Charlson-

Deyo Comorbidity index) were analyzed [24]. Hospital volume was defined as the total new OPSCC cases treated with a primary surgical approach inclusive of 2010–2013, with hospitals divided into quartiles by volume for analysis. Hospital type was defined as either academic, which included academic/research programs as well as National Cancer Institute-designated Comprehensive Cancer Centers, or community, which included Community Cancer Programs, Comprehensive Community Cancer Programs, Integrated Network Cancer Programs, and other specified types of programs.

Analysis

Chi-squared tests were used to analyze TORS adoption over time and to compare tumor factors, patient sociodemographic factors, and hospital factors among patients who underwent TORS versus other surgical approach. For multivariable analysis we used hierarchical generalized linear models with a logit link function to account for clustering of patients within hospitals while evaluating the influence of tumor, patient sociodemographic, and hospital factors on the binary choice of primary surgical approach. P values <0.05 were considered significant. Analyses were conducted using Stata Statistical Software (Release 12.1; Stata Inc., College Station, TX).

RESULTS

Characteristics of the cohort

We identified 3,071 patients with T1–T3 OPSCC treated with primary surgery between 2010 and 2013. Males represented 77% of the study cohort. Table 1 summarizes the patient and tumor characteristics. The majority of patients were ages 50–64 (55%) and white (90.7%). The Charlson-Deyo Comorbidity score was zero for 78.1% of patients. Most patients were treated in an academic center (65.5%), with one quarter of patients (25.4%) being treated in low volume centers (performing 1–4 surgical cases over study time) and 24.3% being treated in high volume centers (treating 34–155 surgical cases over study time). Patients with private insurance represent the majority of the cohort (63.3%). Regarding tumor factors, 44.0% of patients were clinically staged as T1, 45.6% as T2 and 10.4% as T3.

TORS as choice of surgical approach over time

Of the patients with OPSCC with tumor stage T1–T3 disease treated with primary surgery, 27.6% were treated with TORS as the primary surgical modality during the study period. TORS utilization increased over time (20.6% in 2010 to 32.2% by 2013, $p<0.0001$; Figure 2). When TORS was selected as the surgical approach, 14.2% of patients had a positive margin resection compared to an overall positive margin rate of 23.8% in patients treated with other surgical approach ($p<0.0001$; Figure 3a). Positive margin status during this time period remained constant, with no significant difference observed over time ($p=0.261$; Figure 3b).

Patient and tumor factors associated with TORS as choice of a primary surgical approach

There were no significant differences in selecting TORS versus a non-robotic modality (hereafter referred to as “alternative”) based on age, race, or Charlson-Deyo Comorbidity scores. Males were more likely to undergo TORS than females (29.2% vs. 21.9%,

respectively, $p<0.0001$). Clinical tumor classification also influenced surgical modality section; patients with T3 tumors were more likely to undergo an alternative surgical treatment than T2 or T1 tumors (19.1% T3, 27.9% T2, 29.2% T1; $p=0.001$). On multivariate analysis, male sex (female vs male: OR 0.74, CI 0.58–0.95, $p=0.018$) and lower T classification (T2 vs T1: OR 0.75, CI 0.37–0.51, $p<0.0001$; T3 vs T1: O.R. 0.33, CI 0.28–0.38, $p<0.0001$) were associated with increased likelihood of undergoing TORS versus another primary surgical approach.

Early adoption of TORS across insurance status, hospital setting, and geography

Non-tumor and non-patient characteristics were associated with surgical approach selection. These included patient insurance status, hospital setting characteristics, and location of treatment. Insurance status was associated with selection of TORS as the surgical treatment approach for OPSCC on univariate analysis. Patients with Medicare were most likely to have TORS (31.6%), while private insurance, Medicaid and uninsured patients were less likely (28.5% private insurance, 26.8% Medicaid, and 16.4% uninsured, $p=0.021$).

The percentage of total surgical cases done across the 4 quartiles of hospital volume centers were similar (1–4 cases, 25.4%; 5–15 cases, 27.2%; 16–32 cases, 23.1%; 33–155 case; 24.3%; Figure 4a). On multivariate analysis, patients receiving treatment in an academic center were significantly more likely to have TORS than patients undergoing treatment in a community hospital (O.R. 2.23, C.I. 1.29–3.88, $p=0.004$; Figure 4b). Additionally, the highest-volume hospitals were significantly more likely to use TORS compared to the lowest-volume hospitals (34–155 cases vs 1–4 cases: O.R. 9.07, C.I. 3.19–25.79, $p<0.0001$; see Figure 4a). TORS carried out in low-volume hospitals were more likely to have a positive margin resection than cases in high-volume hospitals (16.7% vs. 8.2%, $p=0.001$; Figure 4a). Community hospitals were also associated with a significantly higher rate of a positive margin resections than academic centers (26.9% vs 11.6%, $p<0.0001$; see Figure 4b).

Geographic variability was observed in the early adoption period analyzed. The highest rates of TORS were seen in the Middle Atlantic (NJ, NY, PA) region and the lowest in Northeast (CT, MA, ME, NH, RI, VT; Figure 5a). In the Middle Atlantic, TORS' utilization approached half of cases (42.6%). By contrast, a significant majority of patients (84.8%) in the Northeast were treated with an alternative surgical approach. On multivariate analysis, treatment location was associated with use of TORS, most notably observed with the comparison of the Atlantic vs. the Southeast (DC, DE, FL, GA, MD, NC, SC, VA, WV; Atlantic vs. Southeast: OR 5.66, CI 2.55–12.58, $p<0.0001$). Figure 5b illustrates the distribution of TORS cases by geographic region.

Discussion

As hypothesized, adoption of TORS nationally is concentrated in specific geographic locations, academic hospitals and in high volume centers. These findings allow for analysis of these patterns and have important hypothesis-generating implications for further study of technologic adoption in the field of surgery.

Diffusion of a novel surgical device into clinical practice depends on economic, institutional, and psychological factors. In addition, adoption relies on the technology's proven value when compared to past strategies. Rogers described the Diffusion of Innovations Theory to explain the process of how new technology spreads through society. Rogers and others have described three variables that influence the rate of dissemination: 1) how the novel technology is perceived, 2) the characteristics of people who adopt the innovation, and 3) the environment into which the technology is being adopted [2, 25]. To date, only data from isolated and early time points have been analyzed regarding the national adoption of TORS and the factors associated with the technique's diffusion. Chen et al. demonstrated both increased utilization of TORS in academic centers as well as an increase in utilization over two early time points [21]. In the present study we used the NCDB to assess these trends over a longer time period and analyze the adoption patterns in the context of the Diffusion of Innovations Theory.

Since FDA approval in 2009, use of TORS as a tool for the primary surgical treatment of OPSCC has risen. In 2010, 22% patients undergoing primary surgical treatment for T1–T3 OPSCC were treated with TORS. A modest rise to 28% of cases was observed by 2013. Classically, an adoption curve of new technology takes on an S-shaped normal curve when plotted on a cumulative basis over time. This represents a slow early phase, followed by a more rapid middle phase after a “tipping point,” and finally a plateau with variable market share penetrance. The current study suggests that TORS for the treatment of T1–T3 OPSCC is in the early stages of this adoption curve. While we cannot know the extent to which TORS adoption will continue to follow this classic adoption pattern including how steep the linear phase of the curve will be and what degree of market penetration will be achieved at its plateau, this early view of national diffusion patterns enables us to craft a hypothesis on its anticipated course and potential barriers to adoption (Figure 6).

In line with the Rogers' theory, the head and neck surgical community's perception of the procedure's value will be a key driver in the adoption TORS for the treatment of OPSCC. Defining value as the ratio of benefit over cost, TORS must be proven oncologically sound and technically superior at an equal or reduced cost. The stated goals of primary surgical treatment for OPSCC are a potential increase in the therapeutic index by reducing morbidity via an attenuation of toxicity of adjuvant therapy. Margin status represents an important variable in reducing indications for adjuvant therapy as well as optimizing oncologic results. In the current study, 14% of patients who underwent TORS had a positive margin resection. This rate did not significantly change over time. When comparing positive margin rates in patients having TORS versus other surgical approaches, a lower positive margin resection rate in the TORS group would suggest efficacy and therefore should drive adoption, assuming other factors associated with the technology have perceived benefit. In addition, the lack of significant change in positive margin incidence suggests that surgeons learning the TORS procedure are subject to an acceptable learning curve, which could further hasten adoption. Alternatively, the low positive margin status could result from increased use of TORS in T1 and T2 tumors (for which it is FDA approved) compared to T3 tumors. Intuitively, surgeons would be more apt to use new technology in the treatment of smaller, less-risky primary tumors.

Cost represents the denominator in the value equation required for adoption of new technology. Cost analysis of TORS has been extensively reported [26–28]. In an analysis of how TORS compared to traditional open surgery in overall hospital costs, Richmon et al. showed an overall median reduction of \$4,285 per patient in the 1.2% of patients who underwent TORS [28]. This study only takes into account the acute costs of TORS, with most of the cost benefits of this approach associated with the significantly decreased length of hospitalization compared to open procedures. Importantly, others have shown that the cost benefits of TORS are diminished when adjuvant therapy is required post-operatively [26, 27]. These findings call into question the cost benefits of TORS for a broad group of patients with T1–T2 OPSCC, potentially slowing adoption.

Characteristics of early adopters often set the pace for adoption and diffusion of new technology. Adopters can be described as a bell curve[2]. On the early tail of the curve are the innovators, followed by the early adopters, early majority, late majority, and finally laggards making up the late alternative tail. The current data shows TORS utilization concentrated in the Middle Atlantic states. These findings are consistent with the presence of early adopters in institutions in this region, including the sites of initial TORS studies. The current data would suggest skewed adoption with concentrated use among a small group of early adopters. Early adopters' perception of TORS may differ from surgeons practicing in the in the community, leading to concentrated areas of acceptance. In the present analysis, patients who underwent TORS in an academic setting were more than half as likely to have a positive margin resection (12%) as patients who had TORS in the community (27%). This significant difference was also observed in low vs. high volume settings (17% vs. 8% positive margin resection rate, respectively). It could be hypothesized that early adopters represented in academic and high volume centers perceive benefit based on their outcomes while those in low volume centers question the procedure's value owing to these inferior outcomes. Stratified opinion of the technology based on personal experience could result in concentrated areas of adoption with slow diffusion, as observed in the present study.

The environment into which the technology is being adopted also influences the adoption curve. Rates of surgical treatment of OPSCC are rising [22]. This is secondary to shifts in the understanding of epidemiology and biology of HPV-related OPSCC as well as acknowledgment of the significant morbidity and late toxicities associated with primary radiation treatment [19]. It has been observed that patients with HPV-related OPSCC present with early T classification disease. [16, 17]. This shift in presentation significantly strengthens the argument for surgical treatment of this disease. Additionally, the earlier age of presentation and improved survival observed in HPV-related OPSCC has highlighted the morbidity risks associated with adjuvant treatment and prompted clinical trials examining the role of transoral approaches as part of a de-escalation strategy [14, 29]. Certainly, the current environment in the treatment of OPSCC promotes technologic advancement and diffusion. Findings of ongoing clinical trials as well as enhanced understanding of the biology of HPV-related disease will undoubtedly influence adoption and diffusion patterns of TORS in the future.

This study's findings must be considered in the context of important limitations. First, the NCDB started recording use of TORS in 2010, one year after FDA approval. We are

therefore unable to assess the earliest adoption period of this technology. Additionally, because this is a new code in the NCDB database, coding bias is possible. Delay in accurate coding of this new procedure may result in undercounting of TORS cases. Also, strict inclusion criteria resulted in a significant number of patients deleted secondary to treatment outside of an NCDB facility or incomplete staging. Although the stringent criteria for inclusion results in less patients included, this allows for appreciation of more robust results. Finally, case coverage for oropharynx in the NCDB is estimated to be 70%, with some geographic variation in case coverage related to the proportion of hospitals in a state that are accredited by the American College of Surgeons' Commission on Cancer [20]. This could lead to bias when analyzing geographic distribution of TORS.

CONCLUSIONS

While TORS utilization has increased during the short early adoption period studied, this analysis suggests uneven diffusion the value of this technology in the treatment of OPSCC. Longer time periods need to be analyzed as the adoption curves mature. Results of clinical trials using transoral approaches and advances in robotic technology may shorten the linear phase of the adoption model. While TORS represents an exciting technologic advancement in the treatment of OPSCC, rigorous assessment of any new technology is essential and evidence of value needed in order to justify its adoption. Perception of this technology, experience of the adaptors as well as the mindset of the head and neck surgery community will shape the adoption curve in the following decades.

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Synopsis

Tumor and non-tumor factors are associated with TORS adoption. This analysis suggests uneven diffusion of this technology in the treatment of oropharyngeal squamous cell carcinoma.

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Figure 1.
Flow Diagram of Patient Inclusion and Exclusions

Figure 2. Primary treatment approach for patients with T1–T3 OPSCC over time
N=3,071 including 846 (27.6%) receiving TORS as the primary surgical approach. There were 137 total patients in 2010, increasing to 280 total patients in 2013. $p < 0.0001$ for change in use over time.

Figure 3. Positive Margin Rate in Patients Treated with Primary Surgical Approach

a) Positive margin rate by surgical approach (TORS 14.2% vs Other 23.8%, $p < 0.0001$). b) Margin status for patient having a TORS approach for T1–T3 OPSCC over time were unchanged $p = 0.261$.

Figure 4. Surgical Trends by Hospital Characteristics

a) Surgical trends by hospital volume. While percentage of surgical cases done across all 4 quartiles of hospital volume centers are similar, TORS cases represent a significantly greater proportion of surgical cases in high volume centers ($p < 0.0001$). This is associated inversely with positive margin status. b) TORS cases represent a greater proportion of surgical cases in academic settings with positive margin status being significantly lower in academic centers when compared to community hospitals $p < 0.0001$.

Figure 5. Geographic Use of TORS

a) Uneven regional TORS adoption. b) The skewed distribution suggests TORS cases are concentrated among a small group of early adopters. Geographic Locations: Northeast (CT, MA, ME, NH, RI, VT); Atlantic (NJ, NY, PA); Southeast (DC, DE, FL, GA, MD, NC, SC, VA, WV); Great Lakes (IL, IN, MI, OH, WI); South (AL, KY, MS, TN); Midwest (IA, KS, MN, MO, ND, NE, SD); West (AR, LA, OK, TX); Mountain (AZ, CO, ID, MT, NM, NV, UT, WY); Pacific (AK, CA, HI, OR, WA) * Percentages represent number of cases per region.

Figure 6. Hypothesized Prospective TORS Adoption Curves

A) Failed adoption with eventual abandonment. B) Continued use by early adopters without widespread adoption. C) Classic adoption curve supported by early adaptors followed by diffusion among all groups of surgeons. D) Steep adoption with high market penetrance secondary to favorable adoption environment.

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Table 1

Primary Treatment Modality in Patients with T1–T3 OPSCC

Characteristic	Overall	TORS (vs. Other Surgical Approach)			Multivariable Analysis of TORS (vs. other surgical approach)		
	No. (Column %)	No. (Row % compared to Other)	p-value	Adjusted Odds Ratio (95% C.I.)	p-value		
Patients	3071	846 (27.6%)					
Age at Diagnosis			p=0.137				
<50	474 (15.4%)	116 (24.5%)		1 [Reference]			
50–64	1688 (55%)	471 (27.9%)		1.2 (0.89 – 1.63)	p=0.232		
65–79	803 (26.2%)	236 (29.4%)		1.4 (0.91 – 2.03)	p=0.138		
80	106 (3.4%)	23 (21.7%)		1.1 (0.54 – 2.17)	p=0.816		
Sex			p<0.0001				
Male	2364 (77.0%)	691 (29.2%)		1 [Reference]			
Female	707 (23.0%)	155 (21.9%)		0.74 (0.58 – 0.95)	p=0.018		
Race			p=0.970				
White	2787 (90.7%)	766 (27.5%)		1 [Reference]			
Black	199 (6.5%)	56 (28.1%)		1.23 (0.82 – 1.87)	p=0.316		
Other	85 (2.8%)	24 (28.2%)		0.89 (0.48 – 1.64)	p=0.711		
Clinical T Classification			p=0.001				
T1	1352 (44.0%)	395(29.2%)		1 [Reference]			
T2	1400 (45.6%)	390 (27.9%)		0.75 (0.37 – 0.51)	p<0.0001		
T3	319(10.4%)	61 (19.1%)		0.33 (0.28 – 0.38)	p<0.0001		
Insurance Status			p=0.021				
Private	1944 (63.3%)	555 (28.5%)		1 [Reference]			
Uninsured	128 (4.2%)	21 (16.4%)		0.93 (0.50 – 1.73)	p=0.819		
Medicaid	942 (30.7%)	252 (26.8%)		0.82 (0.61 – 1.12)	p=0.216		

Characteristic	Overall	TORS (vs. Other Surgical Approach)			Multivariable Analysis of TORS (vs. other surgical approach)		
	No. (<i>Column</i> %)	No. (<i>Row</i> % <i>compared to Other</i>)	<i>p</i> -value	<i>Adjusted Odds Ratio (95% C.I.)</i>			
Patients	3071	846 (27.6%)					
Medicare	57 (1.8%)	18 (31.6%)		1.23 (0.59 – 2.58)			p=0.572
Charlson-Deyo Comorbidity Count			p=0.847				
0	2398 (78.1%)	663 (27.7%)		1 [Reference]			
1	539 (17.5%)	149 (27.6%)		0.89 (0.68 – 1.16)			p=0.387
2	134 (4.4%)	34 (25.4%)		0.66(0.41 – 1.08)			p=0.102
Year of Diagnosis			p<0.0001				
2010	665 (21.6%)	137 (20.6%)					
2011	742 (24.2%)	202 (27.2%)					
2012	795 (25.9%)	227 (28.5%)					
2013	869 (28.3%)	280 (32.2%)					
Geographic Location			p<0.0001				
Southeast	585 (19.5%)	99 (16.9%)		1 [Reference]			p= 0.627
Northeast	99 (3.3%)	15 (15.2%)		1.40 (0.36 – 5.44)			p< 0.0001
Atlantic	540 (18.0%)	230 (42.6%)		5.66 (2.55 – 12.58)			p=0.011
Greatlakes	481 (16.0%)	109 (22.7%)		2.72 (1.25 – 5.92)			p=0.007
South	251 (8.4%)	80 (31.9%)		3.82 (1.44 –10.13)			p<0.0001
Midwest	396 (13.2%)	127 (32.1%)		4.63 (2.17 – 9.87)			p=0.035
West	172 (5.7%)	42 (24.4%)		2.93 (1.08 – 7.93)			p=0.577
Mountain	149 (5.0%)	23(15.4%)		1.29 (0.52 – 3.16)			p=0.003
Pacific	328 (10.9%)	107 (32.6%)		3.62 (1.54 – 8.56)			
Facility Type			p<0.0001				
Academic/NCI/CCC	1966(65.5%)	699 (35.6%)		2.23 (1.29 – 3.88)			p=0.004
Community	1035 (34.5%)	133 (12.6%)		1 [Reference]			

Characteristic	Overall	TORS (vs. Other Surgical Approach)	Multivariable Analysis of TORS (vs. other surgical approach)	
	No. (<i>Column</i> %)	No. (<i>Row</i> % compared to <i>Other</i>)	<i>p-value</i>	<i>Adjusted Odds Ratio (95% C.I.)</i>
Patients	3071	846 (27.6%)	p<0.0001	
Hospital Volume				
1–4 cases	779 (25.4%)	49 (6.3%)		1 [Reference]
5–15 cases	835 (27.2%)	212 (25.4%)		5.87 (3.22 –10.69) p<0.0001
16–32 cases	709 (23.1%)	265 (37.4%)		13.82 (6.37– 29.99) p<0.0001
34–155 cases	748 (24.3%)	320 (42.8%)		9.07 (3.19 –25.79) p<0.0001

Abbreviations: OPSCC, oropharyngeal squamous cell carcinoma; NCI CCC, national cancer institute comprehensive cancer center; N, nodal; T, tumor.

Geographic Locations: Northeast (CT, MA, ME, NH, RI, VT); Atlantic (NJ, NY, PA); Southeast (DC, DE, FL, GA, MD, NC, SC, VA, WV); Greatlakes (IL, IN, MI, OH, WI); South (AL, KY, MS, TN); Midwest (IA, KS, MN, MO, ND, NE, SD); West (AR, LA, OK, TX); Mountain (AZ, CO, ID, MT, NM, NV, UT, WY); Pacific (AK, CA, HI, OR, WA)

Bold p-values are <0.05

* Both nodal and T stage defined as clinical staging, since this was the only information available before selection of surgical treatment modality.