Transoral Robotic Surgery vs. Non-Transoral Robotic Surgery Tongue Resection for Obstructive Sleep Apnea

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Abstract

Introduction: The objective was to compare transoral robotic surgery (TORS) vs. non-TORS tongue resection procedures performed for obstructive sleep apnea from 2010-14 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 for TORS and non-TORS tongue resection procedures. Statistical analyses examined potential associations between the use of TORS and prolonged hospital stay and complications, with adjustment for the performance of concurrent procedures and specific patient and hospital characteristics. Results: From 2010-14, 5185 hospital discharges included tongue resection surgery to treat obstructive sleep apnea. There was a gradual decline in overall volumes, with the proportion of TORS use showing an initial increase, followed by a decrease. TORS patients were less likely to undergo concurrent nasal surgery (14% vs. 45%, p<0.01), but there was no association between the use of TORS and concurrent palate/oropharyngeal or other 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=0.045) and pulmonary complications (8.4% vs. 6.0%, p=0.04) but not total complications (7.7% vs. 7.4%, p=0.2). Conclusion: This study provides insight into TORS use in tongue resection surgery for obstructive sleep apnea during this period of early TORS adoption.

KEY POINTS

Question: is transoral robotic surgery tongue resection performed for obstructive sleep apnoea associated with differences in the performance of concurrent procedures, length of hospital stay, and perioperative complications from 2010-14 in the United States of America, compared to non-transoral robotic surgery tongue resection?

Findings: transoral robotic surgery was associated with patient age, payor, and certain hospital characteristics. Transoral robotic surgery use was associated with an increased risk of prolonged hospital stay and pulmonary complications but not total complications.

Meaning: This study provides insight into transoral robotic surgery use in tongue resection surgery for obstructive sleep apnoea during this period of early adoption in the United States of America.

ABSTRACT

Introduction: The objective was to compare transoral robotic surgery (TORS) vs. non-TORS tongue resection procedures performed for obstructive sleep apnoea from 2010-14 using a national database for the

United States of America, focusing on patient characteristics, performance of concurrent procedures, 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 for TORS and non-TORS tongue resection procedures. Statistical analyses examined potential associations between the use of TORS and prolonged hospital stay and complications, with adjustment for the performance of concurrent procedures and specific patient and hospital characteristics.

Results: From 2010-14, 5185 hospital discharges included tongue resection surgery to treat obstructive sleep apnoea. There was a gradual decline in overall volumes, with the proportion of TORS use showing an initial increase, followed by a decrease. TORS patients were less likely to undergo concurrent nasal surgery (14% vs. 45%, $p<0.01$), but there was no association between the use of TORS and concurrent palate/oropharyngeal or other 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%, $p=0.045$) and pulmonary complications (8.4% vs. 6.0%, $p=0.04$) but not total complications (7.7% vs. 7.4%, $p=0.2$).

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

Keywords: obstructive sleep apnoea, sleep medicine, snoring

Level of Evidence: Level 3 (cohort study)

INTRODUCTION

The tongue has long been recognized as contributing to airway obstruction in some adult patients with obstructive sleep apnoea (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 suspension(3)) 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 lingualplasty(8)).

The da Vinci robotic-assisted surgical system (Intuitive Surgical, Sunnyvale, CA, USA) 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 focus primarily on resection of the lingual tonsil tissue alone vs 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 vs. non-TORS tongue resection procedures performed for OSA from 2010-14 using a national database, focusing on patient characteristics, performance of concurrent procedures, 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 in the United States of America 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 because the latter are developed and managed by the American Medical Association, therefore being unavailable for use (also true with some other databases). Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Data were analyzed from the NIS for the years 2010-2014. These years 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 2015. The study population consisted of all discharge records that included an ICD-9 diagnosis code for sleep apnoea (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). 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, 78.49). Because the ICD-9 procedure codes for tongue procedures include all tongue-directed procedures (tongue resection but also non-resection procedures like submucosal tongue radiofrequency, genioglossus advancement, and tongue suspension), we also excluded records with an ICD-9 procedure code for genioplasty or genioglossus advancement (76.63, 76.64, 76.68), or hyoid suspension (83.02), as these procedures were unlikely performed at the same time as tongue resection surgery for OSA but may have been performed in combination with tongue radiofrequency or tongue suspension.

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.

To confirm that we were identifying codes properly, we performed a search of procedures associated with the diagnosis codes for sleep apnoea and, alternatively, a search of diagnoses associated with procedure codes of interest.

This study was deemed exempt from review by the institutional review board at our institution because it is 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 post-operative 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 vs. 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, USA). P values <0.05 were considered statistically significant.

National trend estimate 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 was conducted by surveylogistic regression. Adjustment was performed for the following variables: sex, race, comorbidity, third-party payer, hospital region, 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

During the years 2010-2014, a total of 5185 hospital discharges included tongue resection surgery to treat OSA. Figure 1 displays the annual frequencies and the percentage of cases utilizing TORS. The overall number of discharges that included tongue resection surgery gradually decreased from 1312 in 2010 to 620 in 2014. The use of TORS started at 112 (9%) in 2010, peaked at 255 (24.4%) in 2012, and then decreased to 105 (17%) in 2014 (Figure 1).

Concurrent Procedures

Concurrent procedures were performed in a majority of hospital procedures with tongue resection surgery (Table 1), particularly for concurrent palate/oropharyngeal surgery (75%) but less commonly for nasal surgery (39%) and other hypopharyngeal surgery in 696 (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 or other hypopharyngeal surgery. There were no cases of concurrent tracheostomy.

Patient and Hospital Characteristics

Table 2 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, urban patient residence, and urban non-teaching hospitals. TORS use was not associated with the patient's gender, ethnicity, or medical comorbidity.

Prolonged Hospital Stay and Complications

Overall, there was a notable rate of prolonged hospital stays and complications, particularly pulmonary complications. It was not possible to determine whether pulmonary complications, as defined in this study to include postoperative invasive mechanical ventilation, captured planned or unplanned care. There were no mortalities or tracheostomy in the study cohort.

TORS was associated with an increased risk of prolonged hospital stay and increased risk of pulmonary complications but was not associated with an increased risk of total complications, likely related to the lack of wound infections or cardiac events noted in the NIS database (Table 3).

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 2010-14, 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) This represents a classical adoption curve where the gradual increase is followed by a plateau with variable market share penetrance. It is 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, USA) 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 residents, urban non-teaching hospitals, and in those with Medicaid. The NIS database does not include other important patient clinical characteristics, such as OSA severity (often measured by the apnoea-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 palate/oropharyngeal or other hypopharyngeal procedures. 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 with concurrent procedures after adjustment for clinical characteristics.

The complication rates in this study (7.7%) were lower than in a previous study (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 similar to that reported in this smaller 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 associated with pulmonary complications but not overall complications. There are multiple potential explanations. One is that TORS may enable a more –aggressive tissue resection. This more-aggressive resection may carry a greater likelihood of planned postoperative invasive mechanical ventilation. It may also have an increased risk of aspiration or post-obstructive pulmonary edema (more-pronounced relief of airway obstruction). Future research can explore the mechanism for this observed difference.

Use of TORS was also associated with a greater likelihood of prolonged hospital stay. In addition to the costs associated with use of TORS (other techniques have their own costs, but TORS costs are likely greater, as are the charges sent to the payor for the robot-assisted surgery codes. There could be multiple drivers of increased length of hospital stay: differences in pain and dysphagia (not counted as complications in this study), differences in pulmonary complications, and differences in planned postoperative care, whether due to more-aggressive surgery or simply the use of TORS.

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 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 associated with a greater risk of pulmonary complications (but not all complications) and with a greater likelihood of a prolonged hospital stay. Further research may incorporate clinical characteristics to explore these findings in greater detail.

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Figure 1. Utilization Trend of All Tongue Resection vs TORS from 2010-2014.

Table 1. Concurrent procedures

Concurrent Procedure Type	**TORS (%)**	**No TORS (%)**	**Total**	**pvalue**
Nasal				
No	765 (86%)	2383 (56%)	3148 (61%)	<0.01
Yes	126 (14%)	1910 (44%)	2037 (39%)	
Palate/Oropharyngeal				
No	189 (21%)	1105 (26%)	1293 (25%)	0.16
Yes	702 (79%)	3189 (74%)	3891 (75%)	
Hypopharyngeal				
No	743 (83%)	3746 (87%)	4488 (87%)	0.22
Yes	148 (17%)	548 (13%)	696 (13%)	
Tracheotomy	0	0	0	N/A

Table 2. Patient and Hospital Information

		TORS (row %)	No TORS (row %)	Tot
Gender	Female	226 (16%)	1156 (84%)	138
	Male	664 (17%)	3133 (83%)	379
Age category	<40	204 (10%)	1864 (90%)	206
	41-64	608 (28%)	2216 (72%)	282
	>=65	79 (27%)	213 (73%)	293
Race	Asian/Pacific	43 (32%)	88 (68%)	131
	Black	91 (17%)	427 (83%)	518
	Hispanic	40 (9%)	409 (91%)	449
	Native American	+	19 (79%)	24
	Other	86 (28%)	219 (72%)	306
	White	561 (18%)	2599 (82%)	316
	Missing	64 (10%)	532 (90%)	596
Comorbidity	None to low (1-2)	330 (16%)	1713 (84%)	204
	moderate (3-4)	428 (18%)	1895 (82%)	232
	high (4+)	133 (16%)	686 (84%)	819
National Quartile of Household Income by ZIP code	<45K	170 (16%)	875 (84%)	104
	45K-60K	185 (16%)	977 (84%)	116
	60K-80K	252 (20%)	1010 (80%)	126
	>80K	269 (17%)	1324 (83%)	159
	Missing	15 (12%)	107 (88%)	123
Payor	Medicaid	45 (6%)	752 (94%)	797
	Medicare	148 (24%)	481 (76%)	629

		TORS (row %)	No TORS (row %)	Tot
	Private including HMO	673 (19%)	2854 (81%)	352
	Self Pay	+	35 (87%)	40
	Other Pay	20 (10%)	171 (90%)	191
Hospital Region	Northeast	281 (29%)	676 (71%)	958
	Midwest	394 (30%)	896 (70%)	129
	South	139 (10%)	1371 (90%)	151
	West	77 (5%)	1351 (95%)	142
Patient County of Residence	Non Urban	260 (24%)	828 (76%)	108
	Urban	631 (15%)	3465 (85%)	409
Hospital Type	Urban Non Teaching	27 (4%)	715 (96%)	742
	Urban Teaching	299 (19%)	1313 (81%)	161
	Rural	0	148 (100%)	148
	Missing	565 (21%)	2117 (79%)	268

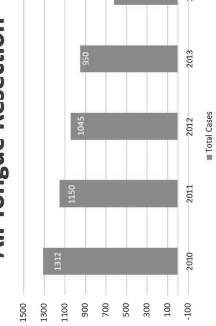
+Cell size <10 not reported, per HCUP guidelines

Table 3. Complications and prolonged hospital stay.

Complications	TORS	Non-TORS	Overall	P
Prolonged hospital stay ([?]3 days)	291 (33%)	1068 (25%)	1359 (26)	0.045
Postoperative hemorrhage requiring Intervention	+	25 (0.58%)	30 (0.5%)	0.99
Pulmonary complications*	75 (8.4%)	256 (6.0%)	331 (6.4%)	0.04
Wound infection	0 (0%)	40 (0.93%)	40 (0.77%)	N/A
Acute Cardiac Events	0 (0%)	21 (0.49%)	21 (0.41%)	N/A
Tracheostomy	0 (0%)	0 (0%)	0 (0%)	N/A
All complications (other than prolonged hospital stay)	80 (9.0%)	317 (7.4%)	397 (7.7%)	0.2

*Pulmonary complications defined as postoperative invasive mechanical ventilation or pneumonia

+Cell size <10 not reported, per HCUP guidelines


All Tongue Resection
1312
1150
1045
950
620
2010
2011
2012
2013
2014
Total Cases


% TORS
9
18
24
21
17
2010
2011
2012
2013
2014
Total Cases