Annals of Medicine and Surgery 19 (2017) 55–61

Contents lists available at ScienceDirect

Annals of Medicine and Surgery

journal homepage: www.annalsjournal.com

Is transoral robotic surgery a safe and effective multilevel treatment for obstructive sleep apnoea in obese patients following failure of conventional treatment(s)?

George Garas [a, *], Anthousa Kythreotou [a], Christos Georgalas [b], Asit Arora [a], Bhik Kotecha [c], Floyd C. Holsinger [d], David G. Grant [e], Neil Tolley [a]

[a] Department of Otorhinolaryngology and Head & Neck Surgery, St. Mary's Hospital, Imperial College Healthcare NHS Trust, London, UK
[b] Department of Otorhinolaryngology and Head & Neck Surgery, Hygeia Hospital, Athens, Greece
[c] Department of Otorhinolaryngology and Head & Neck Surgery, Royal National Throat, Nose and Ear Hospital, University College London Hospitals NHS Trust, London, UK
[d] Department of Otorhinolaryngology and Head & Neck Surgery, Stanford School of Medicine, Stanford, CA, USA
[e] Department of Otorhinolaryngology and Head & Neck Surgery, Mayo Clinic, Jacksonville, FL, USA

HIGHLIGHTS

- There is a paucity of evidence on the subject with complete absence of RCTs.
- The literature supports TORS as a safe multilevel treatment for OSA.
- The effectiveness of TORS for OSA drops with increasing BMI.
- TORS represents an important treatment for OSA in non-morbidly obese patients after failure of conventional treatment(s).
- There is no role for TORS as an OSA treatment in morbidly obese patients.

ARTICLE INFO

Article history:
Received 25 February 2017
Received in revised form
1 June 2017
Accepted 3 June 2017

Keywords:
Transoral robotic surgery
Obstructive sleep apnoea
Obesity
Body mass index
Biometric measures
Palate
Tongue base
Epiglottis
Hypopharynx
Patient selection

ABSTRACT

A best evidence topic was written according to a structured protocol. The question addressed was whether TransOral Robotic Surgery (TORS) is a safe and effective multilevel treatment for Obstructive Sleep Apnoea (OSA) in obese patients following failure of conventional treatment(s). A total of 39 papers were identified using the reported searches of which 5 represented the best evidence to answer the clinical question. The authors, date, journal, study type, population, main outcome measures and results are tabulated. Existing treatments for OSA - primarily CPAP - though highly effective are poorly tolerated resulting in an adherence often lower than 50%. As such, surgery is regaining momentum, especially in those patients failing non-surgical treatment (CPAP or oral appliances). TORS represents the latest addition to the armamentarium of Otorhinolaryngologists - Head and Neck Surgeons for the management of OSA. The superior visualisation and ergonomics render TORS ideal for the multilevel treatment of OSA. However, not all patients are suitable candidates for TORS and its suitability is questionable in obese patients. In view of the global obesity pandemic, this is an important question that requires addressing promptly. Despite the drop in success rates with increasing BMI, the success rate of TORS in non-morbidly obese patients (BMI = 30-35kgm^{-2}) exceeds 50%. A 50% success rate may at first seem low, but it is important to realize that this is a patient cohort suffering from a life-threatening disease and no option left other than a tracheostomy. As such, TORS represents an important treatment in non-morbidly obese OSA patients following failure of conventional treatment(s).

© 2017 The Author(s). Published by Elsevier Ltd on behalf of IJS Publishing Group Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

A best evidence topic was constructed according to a structured protocol. This is fully described in a previous publication [1].

* Corresponding author. Department of Surgery and Cancer, Imperial College London, 10th Floor QEQM Wing, St Mary's Hospital, London, W2 1NY, UK.
E-mail address: g.garas@imperial.ac.uk (G. Garas).

http://dx.doi.org/10.1016/j.amsu.2017.06.014
2049-0801/© 2017 The Author(s). Published by Elsevier Ltd on behalf of IJS Publishing Group Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

2. Clinical scenario

You are discussing with your colleagues in your institutional sleep medicine multidisciplinary team meeting the case of a 42-year-old obese man who despite having lost 55 kg following gastric bypass surgery over two years ago as well as previous uvulopalatopharyngoplasty and radiofrequency ablation to the tongue base, is still suffering from severe obstructive sleep apnoea with an apnoea hypopnoea index of 35 h^{-1}. His body mass index has now stabilised to 32kgm^{-2} and he has failed to tolerate oral appliance and continuous positive airway pressure therapy. Drug-induced sleep endoscopy reveals residual multi-level collapse at the palate, tongue base, epiglottis, and hypopharynx. You are being asked whether transoral robotic surgery would have a role for this patient before recommending a tracheostomy in view of his obesity and previous treatment failures. You resolve to assess the literature yourself.

3. Three-part question

Is transoral robotic surgery a safe and effective multilevel treatment for obstructive sleep apnoea in obese patients following failure of conventional treatment(s)?

4. Search strategy

A literature search was performed using PubMed, Scopus, Ovid, Embase, and Cochrane databases using the terms: (transoral[All Fields] AND ("J Robot Surg"[Journal] OR ("robotic"[All Fields] AND "surgery"[All Fields]) OR "robotic surgery"[All Fields]) AND ("obstructive sleep apnoea"[All Fields] OR "sleep apnea, obstructive"[MeSH Terms] OR ("sleep"[All Fields] AND "apnea"[All Fields] AND "obstructive"[All Fields]) OR "obstructive sleep apnea"[All Fields] OR ("obstructive"[All Fields] AND "sleep"[All Fields] AND "apnea"[All Fields])).

In addition, the reference lists of the relevant papers were searched. The search was current as of 1st June 2017.

5. Search outcome

Thirty nine papers were found using the reported search. Two authors (G.G. and A.K.) independently assessed the titles and abstracts of the identified articles to determine potential relevance. Any disagreement was resolved by discussion or with the opinion of the senior author (N.T.) After reviewing the abstracts, 37 papers were selected to be fully appraised in view of relevance and methods used. From these, 9 were irrelevant, 7 were review articles, 4 included a mixed patient cohort with some patients undergoing TORS and others non-robotic transoral surgical interventions for OSA, 4 described cadaveric studies, 3 did not allow distinction of obese and non-obese patients from the cohort to compare outcomes, 2 evaluated paediatric patients, one was in a language other than English, one only reported airway (i.e. volumetric as opposed to clinical) measures, and two were case reports (including the one article in a language other than English). Inclusion criteria included studies of any size, prospective or retrospective in design assessing the success of TORS in the treatment of OSA between obese and non-obese patients. Included studies must have been composed of adults undergoing TORS for OSA that had failed conventional treatment(s). Exclusion criteria involved studies evaluating paediatric patients, non-clinical studies (e.g. cadaveric or animal studies), and studies reporting non-clinical outcomes only (e.g. volumetric or airway measures). However, due to paucity of studies specifically comparing TORS outcomes for OSA in obese vs. non-obese patients, studies with a mixed cohort were included provided that it was possible to subgroup patients based on their BMI (and thus be able to compare their respective outcomes) in the data analysis and evidence synthesis. Review articles and articles not published in the English language were excluded. Based on design, number of patients and origin (high volume/specialised centres) 5 papers were chosen as representing the evidence to answer the clinical question.

6. Results

The results of the five papers (two prospective and three retrospective cohort studies) are summarised in Table 1.

7. Discussion

TransOral Robotic Surgery (TORS) represents the latest addition to the armamentarium of Otorhinolaryngologists – Head and Neck Surgeons for the management of Obstructive Sleep Apnoea (OSA) [2]. Though the main treatment for OSA still remains Continuous Positive Airway Pressure (CPAP), patient adherence to CPAP has been shown to be particularly low, with a number of studies and audits reporting adherence rates below 50% [3–5]. With non-surgical treatment modalities (i.e. CPAP or oral appliances), patients that fail this or refuse to comply with this often emphasise their frustration of having to use this every night and many prefer the possibility of a "one-stop fix" with surgical intervention [6]. As a result, surgery is regaining momentum in the management of OSA, especially in those patients intolerant of CPAP.

Contrary to 'conventional' (non-robotic) transoral surgical approaches, TORS offers superior visualisation and ergonomics by overcoming the difficulty associated with accessing the base of tongue (BOT) and hypopharynx. This renders TORS ideal for multilevel surgery obviating the need for open access - and its associated morbidity [7]. However, not all patients are suitable candidates for TORS with biometric measures determining patient suitability [8]. Taking into account the existing global obesity pandemic, a particularly relevant biometric measure is Body Mass Index (BMI) [9]. Obesity is closely interlinked with the development of OSA and constitutes the primary reason why OSA is now also seen as a public health problem affecting over 10% of the world's population [10]. Despite this, only a handful of studies have evaluated the success rate of TORS for OSA as a function of patient BMI [2,11–14].

The reason for this paucity of evidence is threefold. Firstly, there is level I evidence to support CPAP as a highly effective (the 'gold standard') treatment for OSA – even at low levels of compliance [15]. Secondly, the results reported for the surgical treatment of OSA (in the pre-robotic surgery epoch) have been inconsistent and, as such, remain an area of intense debate [16]. This however is likely to be the result of poor patient selection combined with inability to address difficult-to-access areas due to 'line-of-sight' limitations associated with conventional transoral (microscopic and/or laser) surgery [2]. Thirdly, TORS – designed to overcome these limitations and thus offering a 'true' multilevel treatment – has only been around for just over 6 years as a surgical treatment option for OSA [17]. As more units take up TORS as a surgical treatment option for OSA in carefully selected patients and further long-term results from multicenter studies become available, the evidence base is likely to strengthen and provide answers to the existing questions on the topic.

In addition to the paucity of studies evaluating the role of TORS for OSA in the obese patient subgroup following failure of conventional treatment(s), those studies are characterised by marked heterogeneity. This heterogeneity extends beyond patient characteristics (e.g. in terms of severity of OSA and level of obstruction), to

Table 1
Best evidence papers.

Author, date and country	Patient Group	Study type and Level of evidence	Outcomes	Key results	Comments
Arora et al., 2015 [2], UK	Prospective analysis of 14 patients (13 male, 1 female): 4 had TORS BOT reduction alone while 10 had TORS BOT reduction in combination with epiglottoplasty (depending on DISE findings) Patient characteristics: - Mean age = 54.3 - Mean preoperative BMI = 28.7kgm^{-2} - Pre-operative AHI = 35.6h^{-1} - Mean pre-operative ESS = 14.9 - Mean pre-operative oxygen saturation level (SaO_2) = 92.9% - 9 patients had undergone previous oropharyngeal surgery for OSA Inclusion criteria: (1) Moderate to severe OSA (2) Intolerant to conventional treatment (CPAP and/or MAD) (3) BMI<35kgm^{-2} (4) Obstruction at the level of the tongue base and/or epiglottis as diagnosed via DISE Exclusion criteria: (1) Numerous comorbidities (2) Limited mouth opening (3) Inadequate follow-up	Level IIb prospective cohort study	Primary: - Post-operative AHI - Post-operative SaO2 - Post-operative ESS Secondary: - Operative time - Blood loss - Complications PROMs: - Voice (VHI-2) - Swallowing (MDADI) - QoL (EQ-5D)	Significant decrease in mean AHI post-TORS (21.2h^{-1}+/−24.6 h^{-1} vs. 36.3 h^{-1}+/−21.4 h^{-1}, p = 0.026) Significant increase in mean SaO2 post-TORS (92.9% ±1.8% vs. 94.3% ±2.5%, p = 0.005) Significant decrease in mean ESS (p = 0.002) and normalised by 6 months Obese patients (BMI>30kgm^{-2}) had significantly higher failure rates compared to non-obese (p < 0.01) One patient had a minor secondary haemorrhage, one patient had dysgeusia and two patients had odynophagia to solids Voice and swallowing worsened initially in first 2 week (p < 0.005) but returned to normal levels within 3 months Quality of life was improved 3 months after the procedure (p < 0.001)	TORS BOT reduction with or without wedge epiglottoplasty are clinically effective in non-obese OSA patients who have failed to tolerate conventional treatment Study strengths: - Prospective nature - Long follow-up - Both subjective and objective outcomes measured Limitations: - No control group - Small sample size
Chiffer et al., 2015 [11], USA	Prospective analysis of a mixed cohort of 19 patients (16 male, 3 female): All underwent TORS bilateral posterior hemiglossectomy with limited pharyngectomy and an uvulopalatopharyngoplasty Patient characteristics: - Mean age = 46.8 years, range 24–59 years - Mean preoperative BMI = 34.0kgm^{-2}, range 26.6–55.0kgm^{-2} - Mean preoperative AHI = 52.9h^{-1}, range 17-112h^{-1} Inclusion criteria: - At least 18 years old - AHI >5 - Informed consent Exclusion criteria: - Under 18 years old - Active infection that is not being treated - Pregnancy - Previous head and neck procedure that prevented transoral access - Comorbidities that prevented them from undergoing TORS or GA due to increased operative risk	Level IIb prospective cohort study	- Post-operative AHI - Volumetric outcomes (based on MRI measurements pre- and post-operatively)	61% of patients (11/18) were classified as surgical successes Patients in the surgical success group experienced a significant mean drop in AHI of 52.9 ± 29.0h^{-1} compared to 4.5 ± 33.5h^{-1} in those that did not meet the criteria for surgical success (p = 0.006) 67% were classified as surgical responders (12/18) There was an increase in airway volume following TORS at the retropalatal and total lateral wall levels	When comparing obese and non-obese patients, no statistically significant difference was found in terms of surgical response (56.3% vs. 50%, p > 0.1) The success rate in the non-morbidly obese patients (BMI = 30-35kgm^{-2}) was 62.5% Study strengths: - Prospective study - Multiple outcome measures (based on both polysomnography and volumetric MRI) - Individual BMI values were presented which allowed further analysis Limitations: - Small sample size - Lack of standardization (pre-op MRI scans as well as pre- and post-op PSG studies were performed at different institutions) - BMI changes were not controlled for - Clinicians analysing the MRI scans were not blinded to post-op AHI values; may introduced bias
Hoff et al., 2014 [12], USA	Retrospective analysis of a mixed cohort of 121 patients (83 male, 38 female) with moderate to severe OSA that underwent TORS tongue base	Level III retrospective cohort study	Postoperative AHI Success if: AHI<20h^{-1} and AHI decreased	Mean post-operative AHI dropped from 42.7h^{-1} to 22.2kgm^{-2} 84.3% of patients showed an improvement in their AHI	Pre-operative BMI can be used as a marker of success in TORS for OSA Study strengths: Largest retrospective analysis of TORS procedures performed

(*continued on next page*)

Table 1 (*continued*)

Author, date and country	Patient Group	Study type and Level of evidence	Outcomes	Key results	Comments
	surgery ± multilevel surgery Patient characteristics: - Mean age = 54.5 years - Mean preoperative BMI = 28.4kgm^{-2} and mean postoperative BMI = 27.5kgm^{-2} - Mean preoperative AHI = 42.7h^{-1} and mean postoperative AHI = 22.2h^{-1} Inclusion criteria: (1) Moderate-to-severe OSA (2) Intolerance to CPAP therapy (3) Tongue base hypertrophy (DISE) (4) Good tongue base exposure during TORS (5) Complete preoperative and 3-month post-operative polysomnography (PSG) data Exclusion criteria: a) Mild OSA b) TORS lingual tonsillectomy not performed c) No postoperative PSG		by 50% Cure if AHI<5h^{-1}	In 51.2% of patients, TORS proved successful 14% of patients were cured Lingual tonsil volume resected correlated with drop in AHI The lower the pre-operative BMI, the higher the percentage of success following TORS (56.5% with BMI<30kgm^{-2} underwent successful TORS compared to 78.3% of patients with BMI<25kgm^{-2}) No complications reported	by a single surgeon Limitations: - Retrospective nature - Significant difference between mean preoperative and postoperative BMI, which could act as a cofounder The condition of 16% of patients worsened and this can be because for 6 of them PSG was done more than 5 years before TORS procedure (and thus not representative of pre-operative BMI) and also smaller lingual tonsil volume was resected in these patients
Lin et al., 2014 [13], USA	Retrospective analysis of 39 patients (24 male, 15 female) with moderate to severe OSA TORS procedures performed: - BOT reduction (11) - BOT reduction plus UPPP (2) - BOT reduction plus epiglottectomy (7) - BOT reduction, plus epiglottectomy, plus UPPP (19) Demographic data: - Mean age = 46.5 years - Race (26 Caucasian, 2 Hispanic and 11 African American) Clinical data: - Mean pre-operative BMI = 32.9 + 7.0kgm-2 - Mean neck circumference = 16.2 + 1.5 cm - Mean Friedman stage = 3.0 + 0.6) - DISE findings (most of the patients experienced collapse in the nasopharynx, BOT, and epiglottis) - Mean preoperative AHI = 43.9 + 32.3), - Mean pre-operative ESS = 15.6 + 5.4) - Mean pre-operative LO2sat = 81.6 + 8.1% - 18 had a tonsillectomy done before, 8 a UPPP, 4 BOT reduction, 4 tracheostomy, and 21 other procedures Inclusion criteria: - Adult patients - Moderate to severe OSA - Have completed demographic and clinical data - Have completed 4 months of follow up	Level III retrospective cohort study	- Post-operative AHI - Post-operative ESS - Post-operative LO2sat	- Mean post-operative AHI = 21.9 + 23.5h-1 - Mean post-operative ESS = 5.7 + 4.3 - Mean post-op LO2sat = 83.4 + 7.3% Overall, 21 patients did have a positive surgical response as defined by >50% decrease in AHI and a post-op AHI <15 together with a post-op ESS less or equal to 9 Patients with BMI<30kgm^{-2} enjoyed an excellent surgical response rate of 88.2%, whereas patients with BMI≥40kgm^{-2} had a poor surgical response rate of only 16.7% Complications: - No airway or haemorrhage - 3 patients experienced dysphagia due to oropharyngeal scarring that needed surgical/medical intervention - Most of the patients had dysgeusia and tongue numbness which resolved within 3 months following TORS except in 3 patients in whom it lasted for more than a year	Patients with BMI<30kgm^{-2} had the best response whereas those with BMI more or equal to 40kgm^{-2} had the worst (BMI<30kgm^{-2} 88.2%, BMI ≥ 30kgm^{-2} but <40kgm^{-2} 31.3%, BMI≥40kgm^{-2} 16.7% p < 0.000) Patients with AHI<60h^{-1} had the best surgical response rate compared to those with AHI>60h^{-1} (67.9% vs. 18.2% p = 0.011) Study strengths: - Adequate number of patients - Specifically looked into the impact of BMI on surgical access Limitations: - Retrospective nature - Absence of long-term follow-up
Spector et al., 2016 [14], USA	Retrospective analysis of 118 patients (87 male, 31 female) with moderate to severe OSA All had TORS lingual tonsillectomy either alone or in combination with multilevel surgery: - epiglottectomy (60) - tonsillectomy (55) - partial midline glossectomy (40)	Level III retrospective cohort study	Post-operative AHI	Mean post-op AHI was 22.6kgm^{-2} 82.5% of the patients experienced an improvement in their post-op AHI In 63% of the patients the intervention was considered successful (AHI<20h^{-1} and 50% drop in pre-op AHI) 16.9% of the patients satisfied the cure criteria	BMI can predict operative success of TORS for OSA As BMI increases, the chances of success of TORS for OSA decrease Study strengths: - Large sample size

- pharyngoplasty (39) - palatoplasty (37) - UPPP (30) - turbinate reduction (29) - uvulectomy (23) - septoplasty (2) - adenoidectomy (1). Patient characteristics: - Mean age = 54.6 years - Mean BMI = 29.0kgm-2 - Mean AHI = 43.0h-1 - Mean excised lingual tonsil volume = 8.0 ml Inclusion criteria: - Moderate-to-severe OSA - Failure to tolerate conventional treatment Exclusion criteria: - Previous TORS	for 3 months post-surgery (AHI<5h^{-1}) Patients with BMI<30kgm^{-2} had a success rate of 69.9% whilst for those with a BMI >30kgm^{-2} the success rate dropped to 51% (p = 0.041)	- Specifically evaluated predictive role of BMI Limitations: - Retrospective study - No control group

Abbreviations: OSA = obstructive sleep apnoea; TORS = transoral robotic surgery; AHI = apnoea-hypopnoea index; CPAP = continuous positive airway pressure; DISE = drug-induced sleep endoscopy; PSG = polysomnography; BOT = base of tongue; MAD = mandibular advancement device; ESS = Epworth Sleepiness Score; PROMs = patient reported outcome measures; QoL = quality of life; GA = general anaesthetic; LO_2sat = lowest oxygen saturation.

also involve the actual intervention (e.g. in terms of the different anatomical obstruction level(s) operated on, i.e. palate, tongue base, epiglottis, hypopharynx, and any combination of these), and outcome measures selected (e.g. AHI, ESS, LO_2sat changes pre- and post-operatively), making it inappropriate to conduct a meta-analysis or other type of statistical pooling of individual study results. Despite this, there are certain important findings that feature in all studies. These include the effectiveness of TORS exceeding 75% in non-obese OSA patients (subject to correct patient selection), the negative effect of an increasing BMI on surgical 'success' and/or 'response' rates (independent of how these were defined in each study, please see text below and Table 1 for individual criteria employed in each study), and that beyond a BMI of 40kgm^{-2}, TORS has no role in the treatment of OSA with surgical response rates dropping to below 20%. Each study is discussed in depth below.

In 2016, Arora et al. [2] conducted a prospective analysis of 14 patients (13 male, 1 female) who underwent TORS for OSA. All 14 patients underwent TORS BOT reduction and 10 also had wedge epiglottoplasty (depending on drug-induced sleep endoscopy (DISE) findings). Inclusion criteria comprised of a diagnosis of moderate-to-severe OSA diagnosed on polysomnography (PSG) and failure to tolerate conventional treatment (CPAP or mandibular advancement device – MAD). Moreover, BMI had to be below 35kgm^{-2}. Median follow up was 24 months (mean = 18.9 ± 6.2, range 12–24) and mean pre-operative BMI was 28.7 ± 2.8kgm^{-2}. Nine patients had previously undergone oropharyngeal procedures for their OSA. The key findings were a post-operative decrease in mean AHI from 36.3 h^{-1} to 21.2 h^{-1} (p = 0.026), a post-operative increase in mean oxygen saturation levels from 92.9% to 94.3% (p = 0.005), and normalisation of the Epworth Sleepiness Score (ESS) 6 months after TORS with the most prominent decrease happening in the first 2 weeks following the robotic surgery (p = 0.002). In general, 64% of the patients underwent a successful TORS procedure (defined by AHI<20 h^{-1} with 50% reduction in baseline AHI and ESS<10), 36% of the patients were cured (defined as AHI<5 h^{-1} with 50% reduction and ESS<10), while 18% required post-operative CPAP despite demonstrating improvement on postoperative PSG. One patient worsened and continued to require CPAP. Overall, in 91% of the patients there was an improvement in the primary outcomes. Non-morbidly obese patients (BMI = 30-35kgm^{-2}, morbidly obese excluded from the study) had significantly lower success rates compared to non-obese (53.3% vs. 75.4%, p < 0.01). Re-intubation, nasogastric tube (NGT) insertion or tracheostomy was not required in any case. Temporary complications included secondary haemorrhage 3 weeks post-TORS (1 patient), dysgeusia (1 patient), and odynophagia to solids (2 patients), all successfully managed conservatively. Patient Reported Outcome Measures (PROMs) including Quality of Life (QoL) were recorded revealing a significant improvement 3 months after TORS (67% vs. 86% on EQ-5D visual analogue scale, p < 0.01). Strengths of this study include the fact that it was prospective and the follow-up period was long. Limitations include the lack of a control group and small sample size.

Chiffer et al. [11] performed a prospective non-randomised study of 19 patients (16 male, 3 female) undergoing TORS for OSA. In addition to AHI, the authors measured the volumetric effect of TORS based on MRI and assessed whether any changes observed were associated with the success rate of the robotic procedures. Patients with significant comorbidities, an active infection, and those pregnant were excluded. All patients underwent DISE to determine the level(s) of obstruction. In all patients, TORS involved bilateral posterior hemiglossectomy with limited pharyngectomy and uvulopalatopharyngoplasty. Individual post-operative BMI was noted (mean 32.2kgm^{-2}, range 22.6–55.7kgm^{-2}). Eleven of eighteen patients (61%) were classified as surgical successes (defined by a

50% decrease of pre-operative AHI in combination with post-operative AHI<20 h^{-1}) and 12/18 patients (67%) were classified as surgical responders (defined only by a 50% decrease in pre-operative AHI). Patients classified in the surgical success group experienced a significant mean drop in AHI of 52.9 ± 29.0 h^{-1} compared to the 4.5 ± 33.5 h^{-1} in those patients who did not meet the criteria ($p = 0.006$). In terms of volumetric MRI measurements, there was an increase in airway volume following TORS at the retropalatal and total lateral wall levels that showed a statistically significant correlation with AHI (rho = 0.69, p = 0.0014, and rho = 0.63, p = 0.0121, respectively). When comparing obese and non-obese patients, no statistically significant difference was found in terms of surgical response (56.3% vs. 50.0%, $p > 0.1$). This was most likely due to the small sample size (n = 19). However, the success rate in the non-morbidly obese patients (BMI = 30-35kgm^{-2}) was reported as 62.5%. Though this study was prospectively conducted and used PSG as well as volumetric data, it is characterised by a number of limitations. These include its small sample size, BMI changes not being controlled for, and bias related to clinicians analysing the volumetric MRI scans not being blinded to post-operative AHI values.

Hoff et al. [12] retrospectively analysed 121 OSA patients (83 male, 38 female) that underwent TORS either to the tongue base alone or combined with other pharyngeal, palatal or nasal procedures. All patients had been trialled on CPAP and failed to tolerate (or declined) this. The success of TORS was defined as both a post-operative AHI<20 h^{-1} and a decrease in AHI by 50%. Body Mass Index (BMI) and the volume of lingual tissue removed were also recorded. In total, 84.3% of patients had an improvement in post-operative AHI, 51.2% of TORS procedures proved successful and in 14% of cases patients were considered cured (AHI<5 h^{-1}). The authors showed that an increased volume of lingual tonsil tissue removed could predict AHI improvement ($r = 0.194$, $p = 0.029$), as did pre-operative BMI ($r = -0.272$ $p = 0.006$). Specifically, it was shown that the lower the pre-operative BMI, the higher the percentage of success following TORS as 56.5% with BMI<30kgm^{-2} underwent successful TORS compared to 78.3% of patients with BMI<25kgm^{-2}. None of the patients required re-intubation, nasogastric tube (NGT) insertion or tracheostomy and no other complications were reported. This represents the largest retrospective analysis of TORS for OSA performed by a single surgeon. Limitations include its retrospective nature and the fact that there was a significant difference between the mean preoperative and postoperative BMI, which could have acted as cofounders.

Lin et al. [13] performed a retrospective analysis of 39 patients (24 male, 15 female) that had undergone TORS for OSA. Of these, 11 (28.2%) underwent BOT reduction alone, 2 (5.1%) BOT reduction combined with uvulopalatopharyngoplasty (UPPP), 7 (17.9%) BOT reduction and epiglottectomy, and 19 (48.7%) BOT, UPPP, and epiglottectomy. All patients underwent DISE prior to surgery to identify the level(s) of obstruction and over half had undergone previous upper airway procedures for their OSA. The aim of this study was to look for predictors of success of TORS for OSA to assist patient selection. A variety of outcomes were recorded including AHI, ESS, BMI, and lowest oxygen saturation (LO_2sat) among others. Follow-up was for a minimum of 4 months. BMI and AHI were classified into clinically relevant partitions. The authors demonstrated that a statistically significant difference continued to exist between the responders and non-responders for both BMI ($p = 0.000$) and AHI ($p = 0.025$). Specifically in relation to BMI, patients with BMI<30kgm^{-2} enjoyed an excellent surgical response rate of 88.2%, whereas patients with BMI≥40kgm^{-2} had a poor surgical response rate of only 16.7%. In the BMI group between 30 and 40kgm^{-2}, the surgical response increased to 31.3%. This group was not further subclassified to non-morbidly obese to comment on their specific surgical response rates. The cutoff for AHI was 60 h^{-1} with patients with AHI<60 h^{-1} having a response rate of 67.9%, whilst in those with AHI≥60 h^{-1} this dropped to 18.2%. This was an important study as it specifically looked into the impact of BMI on surgical success and contains an adequate number of patients. Limitations include its retrospective nature and absence of long-term follow-up.

Spector et al. [14] performed a retrospective analysis of 118 patients (87 male, 31 female) that underwent TORS for OSA. The aim was to assess the efficacy of TORS in patients classified by preoperative factors, including Friedman stage and BMI. All 118 patients underwent TORS lingual tonsillectomy either alone or combined with multi-level surgery including epiglottectomy (60 patients), tonsillectomy (55), partial midline glossectomy (40), pharyngoplasty (39), palatoplasty (37), uvulopalatopharyngoplasty (30), turbinate reduction (29), uvulectomy (23), septoplasty (2), and adenoidectomy (1 patient). The study included patients that were diagnosed with moderate to severe OSA and had failed to tolerate conventional treatment. All patients underwent DISE to determine the level of obstruction in addition to PSG. Surgical success was interpreted as AHI<20 h^{-1} combined with a decrease of AHI by 50% and cure was defined as AHI<5 h^{-1}. In 63% of patients, the intervention was considered successful according to these criteria, whilst 82.2% showed an improvement in their post-operative AHI and 16.9% were cured 3 months following TORS. The percentage of patients that had a successful TORS for OSA varied between the different Friedman stages, though, statistically significant differences between pre- and post-operative AHI were only seen in patients classified in Friedman stages 1 ($p = 0.02$), 2 ($p = 0.0001$), and 3 ($p = 0.0001$). With regards to BMI, it was shown that patients with BMI<30kgm^{-2} had a success rate of 69.9% whilst for those with a BMI>30kgm^{-2} the success rate dropped to 51% ($p = 0.041$). This is an important study due to the large number of patients evaluated and the fact that the role of BMI as a predictive tool was specifically assessed. Limitations include its retrospective nature and absence of a control group.

8. Clinical bottom line

With obesity acting as the main driver for OSA in adults, the two are closely interlinked constituting important public health problems. Existing treatments for OSA - primarily CPAP - though highly effective are poorly tolerated resulting in an adherence often below 50%. As such, surgery is regaining momentum, especially in those patients failing to tolerate CPAP. TORS enhances conventional transoral surgery and facilitates the multilevel treatment of OSA as a direct result of its superior visualisation and ergonomics. The number of obese patients referred for consideration of TORS for their OSA following failure of both CPAP and other surgical treatments is rapidly increasing and likely to continue doing so in the epoch of a global obesity pandemic.

The existing evidence, though characterised by a complete absence of randomised controlled studies, shows that pre-operative BMI is a reliable predictor of success of TORS for OSA. The evidence also suggests that TORS is effective in over 75% of non-obese OSA patients (subject to correct patient selection), and despite the drop in success rates with increasing BMI, the success rate of TORS in the non-morbidly obese OSA group (BMI = 30-35kgm^{-2}) exceeds 50%. Though a 50% success rate may at first seem low, it is important to realize that this is a patient cohort suffering from a life-threatening disease with important socioeconomic consequences not only for them but also for their families and that following a series of treatment failures, these patients are left with

no other option other than a tracheostomy. As such, TORS represents an important treatment in non-morbidly obese OSA patients following failure of conventional treatment(s).

Ethical approval

Not required.

Sources of funding

Dr. George Garas holds an Imperial College London Onassis Foundation Doctoral Research Fellowship (Grant number F ZM 014-1/2016–2017).

Author contribution

G Garas – conducted literature search, data collection and wrote article.

A Kythreotou – literature search and assisted in writing of article.

C Georgalas – data collection and assisted in writing of article.

A Arora – data collection and assisted in writing of article.

B Kotecha – conceived paper, reviewed and corrected manuscript.

FC Holsinger: conceived paper, reviewed and corrected manuscript.

DG Grant: conceived paper, reviewed and corrected manuscript.

N Tolley – conceived paper, reviewed and corrected manuscript.

Conflicts of interest

None.

Research registration unique identifying number (UIN)

Not applicable.

Trial registry number

Not applicable.

Guarantor

Dr. George Garas, BSc(Hons), MBBS(Dist), MRCS(Eng), DOHNS.

Specialty Registrar & Honorary Clinical Lecturer in Surgical Oncology, Department of Surgery and Cancer, Imperial College London, St. Mary's Hospital, London W2 1NY, United Kingdom. Tel.: +44 020 3312 6666; fax: +44 20 3312 6871. E-mail address: g.garas@imperial.ac.uk (G. Garas).

References

[1] O.A. Khan, J. Dunning, A.C. Parvaiz, R. Agha, D. Rosin, K. Mackway-Jones, Towards evidence-based medicine in surgical practice: best BETs, Int. J. Surg. Lond. Engl. 9 (8) (2011) 585–588.

[2] A. Arora, K. Chaidas, G. Garas, A. Amlani, A. Darzi, B. Kotecha, N.S. Tolley, Outcome of TORS to tongue base and epiglottis in patients with OSA intolerant of conventional treatment, Sleep Breath. 20 (2) (2016) 739–747.

[3] C. Georgalas, G. Garas, E. Hadjihannas, A. Oostra, Assessment of obstruction level and selection of patients for obstructive sleep apnoea surgery: an evidence-based approach, J. Laryngol Otol. 124 (1) (2010) 1–9.

[4] N.B. Kribbs, A.I. Pack, L.R. Kline, P.L. Smith, A.R. Schwartz, N.M. Schubert, S. Redline, J.N. Henry, J.E. Getsy, D.F. Dinges, Objective measurement of patterns of nasal CPAP use by patients with obstructive sleep apnea, Am. Rev. Respir. Dis. 147 (4) (1993) 887–895.

[5] W.S. Cho, G. Garas, A. Morgan, M. Chaurasia, Patient compliance to continuous positive airway pressure (CPAP) therapy for sleep apnoea: a completed audit cycle, Ir. J. Med. Sc. 182 (Suppl 12) (2013) S509–S531.

[6] E. Chisholm, B. Kotecha, Oropharyngeal surgery for obstructive sleep apnoea in CPAP failures, Eur. Arch. Otorhinolaryngol. 264 (1) (2007) 51–55.

[7] C. Vicini, F. Montevecchi, K. Pang, A. Bahgat, I. Dallan, S. Frassineti, A. Campanini, Combined transoral robotic tongue base surgery and palate surgery in obstructive sleep apnea-hypopnea syndrome: expansion sphincter pharyngoplasty versus uvulopalatopharyngoplasty, Head Neck 36 (1) (2014) 77–83.

[8] A. Arora, J. Kotecha, A. Acharya, G. Garas, A. Darzi, D.C. Davies, N. Tolley, Determination of biometric measures to evaluate patient suitability for transoral robotic surgery, Head Neck 37 (9) (2015) 1254–1260.

[9] B.A. Swinburn, G. Sacks, K.D. Hall, K. McPherson, D.T. Finegood, M.L. Moodie, S.L. Gortmaker, The global obesity pandemic: shaped by global drivers and local environments, Lancet (London, Engl. 378 (9793) (2011) 804–814.

[10] US Preventive Services Task Force, K. Bibbins-Domingo, D.C. Grossman, S.J. Curry, K.W. Davidson, J.W. Epling, et al., Screening for obstructive sleep apnea in adults: US preventive services task force recommendation statement, JAMA 317 (4) (2017) 407–414.

[11] R.C. Chiffer, R.J. Schwab, B.T. Keenan, R.C. Borek, E.R. Thaler, Volumetric MRI analysis pre- and post-Transoral robotic surgery for obstructive sleep apnea, Laryngoscope 125 (8) (2015) 1988–1995.

[12] P.T. Hoff, T.A. Glazer, M.E. Spector, Body mass index predicts success in patients undergoing transoral robotic surgery for obstructive sleep apnea, ORL J. Otorhinolaryngol. Relat. Spec. 76 (5) (2014) 266–272.

[13] H.S. Lin, J.A. Rowley, A.J. Folbe, G.H. Yoo, M.S. Badr, W. Chen, Transoral robotic surgery for treatment of obstructive sleep apnea: factors predicting surgical response, Laryngoscope 125 (4) (2015) 1013–1020.

[14] M.E. Spector, T.A. Glazer, P.T. Hoff, Addressing the retrolingual space in obstructive sleep apnea: outcomes stratified by friedman stage in patients undergoing transoral robotic surgery, ORL J. Otorhinolaryngol. Relat. Spec. 78 (1) (2016) 1–8.

[15] H.M. Engleman, S.E. Martin, I.J. Deary, N.J. Douglas, Effect of continuous positive airway pressure treatment on daytime function in sleep apnoea/hypopnoea syndrome, Lancet (London, Engl. 343 (8897) (1994) 572–575.

[16] B.T. Kotecha, A.C. Hall, Role of surgery in adult obstructive sleep apnoea, Sleep. Med. Rev. 18 (5) (2014) 405–413.

[17] C. Vicini, I. Dallan, P. Canzi, S. Frassineti, M.G. La Pietra, F. Montevecchi, Transoral robotic tongue base resection in obstructive sleep apnoea-hypopnoea syndrome: a preliminary report, ORL J, Otorhinolaryngol. Relat. Spec. 72 (1) (2010) 22–27.