Transoral Robotic Surgery for Obstructive Sleep Apnea in Asian Patients
A Singapore Sleep Centre Experience

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IMPORANCE  This study investigates the effectiveness of combined palatal surgery and transoral robotic surgical (TORS) tongue base reduction with partial epiglottidectomy in the treatment of obstructive sleep apnea (OSA) in an Asian context. To our knowledge, this is the first report on TORS for OSA in Asian patients in the literature.

OBJECTIVE  To report our preliminary experience with combined TORS tongue base reduction and partial epiglottidectomy with palatal surgery as a multilevel surgical treatment strategy for moderate to severe OSA in Asian patients for whom positive airway pressure treatment had failed.

DESIGN, SETTING, AND PARTICIPANTS  A retrospective study of prospectively collected data on 40 Asian patients who underwent primary TORS tongue base reduction with partial epiglottidectomy and palatal surgery for treatment of moderate to severe OSA at an academic tertiary surgical center.

INTERVENTIONS  Transoral robotic surgery and palatal surgery for surgical management of OSA in patients for whom positive airway pressure treatment had failed.

MAIN OUTCOMES AND MEASURES  Twenty patients with complete preoperative and postoperative overnight polysomnograms were evaluated for surgical success and cure, according to traditional surgical criteria, and for subjective outcome measures (snoring and satisfaction on visual analog scale [VAS] and Epworth Sleepiness Scale [ESS]) as well as complications.

RESULTS  Traditional cure (apnea-hypopnea index [AHI] <5/h) was achieved in 7 of 20 patients (35%), traditional success (AHI <20 [>50% reduction in AHI]) was achieved in another 11 patients (55%), and failure was observed in 2 patients (10%). Subjective improvement in snoring, satisfaction, and ESS score was observed. Improvement in mean (SD) ESS score and snoring loudness on VAS were statistically significant, from 12.4 (2.87) to 6.4 (1.43) and 8.7 (0.8) to 3.5 (1.7), respectively (P < .001 for both). None of the patients needed postoperative tracheostomy. Recorded complications included tonsillar fossa bleeding, pain, temporary dysgeusia, numbness of the tongue, and temporary dysphagia.

CONCLUSIONS AND RELEVANCE  Transoral robotic surgery for tongue base reduction and partial epiglottidectomy for moderate to severe OSA in Asian patients for whom positive airway pressure treatment had failed is associated with good efficacy and low complication rates.
Obstructive sleep apnea (OSA) is a common sleep disorder characterized by repetitive upper airway collapse during sleep causing partial and complete airway obstructions, intermittent hypoxemia, sympathetic nervous system output surges, and sleep arousals. Approximately 10% to 25% of adults have OSA (defined as an apnea-hypopnea index [AHI] ≥5/h) with up to 10% of all adults having moderate to severe disease (AHI ≥15/h).\(^2,3\) Compared with hypopneaindex \([AHI] ≥5/h\), approximately 10% to 25% of adults have OSA (defined as an apnea-hypopnea index \([AHI] ≥5/h\)) with up to 10% of all adults having moderate to severe disease \((AHI ≥15/h)\).\(^2,3\)

Compared with healthy individuals, epidemiological studies have shown that OSA is associated with increased cardiovascular and cerebrovascular morbidity, excessive daytime sleepiness, poor neurocognitive function and work performance, increased motor vehicular accidents, and reduced quality of life.\(^4\) If left untreated, the 15-year mortality for adults with severe disease is increased by 30%, with adjusted mortality hazard ratios of 1.4, 1.7, and 3.8 for mild, moderate, and severe disease, respectively \((P\ value for trend, .004)\).\(^4\)

Positive airway pressure treatment is the gold standard for treatment of OSA and has been shown to be the most effective treatment modality that lowers the AHI, improves symptoms, and reduces observed cardiovascular mortality for compliant and adherent patients.\(^10\)\(^-\)\(^13\) with prior studies demonstrating its cost-effectiveness for the treatment of severe OSA.\(^14\)\(^-\)\(^16\) Proper OSA treatment necessitates continuous positive airway pressure (CPAP) that works by pneumatically stenting open the airway during sleep.\(^17\) However, it is estimated that 30% to 50% of patients with OSA are intolerant of and ultimately reject CPAP therapy, with some 10% to 20% rejecting its use at the outset.\(^18\)\(^-\)\(^23\)

Surgical procedures targeting areas of obstruction are currently available to treat OSA for those intolerant to CPAP. Surgically treated patients have an observed reduced mortality rate \((3.4\%)\) compared with historical untreated controls \((30.6\%)\) \((P < .05)\).\(^24\) In addition, Weaver et al\(^24\) reported that CPAP-treated OSA veterans had a 31% higher probability of death compared with those treated with palatal surgery. Presumably, many CPAP-treated patients in this study were nonadherent to therapy. Unfortunately palatal surgery alone does not normalize AHI consistently. Nasal and tongue base surgical procedures \((eg,\ genioglossal\ advancement,\ hyoid\ suspension,\ tongue\ base\ reduction)\) are required to improve cure and success rates.\(^25\)

Transoral robotic surgery (TORS) for tongue base reduction and partial epiglottidectomy is a new tool for surgical treatment of tongue base obstruction for OSA. Studies documenting its efficacy and safety have been published in white patients in Europe and the United States.\(^26\)\(^,\)\(^27\) However, its efficacy and use have not been reported in an Asian context. Obstructive sleep apnea syndrome is known to be far more severe when adjusted for sex, age, and body mass index in Asian patients compared with other ethnic groups, likely because of contribution from skeletal structural restriction.\(^28\)\(^-\)\(^29\) We report our experience in TORS for tongue base reduction and partial epiglottidectomy combined with palatal surgery for multilevel surgical treatment in an academic tertiary surgical setting in an Asian context. To our knowledge, this is the first report on TORS for OSA in Asian patients in the literature.

### Methods

The institutional review board of Singapore General Hospital approved this study and the collection of data and waived the requirement for patient informed consent for the collected data. We performed a retrospective review of prospectively collected data in patients with OSA who presented for surgical treatment from October 1, 2011, to June 30, 2013, in Singapore General Hospital, an academic tertiary surgical center. Patients had either refused positive airway pressure treatment or the treatment had failed.

All patients underwent primary tonsillectomy with uvulopalatal flap and TORS tongue base reduction with partial epiglottidectomy. All patients were counselled on possible alternative surgical alternatives including maxillomandibular advancement, genial tubercle advancement, hyoid suspension, radiofrequency reduction and gave their consent for the procedure. Patients must have had preoperative and 6-month postoperative polysomnograms (PSGs) to be included in the analysis. We excluded patients who had TORS tongue base reduction and partial epiglottidectomy done for failed previous nasal, palatal, and/or other tongue base procedures. Drug-induced sleep endoscopy was used to determine the level of obstruction, both at palate and at the tongue base.\(^30\) None of our patients underwent tracheostomy.

Transoral robotic tongue base reduction with lingual tonsillectomy surgery was performed with an Intuitive Da Vinci robot (Intuitive Surgical). The operative surgical robotic setting was as described by O’Malley et al\(^31\) for the tongue base neoplasms. The technical aspects for management of tongue base with the robot was published previously by Vicini et al.\(^32\) The robot was set up on the right side of the patient. The eyes of the patients were protected by means of specific padding.

After the insertion of a Crow-Davis mouth gag, the da Vinci robotic arms (Maryland Dissector on the left arm and electrocautery on the other) and a 30°-angled 3-dimensional scope were placed in the oral cavity. Surgery began with the visualization of the epiglottis, when possible, to orientate the surgeon. If the epiglottis was not visualized, the circumvallate papilla and center of the tongue base and/or foramen cecum was identified for orientation. Resection of the lingual tonsils was performed stepwise with electrocautery. A midline incision at the tongue base from the foramen cecum to vallecula was made and extended laterally, removing the right tongue base first, followed by the left side. At the end of the operation, the anesthetist performed a Valsalva maneuver to visualize bleeding sites and for the surgeon to ensure proper hemostasis. The volume of tongue base removed was measured using water displacement technique.\(^26\) A full lingual tonsillectomy was performed in every case with partial epiglottidectomy.

Partial epiglottidectomy was performed using the Da Vinci robot. The upper third of the epiglottis was resected. The epiglottis was grasped with the Maryland dissector, and an incision was made at the midline of the free edge of the epiglottis using the robotic monopolar diathermy. The incision was extended vertically toward the base of the epiglottis, until about two-thirds of the distance from the base of the epiglottis.
The incision was then turned laterally to the lateral edge of the epiglottis. This would remove part of the upper one-third of the epiglottis. The procedure was repeated to remove the other upper one-third.

Clinical history, awake upper airway evaluation and drug-induced sleep endoscopy video recordings, preoperative and postoperative PSG data, Epworth Sleepiness Scale (ESS) scores, and patient satisfaction were all collected and analyzed. Preoperative and postoperative snoring loudness and patient and bed partner satisfaction were evaluated by means of a visual analog scale (VAS; scale, 0-10, where 0 means no satisfaction at all and 10 means complete satisfaction).

We tailored the surgery to the pattern of upper airway collapse during drug-induced sleep endoscopy, as much as possible, to the needs of the patients. We analyzed the length of hospitalization, swallowing recovery time, and pain profile and complication rates.

Operative and hospitalization parameters included robotic setup time and operative time at the robotic console. Hospitalization parameters recorded included need for tracheostomy, need for intubation, intensive surgical unit stay, pain score, time to feeding, and hospitalization stay. Acute complications recorded included pain, dysphagia, postoperative bleeding, and dysgeusia.

Polysomnographic evaluation was performed by means of a level 1 in-laboratory attended study when possible. If a level 1 study was not performed, a level 2 unattended study was performed. The overnight PSG was performed in accordance to American Association of Sleep Medicine guidelines for overnight PSG. Polysomnographic data collected included sleep architecture and respiratory parameters like the apnea index, hypopnea index, respiratory effort related arousals index, respiratory disturbance index, and oxygenation parameters during sleep, including the lowest oxygen saturation, oxygen desaturation index, and time spent in hypoxia (oxygen saturation less than 90%). The criteria for apnea and hypopnea are defined according to the American Academy of Sleep Medicine guidelines and scoring manual. Surgical cure and success were defined accounting to traditional surgical criteria.33

All statistical analyses were performed using the SPSS statistical package version 21.0 (IBM Corporation). All mean values were shown as mean (SD). Differences in the value of mean with the appropriate 95% CIs are shown when indicated using a paired sample t test.

Results

Medical records of 40 patients who had primary TORS tongue base reduction with partial epiglottidectomy and palatal surgery from October 2011 to July 2013 at Singapore General Hospital were reviewed. Twenty patients who had preoperative and at least 6 month postoperative overnight PSG were included in the analysis. The mean (SD) length of follow-up was 8.2 (3.2) months (range, 6-15 months). The demographics of the 20 patients with preoperative and postoperative sleep study are given in Table 1. The other 20 patients refused postoperative overnight PSG because of cost concern, as well as because of resolution of snoring, apneic episodes, and daytime symptoms. These patients were evaluated for subjective outcome measures.

None of our study patients required tracheostomy. The patients were either admitted to a surgical intensive care unit or high-dependency care unit for overnight observation before being sent to the general ward. All patients received intravenous antibiotics, intravenous dexamethasone sodium phosphate, intravenous omeprazole, and topical lozenges. The mean (SD) duration of hospitalization stay was 4.05 (0.7) days (range, 4-6 days). Oral feeding was achieved in the first postoperative day, full soft diet was achieved within the first week, and normal feeding was achieved within 2 weeks after the procedure. The mean (SD) immediate postoperative pain score on VAS was 6.5 (3.7), and pain was adequately controlled with oral analgesics.

The mean (SD) robotic setup time was 20.9 (16.0) minutes (range, 8-55 minutes). Similarly, the mean (SD) robotic console time was 26.8 (7.3) minutes (range, 20-50 minutes). The mean (SD) amount of tongue base tissue with lingual tonsils removed was 9.15 (4.1) mL (range, 4-16 mL).

The preoperative and postoperative PSG results for patients with complete data are given in Table 2. Improvement in sleep architecture was observed in the study patients. There were statistical significant reduction in N1 sleep stage and increase in slow-wave sleep and rapid eye movement sleep (Table 2). In this study group, the surgical treatment resulted in a statistical reduction in AHI, respiratory disturbance index, oxygen desaturation index, percentage time spent in hypoxia (oxygen saturation less than 90%), and improvement in the lowest oxygen saturation (Table 2). Using traditional surgical criteria for cure (AHI <5) and success (AHI <20 [50% reduction in AHI]), we determined that cure was achieved in 7 of 20 patients (35%), success was achieved in 11 of 20 patients (55%), and failure occurred in 2 of 20 patients (10%). Subjective outcomes measure obtained showed statistical improvement in ESS score and snoring (Table 2). Mean (SD) VAS scores for patient’s satisfaction and bed partner’s satisfaction were 8.15 (0.9) and 8.0 (1.26), respectively. There was no statistical difference in the preoperative and postoperative body mass index.

Complications include tonsillar bleeding (1 of 20 patients [5%]), temporary anterior tongue numbness (all 20 patients [100%]), temporary tongue soreness (all 20 patients [100%]), temporary change in taste (7 of 20 patients [35%]), and slight
difficulty in swallowing (1 of 20 patients [5%]) were recorded. No other complications relating to tongue mobility, hypoglossal nerve injury, or lingual artery injury were recorded. None of the patients had primary postoperative bleeding from the tongue base.

There were 20 patients who refused to participate in the postoperative sleep study because of resolution of symptoms of snoring, apneic, and gasping episodes, as well as excessive daytime sleepiness. These patients were analyzed for subjective symptoms outcome measures using the ESS, snoring VAS preoperatively and postoperatively, and patient and bed partner satisfaction on VAS to investigate overall patients’ satisfaction and bed partners’ satisfaction. Improvement in these parameters was observed and were statistically significant. An analysis between patients who have preoperative and postoperative PSG data vs patients with only preoperative PSG data did not demonstrate a statistically significant preoperative difference.

Discussion

To our knowledge, this is the first study to document the efficacy and complication rates of TORS tongue base reduction with lingual tonsillectomy and supraglottoplasty using the da Vinci system for the treatment of OSA in Asian patients. This new modality to access and operate on the tongue base and supraglottis has been reported in 5 previous articles.26-30,32,34,35 However, these reports described its use mainly in white patients, and its use and efficacy in Asian patients were not previously documented.

It is known that OSA in Asian patients is more severe compared with white patients when adjusted for sex, body mass index, and age.39 Therefore, currently published results on primary palatal surgery and TORS for tongue base reduction may not be extrapolated to Asian patients. Our results showed that mean (SD) preoperative AHI reduced by 67.3%, from 41.3/h (22.1/h) to 13.5/h (17.1/h) (P < .001). Traditional definition of cure (AHI <5.0/h) was achieved in 7 of 20 patients (35%). Of the patients who achieved an AHI lower than 5.5/h, 2 had severe OSA, while 5 had moderate to severe OSA. All the patients who fulfilled criteria for success had AHI reduced to below 15.0/h with a mean AHI of 10.3/h. The 2 patients in whom surgery had failed had severe OSA with a preoperative AHI of 95.2/h and 55.2/h and 6-month postoperative AHI of 72.6/h and 38.3/h, respec-

### Table 2. Preoperative and Postoperative Sleep Architecture Characteristics, Respiratory Events, and Subjective Outcome Measures of the 20 Patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD)</th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>Difference, Mean (SD) [95% CI]</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep architecture characteristic on PSG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep efficiency, %</td>
<td>80.0 (13.7)</td>
<td>81.5 (11.5)</td>
<td>1.49 (8.13)</td>
<td>[−2.32 to 5.29]</td>
<td>.42</td>
</tr>
<tr>
<td>Total sleep time, min</td>
<td>382.7 (72.6)</td>
<td>372.5 (55.7)</td>
<td>−12.3 (51.1)</td>
<td>[−36.2 to 11.6]</td>
<td>.30</td>
</tr>
<tr>
<td>Sleep stage, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N1</td>
<td>18.3 (13.7)</td>
<td>11.1 (8.1)</td>
<td>−7.16 (14.3)</td>
<td>[−13.8 to −0.47]</td>
<td>.04</td>
</tr>
<tr>
<td>N2</td>
<td>54.5 (11.7)</td>
<td>52.3 (10.8)</td>
<td>−2.20 (12.7)</td>
<td>[−8.2 to 3.80]</td>
<td>.45</td>
</tr>
<tr>
<td>N3</td>
<td>12.9 (9.7)</td>
<td>17.1 (6.8)</td>
<td>4.26 (8.8)</td>
<td>[0.14 to 8.40]</td>
<td>.04</td>
</tr>
<tr>
<td>Sleep-stage REM, %</td>
<td>14.6 (7.9)</td>
<td>19.5 (6.8)</td>
<td>4.84 (6.71)</td>
<td>[1.70 to 7.98]</td>
<td>.004</td>
</tr>
<tr>
<td>BMI</td>
<td>26.9 (2.92)</td>
<td>26.2 (2.99)</td>
<td>−0.72 (2.14)</td>
<td>[−1.72 to 0.28]</td>
<td>.15</td>
</tr>
<tr>
<td>Respiratory event</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Apnea-hypopnea index (per hour)</td>
<td>41.3 (22.1)</td>
<td>13.5 (17.1)</td>
<td>−27.8 (16.7)</td>
<td>[35.6 to −20.0]</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Respiratory effort related arousal index (per hour)</td>
<td>11.4 (14.0)</td>
<td>8.9 (7.6)</td>
<td>−2.5 (10.8)</td>
<td>[7.6 to 2.5]</td>
<td>.31</td>
</tr>
<tr>
<td>Respiratory disturbance index (per hour)</td>
<td>52.7 (18.6)</td>
<td>22.4 (17.4)</td>
<td>−30.3 (14.3)</td>
<td>[37.0 to −23.7]</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Lowest oxygen saturation, %</td>
<td>72.9 (19.3)</td>
<td>84.5 (7.1)</td>
<td>11.6 (17.8)</td>
<td>[3.2 to 19.9]</td>
<td>.009</td>
</tr>
<tr>
<td>Oxygen desaturation index</td>
<td>36.6 (20.7)</td>
<td>12.7 (16.5)</td>
<td>−23.9 (16.3)</td>
<td>[31.6 to −16.3]</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hypoxic time (% time in sleep with oxygen saturation &lt;90%)</td>
<td>18.2 (20.0)</td>
<td>3.4 (6.8)</td>
<td>−14.7 (19.0)</td>
<td>[−23.6 to −5.85]</td>
<td>.003</td>
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<tr>
<td>Subjective outcome measure</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Epworth Sleepiness Scale</td>
<td>13.0 (2.8)</td>
<td>5.6 (4.4)</td>
<td>−7.5 (5.0)</td>
<td>[−9.9 to −5.2]</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Snoringa</td>
<td>9.5 (0.61)</td>
<td>2.45 (1.76)</td>
<td>−7.5 (1.88)</td>
<td>[−7.9 to −6.2]</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); PSG, polysomnography; REM, rapid eye movement.

* Measured by visual analog scale (scale, 0-10, where 0 means no satisfaction at all and 10 means complete satisfaction).
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Study concept and design: Toh, Tay.

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Conclusions

To our knowledge, this is the first study reporting the use of the da Vinci robotic system for treatment of tongue base and epiglottis obstruction in Asian patients. Transoral robotic surgery for tongue base reduction and partial epiglottectomy with palatal surgery showed good efficacy in the Asian patient in reducing severity of OSA in patients for whom positive airway pressure treatment had failed.


