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Transoral Robotic Surgery (TORS) Versus Non-TORS Tongue Resection for Obstructive Sleep Apnea

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Objective: To compare transoral robotic surgery (TORS) versus non-TORS tongue resection procedures performed for obstructive sleep apnea from January 2010 to September 2015 using a national database, focusing on patient characteristics, performance of concurrent procedures, operative time, length of hospital stay, and postoperative complications.

Methods: A cohort of adults undergoing TORS and non-TORS tongue resection procedures was identified in the Nationwide Inpatient Sample, a publicly-available national administrative database incorporating a stratified sample of hospital discharge records. Outcomes were annual case volumes, prolonged (≥ 3 days) hospital stay, and complications. Statistical analyses examined potential associations between TORS and prolonged hospital stay and complications.

Results: From 2010 to 2015, 5709 hospital discharges included tongue resection surgery to treat obstructive sleep apnea. There was a gradual decline and stabilization in overall volumes, with the proportion of TORS use showing an initial increase, followed by a decrease and rebound increase. TORS patients were less likely to undergo concurrent nasal surgery (15% vs. 44%, $P < .01$), but there was no association between the use of TORS and concurrent palatal surgery. TORS use was not associated with concurrent hypopharyngeal surgery overall, but it was associated with specific types of hypopharyngeal surgery. TORS use was associated with patient age, payor, and certain hospital characteristics. TORS use was associated with an increased risk of prolonged hospital stay (33% vs. 25%, $P = .045$) but was not associated with complications.

Conclusion: This study provides insight into TORS use in tongue resection surgery for obstructive sleep apnea during this period of early TORS adoption.

Key Words: obstructive sleep apnea, sleep medicine, surgical treatment of obstructive sleep apnea.

Level of Evidence: Level 3 (cohort study).

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INTRODUCTION

The tongue has long been recognized as contributing to airway obstruction in some adult patients with obstructive sleep apnea (OSA). Numerous techniques and technologies have been developed to treat the tongue, starting with Fujita's description of the carbon dioxide laser to perform midline glossectomy in 1991.¹ Other approaches that address tongue-related obstruction include procedures without resection of tissue (submucosal radiofrequency,² genioglossus advancement,³ tongue suspension/stabilization,⁴ and hyoid suspension³) and tongue resection procedures, also referred to as partial glossectomy (submucosal

minimally invasive lingual excision (SMILE),⁵ various approaches for lingual tonsillectomy,^{6,7} and submucosal lingualplasty⁸).

The da Vinci robotic-assisted surgical system (Intuitive Surgical, Sunnyvale, CA) received FDA approval in 2009 for the resection of certain malignant lesions of the head and neck. Vicini was the first to report on transoral robotic-assisted surgery (TORS) for tongue resection in OSA in 2010,⁹ and TORS use grew over the ensuing years. The TORS technology has been used for performance of partial glossectomy with surgeon-specific techniques, including its focus primarily on resection of the lingual tonsil tissue alone versus wider resection involving tongue muscle and fat. Proposed advantages of TORS include better visualization of and access to the base of tongue, allowing more extensive resection of tissue (whether lingual tonsil tissue or additional tissue) that may improve outcomes. Systematic reviews of partial glossectomy (TORS and non-TORS techniques) indicate general feasibility, safety, and clinical success in appropriately selected patients.^{10,11} However, there have been no comparisons of TORS and non-TORS tongue resection procedures.

The objective of this study was to compare TORS versus non-TORS tongue resection procedures performed for OSA from 2010 to 2014 using a national database,

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focusing on patient characteristics, performance of concurrent procedures, operative time, length of hospital stay, and postoperative complications.

MATERIALS AND METHODS

Study Population

This study was conducted utilizing the Nationwide Inpatient Sample (NIS), a publicly-available administrative database consisting of a stratified sample of hospital discharge records administered by the Agency for Healthcare Research and Quality, as part of its Healthcare Cost and Utilization Project. NIS consists of a sampling of individual de-identified patient discharge records from every Healthcare Cost and Utilization Project-participating hospital nationwide, and the analyzed data can be weighted based on the database's sampling scheme to obtain broader nationwide estimates of procedure volumes. The NIS database includes hospital characteristics as well as patient age, gender, race, national income quartile, procedures performed during hospital stay, diagnoses, hospital charges, and length of hospital stay. Diagnoses and procedures are included using International Classification of Diseases codes without use of Current Procedural Terminology codes (used by physicians for billing payors) because the latter are developed and managed by the American Medical Association, therefore being unavailable for use (also true with many other administrative databases).

Data were analyzed from the NIS from January 2010 to September 2015. These dates were included because they coincided with the adoption of TORS and because International Classification of Diseases, Ninth Revision (ICD-9) codes were utilized over this period before a transition to the Tenth Revision in October 2015. The study population consisted of all discharge records that included an ICD-9 diagnosis code for sleep apnea (327.23–327.53, 780.50, 780.51, 780.53, 780.55, 780.57, 780.59, 786.03) as well as an ICD-9 procedure code for partial glossectomy (25.1, 25.2, 25.94, 25.99, 28.5) or lingual tonsillectomy (28.5). Of note, ICD-9 procedure codes are used in administrative databases but may not be familiar to physicians that generally use Current Procedural Terminology codes for billing purposes. All records with a diagnosis of a benign or malignant head and neck neoplasm were excluded. We excluded records with an ICD-9 procedure code indicating maxillary and/or mandibular advancement (76.43, 76.46, 76.61, 76.62, 76.65, 76.66, and 78.49).

The use of TORS was identified by the presence of an ICD-9 procedure code for robot-assisted surgery (17.41, 17.44, 17.49). Other dichotomous indicator variables were generated for the performance of concurrent nasal, palatal (including isolated palatine tonsillectomy), or hypopharyngeal procedures as well as tracheostomy.

This study was deemed exempt from review by the Institutional Review Board of the University of Southern California as a secondary analysis of a publicly-available database containing no identifiable personal information.

Outcomes

Outcomes included national estimates for annual case volumes for TORS and non-TORS procedures, prolonged hospital stay, and complications. Prolonged hospital stay for each hospital discharge was defined as a dichotomous variable reflecting prolonged length of hospital stay (≥ 3 days). Complications were defined by those occurring prior to discharge and included postoperative hemorrhage, pulmonary complications (such as requiring postoperative invasive mechanical ventilation or pneumonia),

wound infection, tracheostomy, and acute cardiac events. Mortality was considered separately.

Association with Patient and Hospital Variables

Patient and hospital-specific variables were examined for an association with outcome measures. These were selected based on an a priori expectation of potential association with the use of TORS versus non-TORS techniques and other outcomes. Patient demographic variables included age, gender, race/ethnicity, medical comorbidity, quartile of median household income for patient ZIP code, and third-party insurance payor status. Medical comorbidity was treated as a categorical variable based on the Elixhauser method,¹² defined as no comorbidity (0 of 29 potential comorbid conditions defined in the database), low (1–2 conditions), moderate (3–4), and high (4+ conditions). Hospital-level variables were hospital region (Northeast, Midwest, South, West) and hospital type (rural, urban non-teaching, or urban teaching hospital).

Statistical Analysis

All analyses were conducted using SAS 9.4 (SAS Institute, Cary, North Carolina). *P* values < 0.05 were considered statistically significant.

National trend estimates followed HCUP methodical standards, which adopted the design change at 2012 with appropriate trend weight for making comparable estimate across years. SAS 9.4 surveymean procedure was used. Strata-specific estimate was conducted with domain statement under surveymean.

Comparisons between the use of TORS and concurrent procedures for outcome (prolonged hospital stay and complications) and patient and hospital characteristics used SAS 9.4 surveyfreq procedure with Rao-Scott chi-square test. Unadjusted and adjusted associations between TORS and outcome measurements were conducted by surveylogistic regression. Adjustment was performed for the following variables: sex, race, comorbidity, third-party payer, hospital region, and hospital type. NIS weights were not used because these analyses were limited to a subgroup of the entire NIS database, making the weighting invalid.

RESULTS

Surgical Volumes

From January 2010 to September 2015, a total of 5709 hospital discharges included tongue resection surgery to treat OSA. Figure 1 displays the annual volume of tongue resection procedures, and Figure 2 shows the

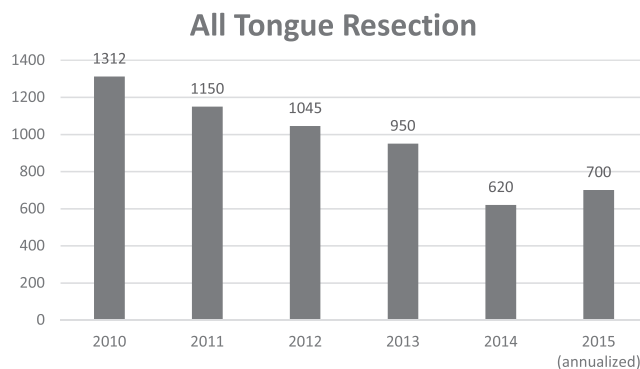


Fig. 1. Volume of all tongue resection procedures from 2010 to 2015.

Percentage of TORS Procedures

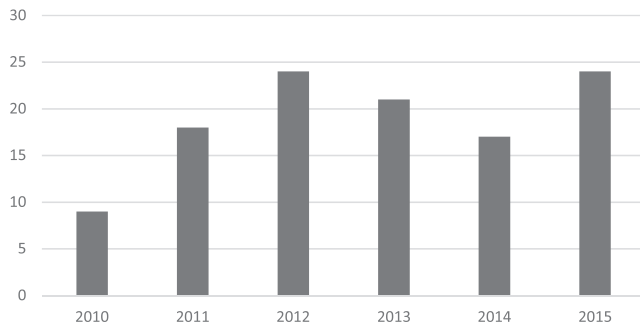


Fig. 2. Percentage of tongue resection procedures with use of TORS from 2010 to 2015.

percentage of tongue resection procedures utilizing TORS in each year. The overall number of discharges that included tongue resection surgery gradually decreased from 1312 in 2010 to an annualized rate of 700 in 2015. The use of TORS started at 112 (9%) in 2010, peaked at 255 (24%) in 2012, and then decreased before returning again to an annualized figure of 167 (23.8%) in 2015 (Fig. 1).

Concurrent Procedures

Concurrent procedures were performed in a majority of hospital procedures with tongue resection surgery

(Table I), particularly for concurrent palatal surgery (75%) but less commonly for nasal surgery (39%) and other hypopharyngeal surgery (13%). TORS patients were less likely to undergo concurrent nasal surgery, compared to non-TORS patients (14% vs 45%, $P < 0.01$). There was no association between the use of TORS and concurrent palate/oropharyngeal surgery. There was no association between the use of TORS and concurrent hypopharyngeal surgery overall, but the use of TORS was associated with greater performance of epiglottis surgery and lesser performance of genioglossus advancement or hyoid suspension. There were no cases of concurrent tracheostomy.

Patient and Hospital Characteristics

Table II presents patient and hospital characteristics for the total national estimates and patient and hospital characteristics. TORS use was less likely in patients 21–40 years of age, in those with Medicaid as payor, in the South and West regions, and urban nonteaching or rural hospitals. TORS use was not associated with the patient's gender, race/ethnicity, medical comorbidity, or median income for patient zip code.

Prolonged Hospital Stay and Complications

Overall, there was a notable rate of prolonged hospital stays and complications, particularly pulmonary complications. Pulmonary complications were defined in this study to include a postoperative diagnosis of

TABLE I.
Concurrent procedures.

Concurrent procedure type	TORS (%)	No TORS (%)	Total	P value
Nasal				
No	865 (85%)	2623 (56%)	3488 (61%)	<.01
Yes	151 (15%)	2070 (44%)	2222 (39%)	
Palatal				
No	219 (22%)	1275 (27%)	1493 (26%)	.05
Yes	797 (78%)	3419 (73%)	4216 (74%)	
Hypopharyngeal—all (other than tongue resection)				
No	843 (83%)	4116 (88%)	4958 (87%)	.09
Yes	173 (17%)	578 (12%)	751 (13%)	
Hypopharyngeal—genioglossus advancement				
No	1011 (18%)	4507 (82%)	5518 (97%)	<.01
Yes	†	186 (97%)	191 (3%)	
Hypopharyngeal—hyoid suspension				
No	1011 (19%)	4335 (81%)	5347 (94%)	<.01
Yes	†	358 (99%)	363 (6%)	
Hypopharyngeal—epiglottis surgery				
No	852 (16%)	4645 (84%)	5497 (96%)	<.01
Yes	164 (77%)	48 (23%)	212 (4%)	

†Cell size <10 not reported, per HCUP guidelines.

TABLE II.
Patient and Hospital Information.

		TORS (row %)	No TORS (row %)	Total (% of total within category)	P value
Gender	Female	276 (18%)	1271 (82%)	1547 (27%)	.96
	Male	739 (18%)	3418 (82%)	4157 (73%)	
Age category	21–40 years	244 (10%)	2084 (90%)	2329 (41%)	<.01
	41–64 years	683 (22%)	2376 (78%)	3058 (54%)	
	≥65 years	89 (28%)	233 (72%)	323 (6%)	
Race	Asian/Pacific	43 (32%)	93 (68%)	136 (3%)	.08
	Black	121 (21%)	467 (79%)	588 (12%)	
	Hispanic	55 (10%)	489 (90%)	544 (11%)	
	Native American	†	19	24 (0%)	
	Other	86 (28%)	224 (72%)	310 (6%)	
	White	636 (18%)	2834 (82%)	3470 (68%)	
	Missing	69 (10%)	567 (90%)	636 (11%)	
Comorbidity	None to low (1-2)	385 (17%)	1858 (83%)	2242 (39%)	.7
	moderate (3-4)	473 (19%)	2080 (81%)	2553 (45%)	
	high (4+)	158 (17%)	756 (83%)	914 (16%)	
National quartile of household income by ZIP code	<45 K	205 (18%)	965 (82%)	1170 (21%)	.24
	45 K-60 K	210 (16%)	1077 (84%)	1286 (23%)	
	60 K-80 K	287 (21%)	1100 (79%)	1388 (25%)	
	>80 K	294 (17%)	1439 (83%)	1733 (31%)	
	Missing	20 (17%)	112 (83%)	133 (2%)	
Payor	Medicaid	65 (7%)	877 (93%)	942 (16%)	<.01
	Medicare	163 (24%)	521 (76%)	684 (12%)	
	Private including HMO	753 (20%)	3079 (80%)	3832 (67%)	
	Self pay	†	40	45 (1%)	
	Other pay	30 (15%)	176 (85%)	206 (4%)	
Hospital region	Northeast	311 (29%)	756 (71%)	1068 (19%)	<.01
	Midwest	3429 (30%)	986 (70%)	1415 (25%)	
	South	164 (10%)	1496 (90%)	1660 (29%)	
	West	112 (7%)	1456 (93%)	1567 (27%)	
Hospital type	Urban non-teaching	107 (9%)	1095 (91%)	742 (21%)	<.01
	Urban teaching	874 (21%)	3293 (79%)	4167 (74%)	
	Rural	25 (9%)	248 (91%)	273 (5%)	
	Missing	†	57	67 (1%)	

†Cell size <10 not reported, per HCUP guidelines.

TABLE III.
Complications and Prolonged Hospital Stay.

Complications	TORS	Non-TORS	Overall	P
Prolonged hospital stay (≥3 days)	346 (34%)	1198 (26%)	1544 (27 ± 1.2%)	.02
Postoperative hemorrhage requiring Intervention	†	25 (0.53%)	30 (0.52 ± 0.12%)	.99
Pulmonary complications*	80 (7.9%)	296 (6.3%)	376 (6.6 ± 0.49%)	.13
Wound infection	†	50 (1.07%)	50 (0.87 ± 0.16%)	N/A
Acute cardiac events	†	31 (0.66%)	31 (0.55 ± 0.17%)	N/A
All complications (other than prolonged hospital stay)	85 (8.4%)	362 (7.7%)	447 (7.8 ± 0.6%)	.55

*Pulmonary complications defined as postoperative invasive mechanical ventilation or pneumonia.

†Cell size <10 not reported, per HCUP guidelines.

pneumonia or invasive mechanical ventilation; it was not possible to determine whether the mechanical ventilation was planned or unplanned (i.e., related to respiratory distress following extubation). There were no mortalities or tracheostomy in the study cohort.

TORS was associated with an increased risk of prolonged hospital stay but was not associated with an increased risk of complications (Table III).

DISCUSSION

This is the first study of national utilization patterns for tongue resection procedures, and it is based on the largest all-payor administrative database available in the United States.

From January 2010 to September 2015, there was a gradual decline in tongue resection procedure, with the proportion performed using TORS demonstrating an increase following the 2009 FDA approval of the da Vinci system, followed by a decrease. This is in contrast compared to the patterns seen in oropharyngeal squamous cell carcinoma, where an estimated 22% of patients undergoing primary surgical treatment for T1–T3 and OPSCC were treated with TORS in 2010, with a modest rise to 28% in 2013, all within the context of a relatively stable number of procedures performed over that time.¹³ The pattern of TORS surgical volume represents a classical technology adoption curve where the gradual increase is followed by a plateau with variable market share penetrance. It is unclear why there was a gradual decline in tongue resection procedures over this time. It is also unclear whether the volume of tongue resection procedures has changed substantially since 2014, but the 2014 FDA approval of the Upper Airway Stimulation system (Inspire Medical Systems, Inc., Golden Valley, Minnesota) has offered another treatment option for patients with OSA and tongue-related obstruction.

Specific patient and hospital characteristics were associated with TORS use. Some of these are related to access to expensive technology, such as lower TORS use in urban nonteaching and rural hospitals and in those with Medicaid health care coverage. The NIS database does not include other important patient clinical characteristics, such as OSA severity (often measured by the apnea-hypopnea index) or physical examination findings. These may also be associated with TORS use, and future studies can evaluate their potential association with choice of technique and technology for tongue resection procedures.

TORS use was associated with a lower likelihood of concurrent nasal surgery, but otherwise there was no association with concurrent palatal procedures. Drug-induced sleep endoscopy may be performed in conjunction with nasal procedures prior to tongue resection surgery; it is unclear whether the use of drug-induced sleep endoscopy prior to tongue resection surgery differs for TORS vs. non-TORS tongue surgery. What may be more important is that TORS is often performed with nasotracheal intubation, making the performance of concurrent nasal procedures especially challenging and likely contributing to the lower likelihood.

There was no association between TORS and concurrent hypopharyngeal surgery overall, but there was an

association with subtypes of hypopharyngeal surgery. Again, the main limitation of this analysis is the absence of important clinical characteristics that may be associated with the performance of concurrent procedures; this makes it unclear whether there was an association between TORS and concurrent procedures after adjustment for clinical characteristics.

The complication rates in this study (7.8%) were lower than in the largest previous study reporting complications after TORS for OSA (20%).¹⁴ Some of this discrepancy relates to different definitions of complications, with the current study having a more-limited definition, as compared to the previous study that included any bleeding, dehydration, or dysphagia/odynophagia requiring treatment, hypoxemia, significant pain, gastrointestinal complications, and cardiac arrhythmias. If the definition of complications from the current study is applied to this previous study, their complication rate may be closer to 7.8% (23/293), making the national experience of this study similar to that reported in the previous cohort. It is important that these complication rates are higher than in a large cohort study of soft palate surgery for OSA, where the rate of serious perioperative complication was 1.6%,¹⁵ and in a series of case series studies of tongue radiofrequency, where the pooled estimate of moderate to severe complications was 2.7%.¹⁶

Use of TORS was not associated with complications but was associated with a greater likelihood of prolonged hospital stay. The overall impact is that TORS may be associated with greater total health care costs, both in terms of the surgery (TORS includes robot-assisted surgery codes) and the hospitalization (increased length of stay). There could be multiple drivers of increased length of hospital stay: differences in pain and dysphagia (not counted as complications in this study), practice patterns (the prolonged stay may be planned with TORS but may not be needed in all cases), or a difference in pulmonary complications (point estimates differed with TORS, although this was not statistically-significant).

Previous studies have compared outcomes in TORS vs. non-TORS tongue resection surgery, showing little or no differences between the techniques in individual studies from single institutions^{17–22} or in systematic reviews comparing the techniques.^{23–25}

There are important limitations of this study. First are those inherent to administrative databases. There may be variations in coding practices at participating institutions. No follow-up was possible beyond the index hospital discharge to identify complications that may have occurred after discharge. The database lacks important clinical information, principally OSA severity measures (such as the apnea-hypopnea index) as well as physical examination findings; these data would enable examination of additional patient characteristics associated with the use of TORS as well as a comparison of treatment outcomes. Finally, the NIS includes only inpatient hospital discharges, and it is possible (but perhaps not likely) that tongue resection procedures may have been performed in the outpatient setting.

CONCLUSION

Utilization of TORS for tongue resection surgery in OSA during this period of early TORS adoption was characterized by an increase then decrease in the proportion of procedures performed with TORS against a background of declining numbers of tongue resection procedures in the United States. Multiple patient and hospital characteristics were associated with the use of TORS for tongue resection surgery. Use of TORS was not associated with a greater risk of complications but was associated with a greater likelihood of a prolonged hospital stay. Further research may incorporate clinical characteristics to explore these findings in greater detail.

Conflict of Interest

Kim, Poole, Cen, Sanossian—none. Kezirian—Research funding (Inspire Medical Systems); Medical Advisory Board (CryOSA, Pillar Palatal, Cognition Life Science); Consultant (Nyxoah, Split Rock Scientific, Berendo Scientific); Intellectual Property Rights (Berendo Scientific, Magnap).

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